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PREFACE

The Institute for Science and Technology Education (ISTE) and the organising committee of the 5th ISTE International Conference on Mathematics, Science and Technology Education (ISTE 2014) welcomes you to the ISTE 2014 International Conference at the Kruger National Park, South Africa. This conference has become a rallying point for mathematics, science and technology education researchers, students and practitioners from Africa and globally, as a result of the ambient environment it provides for intellectual and academic interaction and also the opportunity it provides for local academics to interact with an international audience. Through the efforts of the staff of ISTE, friends and well-wishers, support for the conference has continued to grow and participation has increased over the years. While we acknowledge that the journey has not been easy, considering the many recent challenges, both internal and external, it is a thing of joy to affirm that in South Africa, a tradition has been established to accommodate the views of the rest of the world in this area of scientific research.

The number of abstracts and full papers received has increased steadily every year since the first edition of the conference. As a result, more stringent measures have been introduced to review papers for acceptance for the conference. This has put some strain on the editorial committee who kept working hard to keep the standard. The organising committee, which has changed very little since inception, has continued to work relentlessly every year to keep the conference at its best. The results of these efforts are a sustained participation in the conference, high quality presentations and high standards in the quality of papers published in the conference proceedings. This has resulted in the South Africa Department of Higher Education and Training adopting the proceedings as one of its accredited Conference Proceedings. A total of 149 papers were received for the 2014 conference out of which 56 were accepted for publication in the conference proceedings. While it can be argued that the Kruger National Park and the charisma of its diverse African wildlife is one of the most visited Parks in the world the ISTE International Conference has contributed to this traffic, as over 100 participants besiege the Mopani Camp of the Park every October.

We wish to thank our sponsors, the South African National Parks who has continued to provide support for the conference for 5 years running and the College of Graduate Studies, University of South Africa who beyond providing conference bags for participants has provided funding to sponsor some local and international masters and doctoral students to attend the 2014 conference.

May we once again thank all past and present participants, particularly the wonderful plenary speakers from all over the world, who have continued to give the conference its flavour and urge you all to continue to believe that the conference would continue to be a space where Mathematics, Science and Technology Education challenges facing our generation's world would be addressed.

Prof. Harrison Ifeanyichukwu Atagana. *Pr. Sc. Nat. FSB*
Chair: ISTE 2014 International Conference

Review Process

Authors ranging from the fields of Mathematics, Science and Technology Education submitted to The Editorial Committee of ISTE 2014 Conference Proceedings their papers for review with possible inclusion in the conference proceedings. In total 149 papers were submitted. All papers were then subjected to a blind review by reputable experts in the respective fields. After reviewing the papers, the reviewers sent their comments to the Editorial Committee, which it assessed and validated before compiling feedback reports for the respective authors suggesting how the papers could be improved. Upon receipt of the revised 56 papers (about 37,6%), the Committee reassessed them before it could finally accept them for publication in the proceedings. Of this number, 41 (73,2%) constitute papers from non-UNISA affiliates.

The Editorial Committee did accept a few papers which were not received back from the authors at the time of going to press and such were not included in the proceedings. We apologise for our inability to include such papers in the proceedings as we had a deadline to meet with the publishers and an obligation to make the proceedings available to participants at the conference.

Editorial Committee

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The organising committee of ISTE 2014 is indebted to the following organisations/institutions whose generous donations contributed to the success of the conference:

College of Graduate studies, University of South Africa

South African National Parks

CONTENTS

KEYNOTE ADDRESS

GOOD INTENTIONS ARE NOT ACTIONS: MATHEMATICS EDUCATION OF SOUTH AFRICA DEMANDS ACTION AND PRIDE FROM THE CITIZENRY

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Abstract–A desktop review of three educational systems is conducted to gain insight on factors that hinder quality mathematics education in South Africa. Mathematics performance of South African students has been repeatedly reported to be at a lowest level compared to other countries. Research has highlighted social class as an emerging strong factor in the system that plays a significant contribution in this low performance. This paper examines the barriers behind aiming for excellence in the mathematics education of the country. This examination uses the highest performing countries' stories to set the bar and highlight challenges. The findings indicate that social class, teacher morale and mathematics knowledge, and curriculum instability are key areas that challenge the country's mathematics education system. This paper recommends international teacher exchange programmes, curriculum stability that puts the student in the center using national assessments to improve practice rigorously, and attention to teacher welfare.

Key words: Reforms, Curriculum Stability, Mathematics Knowledge, Teacher Welfare, Excellency

INTRODUCTION

The 2011 TIMSS findings compared to 2002 indicate hope for South Africa, however only a rigorous plan can rescue the South African education esteem. South African history of segregation continues to evolve itself in different forms. The country emerged from Apartheid with a new emerging status of classism that continues to deprive the poor who unfortunately continue to be dominated by the Africans, Coloured and Indians who were deprived during Apartheid. The curriculum reforms after 1994 focused at replacing the old curriculum with the new. The new school curriculum that the Council of Education Ministers (CEM) decided on was the Outcomes-Based Education (OBE). This curriculum was introduced in 1998 to the General Education and Training (grades 1 to 9) band with a plan to phase it in to all grades including the Further Education Training (grades 10 to 12) band by 2005. That led to the curriculum known as Curriculum 2005 (C 2005). It is important to note that when this curriculum was implemented it was only 3 years into the democratic administration with all the apartheid segregated structures still in place. The inheritance of poor quality education for the previously disadvantaged communities was more visible in implementing C 2005. Reviews on C 2005 suggested changes that lead to the Revised Curriculum Statement that the cohort of students who participated in TIMSS 2011 went through since 2002 to 2011. South Africa is not unique in this journey of curriculum changes and reforms driven by political changes, South Korea and Singapore two of the top performing countries in TIMSS went through these curriculum reforms and have managed to have their students as the lead performers in TIMSS.

This paper aims to highlight the factors that impede South Africa in achieving mathematics student performance that moves towards excellent mathematics learning and practices. The questions this paper responds to are: (1) what are the factors behind the poor mathematics performance in South Africa with particular focus to curriculum implementation and teacher readiness? (2) What are the strengths and weaknesses of the South African education system in adapting towards raised mathematics performance for Excellency? In responding to these questions, the three countries' curriculum reforms will be presented and analysed to identify strengths and challenges that hinder excellence in mathematics education. The selection of the two Asian countries in this paper is based on Excellency, and similar historic political changes to South Africa. The paper will therefore present the literature review, the research design of the paper, the findings will also be presented followed by discussion and recommendations.

LITERATURE REVIEW

Curriculum reforms

Mathematics reforms have been driven by the democratic nature of ruling that originates from the need for "Mathematics for all" (WCER, 2009, 1). However, TIMSS results indicate performance that is skewed positively to certain countries compared to others. The mathematics performance gap between first world countries combined with Asian countries is huge against developing countries. This gap can be associated with the curriculum students are engaged with and attain. Kilpatrick (2009) suggests that there are multiple ways of viewing school curriculum such as: "Intended: The administrator's point of view; Implemented: The teachers' point of view; and Attained or realized: The students' point of view." (p.109). This suggestion assumes that the curriculum inspiration drizzles directly from administrator to teacher to student, a questionable approach as Kilpatrick views intended curriculum as a" blue print" than a curriculum (Kilpatrick, 2009, 109). Hence, Kilpatrick defines curriculum as reality than the intended. The shortcomings of using intended curriculum as the benchmark in describing students' performance can be observed in the students' mathematics performance in TIMSS that reflects on the implemented curriculum than the intended one. As WCER (2009) states that "students are either tested on mathematical content they have not had the opportunity to learn, or they are tested on only a small part of what they have learned"(p.1). The aforementioned literature reveals the importance of the role of the teacher in the realization of curriculum although the teacher has no role in the designing of the curriculum. The definition of the curriculum regarding the assessments is challenged. Whose curriculum should be assessed from the three views used in the international assessments? If intended curriculum is accepted as the curriculum, who is being assessed by the international assessments, the administration, the teacher or the students? Therefore, it is important to note that international assessments are a benchmark for the education system not for reflecting on student knowledge. Regardless of the responses the teacher seems to be the core in delivering the curriculum. Klyeleve (2009) suggests the importance of teacher's attitudes towards curriculum reform.

Curriculum reform in South Africa

Generally the curriculum reform in South Africa has been political driven. Moutin et al (2012) indicated that South African history and the curriculum changes after apartheid disabled education. They support their claim by reflecting on the National Senior Certificate results that indicated shortcomings of the outcome based education, also poor performance of South African learners in international studies such as TIMSS. Jansen and Taylor (2003) highlighted the major factors that had a greater impact in this disabling of education such as, inequities that the government struggles to address, and impact of HIV and AIDS in schooling. Bennie and Newstead (1999) suggested details of how teachers and schools were challenged by the new curriculum. According to them the documents provided by the department of education to guide were too technical and complex for teachers. In addition, they also highlight that the documents themselves lacked quality, as they had some errors, omissions and inappropriate content specifically in the foundation phase. With such challenges implementation of the new curriculum became difficult for teachers.

Mathematics curriculum reform in South Africa

Research on curriculum changes and implementation in mathematics education does not give evidence that is too far from the general curriculum change debate. Molefe and Brodie (2010) also highlight the shortfall of the curriculum documents in differentiating between the traditional practices with the reform accounts. This supports Jansen and Taylor (2003) in their critique of the quality of the curriculum documents. Sidiropoulos (2008) support this literature by indicating that classroom practices of mathematics teachers remain unaffected in spite of their enthusiasm in agreement with the reform. Parker (2006) reports noticeable changes regarding the approach to mathematical knowledge and pedagogy suggested by the new curriculum. However, as indicated by Sidiropoulos (2008) practice remains unchanged.

Teacher preparedness

In highlighting characteristics of schools attended by students from low socio economic backgrounds teacher qualification is one of the factors that contribute to the quality of education received by students. Teacher knowledge has significant role on the instruction. Researchers reveal that the mathematics content knowledge and mathematics pedagogy knowledge are intertwined and interdependence for effective teaching of mathematics (Blömeke et al, 2011). Teacher knowledge for teaching mathematics involves multiple components. Smidt et al (2011) and McTighe & Seif (2011) suggest three types of knowledge needed by teachers that are: Mathematics content knowledge (MCK), Mathematics Pedagogy knowledge (MPK) Mathematics Pedagogy Content Knowledge originating from Shulman's work on teacher knowledge. Findings of the studies that investigate the relationship between mathematics teacher knowledge for teaching and students' mathematics performance reveal that improving teachers' mathematical knowledge plays a significant role in students' mathematics performance (Smidt et al, 2011; Hill et al, 2005; Feza & Diko, 2013). Blömeke et al (2011) reveal the interdependence of teacher mathematics knowledge and teacher mathematics pedagogy content knowledge in contributing to mathematics student performance. This suggests that mathematics knowledge alone is not enough as a requisite for teacher training. However, this knowledge is of no use if teacher morale is low.

Teacher morale

Teacher morale plays a significant role in quality teaching and learning as knowledge alone does not stimulate enthusiasm. Literatures suggest a number of factors that contributes towards teacher morale Perumal (2011) elicit that sources of low teacher morale are student-related, academic instruction with curriculum, teacher support, administrative challenges, and relationship problems. Perumal (2011) adds that students lack of commitment to their learning, their increasing levels of disrespect towards teachers and school and high absenteeism rate of students demotivate teachers in doing their job. Sandra Nichols cited by Perumal (2005) states that "Teachers suffer from low morale due in part to the low-pay-high-cost-of-living gap."(p.6) Steyn (2002) also highlights salaries as one of the extrinsic motivating factor on teacher morale. In addition lack of support from parents, management and peers contributes to low teacher morale (Hendricks, 2009).

RESEARCH DESIGN

A qualitative desktop review of the three educational systems is conducted to extract lessons and determine areas of strengths that can be used in the South African system to achieve Excellency in mathematics education.

Participants

The participants of this study are three selected systems of education: South Africa, South Korea and Singapore.

In highlighting challenges in the South African mathematics education Singapore and South Korea are selected as models for Excellency in mathematics performance and history of colonization that is similar to the history of South Africa. These two countries stories are used to determine strengths if there are any and challenges that the South African system has on its way to excellency in mathematics education.

Excellency

Table 1: Top ten performing countries in TIMSS since 1999

1999	2003	2007	2011
Singapore	Hong Kong SAR	Korea Republic of	Korea Republic of
Korea Republic of	Japan	Singapore	Singapore
Chinese Taipei	Chinese Taipei	Hong Kong SAR	Chinese Taipei
Hong Kong SAR	Belgium-Flemish	Japan	Hong Kong SAR
Japan	Netherlands	Hungary	Japan
Belgium-Flemish	Latvia	England	Russian Federation
Netherlands	Lithuania	Russian Federation	Israel
Slovak Republic	Russian Federation	United States	Finland
Hungary	England	Lithuania	United States
Canada	Hungary	Czech Republic	England

Source: Adapted from Reddy, V., Winnaar, L., Visser, M., Feza-Piyose, N., Arends, F., Prinsloo, C.H., Mthethwa, M., Juan, A. & Rogers, S. (2013). Highlights from TIMSS 2011 South Africa

Table 1 reveals the consistency of high quality performance South Korea and Singapore demonstrate in the TIMSS findings. The highlights on the table indicate that since 1999 these two countries have maintained being the top two performing countries except in 2003 consecutively.

History of colonization

Singapore

According to Lambert (1994) in 1824 Singapore was officially a British colony until 1941. In 1942 it was taken by Japanese for three and half years and went back to British administration in 1946. Singapore gained self-government in 1959 after a Constitutional agreement was signed in London. In 1961 a merger was formed between the Federation of Malaysia, Singapore, Sarawak, North Borneo and Brunei and Malaysia was formed in 1963 with Brunei opting out. In 1965 Singapore was separated from Malaysia and became an independent, democratic country (Lambert, 1994).

South Korea

Korea was under the Japanese rule from 1910 to 1945 (Yukhoon, 2007). It took Korea a long time to be empowered enough to fight for their independence as in other colonized nations their lives were hardened under the Japanese Empire. Unfortunately, the liberation of Korea divided Korea into two: South Korea and North Korea with different allies. South Korea became an associate of the United States while North Korea became an associate of the Soviet Union until today (Yukhoon, 2007).

In summary these two countries have experienced what South Africa has although the experiences are unique to each country. Each of these three countries' citizens knows how it is not to have a voice in your children's education. They also experienced backlog when they received liberation that were intertwined with challenges in moving forward. For these commonalities South Africa can learn some strategies in facing its' challenges.

Data Collection

Desk top review of the mathematics education processes of each country. The following table present a list of sources used during the desktop review to obtain the synthesised data:

Table: 2 List of sources reviewed for this paper

Author	Citation	Relevancy
Center on International Education benchmarking	South Korea Overview http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/south-korea-overview/	South Korea education
	South Korea Education reforms http://asiasociety.org/education/learning-world/south-korean-education-reforms	
Sorensen, C. W. (1994)	Success and Education in South Korea, Comparative Education Review, 38(1), 10-35 https://csde.washington.edu/~scurran/files/readings/SIS511/sorensonEducation.pdf	Reform and success
Lambert, T (1994)	A brief History of Singapore. Retrieved at http://www.singaporeexpats.com/about-singapore/brief-history.htm by 15 December 2012.	Singapore Education

Data Analysis

Two methods of analysis are employed in this paper an analytical framework and a thematic approach. Analytical Framework is employed in this paper for it's power in organising data using codes (Gale et al., 2013). Then later the codes were triangulated for trust worthiness and allowing themes to merge. This approached makes it easy to conduct a thematic analysis in this paper.

FINDINGS

Curriculum landscapes

South Korea

South Korea has been reformed six times since 1955 to 1999 because of the changes in leadership of the government. Below Table 1 presents in detail these reforms.

Table 3: Timeline on curriculum changes in South Korea from 1955

Curriculum	Years	Reasons	Duration
National curriculum	1955 - 1962	First national curriculum in South Korea	7 years
Quantitative expansion of the national curriculum	1963 - 1972	After the military revolution	9 years
National Curriculum enhancing national quality, human education, knowledge and technical education	1973 - 1981	Amendment of the national constitution	8 years
Curriculum appropriate to Korean context	1982 - 1988	New military office in power, assassination of the former president	6 years
Maintaining the framework of the curriculum appropriate to Korean context	1989 - 1994	Democratic government in power	5 years
Curriculum cultivating morality and creativity	1995 - 1999	Democratic government cultivating morality, and creativity	4 years
	2000 - present	Promoting students' learning	+12 years
	2005 - present	Established on demand curriculum revision	+8 years
	Present	Aligning curriculum with knowledge based society	

Table 3 indicates clearly that in South Korea curriculum changes were political driven with political agendas from 1955 to 1999. When the democratic government took over the changes were driven by the needs from Korean identities to Korean values and maintaining Korean dignity between 1989 and 1999. Beyond 1999 the curriculum reforms began to focus to students' learning and children and parents treated as consumers. The core curriculum has been kept stable and evolution of knowledge incorporated continuously.

Singapore

Singapore designed their first curriculum reform in 1965 that was a uniform curriculum between the years 1965 to 1980. This phase of reform brought stability in school management but it was weak in bilingual policy, had low literacy levels and high expenditure. The second reform was informed by a review conducted in educational system in 1979 and the curriculum was one of the highlighted areas than needed attention. The reform led to the launch of the Curriculum Development Institute of Singapore (CDIS) to develop curriculum and teaching materials and to implement a New Education System (NES). Improving mathematics and science curricula in both primary and secondary schools was one of the major priorities in the responsibilities allocated to the CDIS.

Table 4: Timeline on curriculum changes in Singapore from 1965

Curriculum	Years	Reasons	Duration
Chinese Edition of the civics syllabus	1967 – 1978	Gaining independence in 1965	11 years
Piloting method of teaching English language	1971 -1973		3 years
Piloting methods of teaching Chinese language	1974 – 1976		2 years
Trial approach to revise and replace general science syllabus	1974 – 1978		4 years
Institutionalized innovations in curriculum development	1980 – 1995	Reducing education wastage and promote more effective learning	15 years
Textbook market liberalization	1996 – 2006	Becoming a national recognized publisher for a decade	10 years
PANPAC education	1990 – Present	To gain international publishing capabilities in Brunei, China, United States, Malaysia, Caribbean, Pakistan, Vietnam, Thailand, Indonesia. Other developing countries have already invited PANPAC to assist them develop their own textbooks e.g Egypt	

Table 4 indicates that the reform was driven by change in government in 1967, however Singapore used a research based approach in reforming their curriculum with more focus on effective textbooks production. They maintained a core curriculum and have more influence on competitive textbook marketing which later became international recognized and used. The drive behind this reform was business based that increase competitiveness.

South Africa

In South Africa the similar changes of three reforms occurred from 1997 to 2009, however driven by different needs. In the beginning with the first curriculum was driven by the need to have a new curriculum after apartheid government (1998-2000). The second reform (2002-2009) was revised because of the teething problems of the democratic government such as inequitable infrastructural resources, teacher competencies, shortage of human resources and lack of quality supporting materials. However, the teething problems of the democratic government and ambitious goals of education led to lack of implementation plan of the revised curriculum, too much/many guidelines and interpretation of policies and unclear roles of subject advisors.

Below Table 5 presents changes in school curriculum implemented in South Africa post 1994, reasons for changes and teacher readiness.

Table 5: Timeline on curriculum changes in South Africa from 1994

Curriculum	Years	Reasons	Duration
Interim syllabus	1995 - 1997	Changing from Apartheid system to the democratic system	2 years
Curriculum 2005	1998 - 2001	Skewed curriculum, lack of human resources for implementation, curriculum and assessment policy not aligned policy overload, no classroom transferability, inadequate teacher training, and inequitable quality of materials.	3 years
Revised National Curriculum Statement	2002 - 2011	Lack of a plan for implementation, an overabundance of policies, guidelines and interpretations of policies and guidelines at all levels of the education system, and unclear role of subject advisor.	9 years
Curriculum Assessment Policy Statement	2012	Currently implemented	

Table 5 shows that the South African reform had similar historical nature of changing from an old government to the new government like the other two Asian countries. However, the curriculum changes in South Africa indicate curriculum design challenges and teacher preparedness compared to the citizenry shown by the other countries and an element of too much excitement. Firstly the curriculum was skewed, not aligned with assessment and inadequate teacher training. Again the following revision did not indicate any improvement on the teacher preparation and implementation, lack of human resources continues to be a challenge to implementation. However, too much jargon continues to overwhelm implementers.

Summary of the three countries reform approaches

The Singapore approach in curriculum reforms brings in the strength of conducting research prior rolling out rather than conducting reviews of what failed. This approach controls unnecessary waste of funds and resources. Excellence is another element that drives the Singapore approach by treating students and parents as consumers and striving for national and international recognition and leadership. The status of PANPAC education proves that Singapore education system has international status and continues to influence education globally.

South Korean reforms have lots of similarities with the South African reforms. The democratic government of Korea faced similar challenges of bringing back Koreans human dignity, values and creativity that were lost during the colonization regime. Therefore similar to South Africa their curriculum reforms aimed at restoring identities, values and creativity. However, the time spent on restoring the South Korean dignity was only 9 years, their focus skewed to student learning. Their curriculum developments ensured that the student is learning continuously.

South African reforms were driven by the need to rectify the South African history of oppression and division. This objective continues to be the focus of South African reforms to an extent that the curriculum reforms fail to bring the student at the center of the planning. The multiple interpretations of policies and guidelines indicate lack of clarity on the main objectives of the education. Teacher readiness continues to lag behind in the South African curriculum reform. Lack of prompt intervention strategy through pilot studies exhaust resources and impede progress.

Mathematics Teacher Readiness

Research has proven the vital role played by the teacher in student learning hence teacher readiness is important for any curriculum reform (Schmidt et al, 2011). Teacher readiness for curriculum reforms plays a significant role in the coverage of the curriculum at hand as it is the teacher who exposes students to the curriculum using effective strategies. Reflecting on teacher readiness will assist in understanding the depth of the curriculum coverage that can be associated with students' performance. The three countries

South Korean Teacher readiness

South Korea teacher education was highly influenced by the government changes. Therefore their teacher education is reported from their first democratic government in 1994. Teacher profession had a sacred position in the Korean society. However, their struggle to legalize the Korea Teachers and Workers Union (KTWU) changed this status for teachers influencing teacher policies too. Table 6 presents the evolving status of Korean teacher education.

Table 6: Teacher evolution in South Korea from 1994

Year	Teacher status	Challenges	Solutions
1999	Weakened teacher morale	Economic crisis Inequitable teacher retirement age reduced from 65 to 62, a reduction that was heavier compared to other sectors.	Comprehensive Plan to Develop the Teaching Profession announced in 2001 to heighten teacher morale
1997		Teacher supply decreased caused by increased demands on teachers by the seventh curriculum	In 1999 the Ministry of Education proposed a policy plan that creates "teaching profession full of zeal to teach and the pride to teach"
2001	Low teacher morale	Hostility towards teachers.	Announcement of the "Comprehensive Plan to Develop the Teaching Profession" Measures to boost teacher morale 1)Reduced teacher work load by increasing the size of teacher quota 2)Increase teacher salaries 3)Improve teacher welfare through research 4)Encourage teacher participation in competing for research projects 5)Increase support from volunteers

Table 6 reveals that Korean teachers went through many challenges that weakened their morale and affected the number of candidates to the field. South Korean Ministry of Education worked energetically to fix this status by addressing teacher grievances directly. They nurtured the status of the teacher through reduction of workload, increasing salaries, improving teacher welfare, developing the research culture amongst teachers and increased support from volunteers.

Singapore Teacher readiness

Singapore teacher education went through changes in different time during 1960s the country faced with teachers with low moral due to their six day teaching strategy that led to exhaustion and demotivation. In 1962 the Singapore government recognized this plight and decided to take action. Table 7 presents the evolution of teacher preparation in Singapore over the years

Table 7: Teacher evolution in Singapore from 1962

Year	Teacher status	Challenges	Solutions
1962 - 1965	Exhaustion from the six day work a week	Importing teachers outside the country	Recruiting teachers in training to assume partial teaching responsibility while in training Give female teachers equal pay as male counterparts
1966	Routine work dominated teacher work with no time for reflection, innovations and self-improvement	Number of pupils increased and teacher quality compromised	More teachers recruited
1970-1973	Teacher demand stabilized	Teacher quality	A one stop teacher training institution was established the Institute of Education (IE) with the mission to improve quality of teaching in schools.
1973 - 1999	Professional status	Teacher quality	Upgrading professional standards by appointing Dr William Taylor from the University of London's Institute of Education and providing grants to faculty to pursue higher degrees. Collaborating with overseas reputable colleges to enhance the Singapore education and it's degrees.
1996	Improved teacher quality	Teacher retention	Continuous teacher upgrading and professional development, providing good salaries and promotion prospects in the education service, give incentives to teacher trainees in form of teacher salary with service benefits instead of bursary.
2001	Highly remunerated and receive incentives for excellency in their job		Promotion tracks and performance incentives were put in place for teachers. A new system of assessing teacher performance introduced to all schools.
	Beginning teachers receive induction		Inducted through talks, enrichment courses prior leaving school for full time teaching jobs. At school level mentoring sessions are offered.
2003	Nation's quality teachers	Excellence in teacher education	Development of a comprehensive teacher education framework that uses an expert consensus-building approach; a research-based approach; and a professional-consensus approach.

Table 7 indicates that Singapore teacher education evolved continuously as the needs rise. The Singaporeans approach in addressing teacher education is always inclusive of quality. When there was a demand for more teacher recruitment involved quality training. When there was a need to retain teachers retention approach did not only focus on incentives but professionalism, continuous learning, excellence and accountability through teacher performance assessment. Singapore provides induction to new teachers in order to maintain quality, encourage professionalism and motivate teachers. The status of the teacher in Singapore is high and therefore teachers themselves are used as experts, researchers, and professionals in maintaining quality teachers.

South African Teacher Readiness

South African teacher evolution share similar challenges with Singapore and South Korea. Teacher status and quality during the democratic era evolved at different levels. In conceptualizing the inherited challenges of the apartheid regime the National Teacher l Education Audit (1995) was conducted. This audit revealed that the general teacher education "quality was poor, inefficient and cost-ineffective" (2005, p. 3). Table 6 presents the evolution of teacher education in South Africa post 1994.

Table 8: Teacher evolution in South Africa from 1995

Year	Teacher status	Challenges	Solution
1994	Disaggregated teachers	Varied quality of teacher training in historical colleges	Incorporation of teacher education colleges
2001	Varied teacher qualifications	Unequal standards of colleges of teacher education	Colleges of education incorporated to Universities to improve the quality of teacher education programmes
2002 – 2006	Varied teacher qualification	Scarcity of materials to serve the incorporated education sectors	Catering for teachers with lower qualifications through a National Professional Diploma in Education through bursaries
2007-current	Declined interest in teaching and morale for teaching	Enrolments of teacher trainees went down Supply of teachers in certain subject such as language, mathematics and science went down Poor teachers attendance in school reported Lots of teacher strikes about teaching conditions, and teacher salaries	Fundza Lushaka comprehensive bursary for teacher training was launched Increased interest on teacher training

Table 8 reveals that South African incorporation of colleges was done without planning and looking on the impact the incorporation will have on producing teachers. Hence the shortage of teachers for certain subjects and rural schools came into place. The in-depth of inequalities was not properly addressed prior to designing catch up programmes. Teacher morale has been attended to through the comprehensive bursary to attract more teachers, however improving teacher morale of the practicing teacher still needs attention.

Students' Mathematics Performance on Cognitive Domains

Below the cognitive performance of students from the three countries are presented. All three figures reveal an equal distribution of knowledge across the three domains.

Singapore

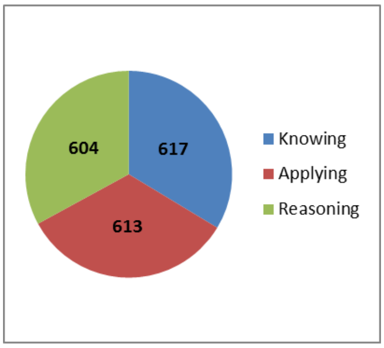

Figure 1: Singapore's eighth grade students' mathematics performance on cognitive domain

Figure 1 indicates that Singapore students are slightly stronger on knowledge followed by ability to apply the knowledge. Reasoning abilities are slightly lower than knowledge and application.

South Korea

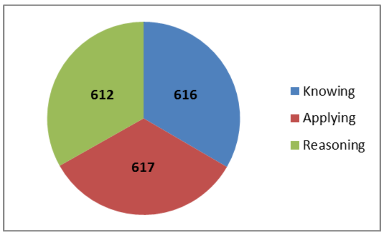

Figure 2: South Korea's eighth grade students' mathematics performance on cognitive domains

Figure 2 reveals equal distribution of knowledge and application followed by reasoning that is slightly lower.

South Africa

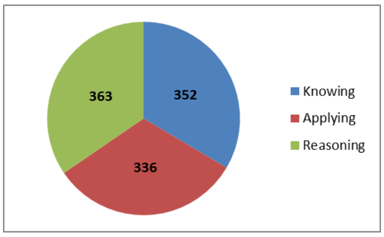

Figure 3: South African ninth grade students' mathematics performance on cognitive domains

South African students in Figure 3 indicate strength in reasoning than knowledge and slightly lower in application of knowledge. In addition their performance is below the international mean which is 500.

DISCUSSION

The findings of this paper are discussed by highlighting challenges in the South African mathematics education followed by lessons to be learnt from the two selected Asian countries.

Challenges in South African mathematics education

The findings of this paper highlight a number of challenges from the South African education, which are in different levels. The discussion will first focus on the challenges that are emerging from this paper and within those challenges influential factors will be highlighted. Curriculum reform, teacher preparedness, and student performance emerge from this paper as the challenges the education has.

Curriculum reform

The findings presented in this paper highlight the importance of teacher preparedness, curriculum stability, research based approach and putting a child in the center of reform as strengths of curriculum reforms. South African data indicates challenges in curriculum reforms because of the influential factors such as not having mathematical skilled human resources, inability to put a child as the center of reform, not aiming for curriculum stability, and not rolling out research based curriculum for effective practice. According to Howie (2003); Adler (2009) and Feza (2012) the lack of mathematical skilled human resource indicates the significant role social class has in the mathematics education of South African students. This lack of mathematical skilled human resource reflects to the country's affluence in being able to produce such skill.

The inability to put the child as the center of the curriculum reform reflects miscommunication and misunderstanding of role of international assessments. For example, Kilpatrick's (2009) detailed account on intended curriculum suggests that expecting students to perform well on intended curriculum is senseless rather than expect them to perform on the implemented curriculum. As suggested by Douglas (2009) the findings of the international assessments are not reporting students' performance rather they report the mathematics education system's performance of a country. I infer that the poor mathematics student performance on international assessments reflects the mathematics education system not students' inabilities. Hence, national assessments should be used to inform and improve teaching and learning of students.

Curriculum reforms have to happen when changes in the government happens, however the student should be the center of the change. The findings of this paper reveal that the student and parent should be treated as consumers, active teacher involvement as experts in curriculum reform is crucial and curriculum stability will be the starting point to maintain quality education.

Teacher preparedness

These findings also highlight the impact teacher morale has on improved quality mathematics education. Lessons from this data indicate that teacher complaints cannot be ignored for better education in general. Teacher salaries, work conditions, teacher health have significant impact on students' success. Hence these findings reveal that improved teacher well-being develops teacher attitude for the benefit of the education as it happened in South Korea. Teacher education has to be intertwined with quality for better student output. Improving the status of the teacher holistically, using them as experts, researchers, and professionals is more rewarding in maintaining quality teachers a lesson from Singapore. In this paper, South African findings highlights low teacher morale, poor teacher knowledge, severe inequalities in the education system as main factors that continue to impede success in mathematics teaching and learning. Chilsom (2009) support these findings bringing forth their contribution to low teacher morale.

Student performance

South African student performance highlights reasoning abilities South African students have. However, these reasoning abilities are hindered by the lack of knowledge. Hence South African students perform below the international mean in general. These findings support Smidt et al (2011) in their findings that poor performing students in TIMSS are taught by teacher with poor mathematics content knowledge. Hence they propose together with Hill et al (2005); Feza & Diko (2013) that teacher mathematics knowledge needs to be improved for better mathematics learning. Adler (2009) suggests that in addition teachers' knowledge for teaching has a significant role.

RECOMMENDATIONS

This paper recommends that South Africa accept that there is lack of expertise in the mathematics education and the country on its own cannot deal with this challenge. I recommend that the country engage with international counterparts on teacher exchange programmes to assist in addressing the lack of expertise. Mathematics teacher education needs to re-visit the admission requirements and strategies of increasing mathematical knowledge of student teachers. Improving teacher morale through incentives and addressing salary plight teachers have is no longer a debatable issue, and allowing teacher to become experts in their fields through research and incentivize attainment of such skills. On policy level, it is time for curriculum stability and focus on effective learning by putting the student where s/he belongs in the center. It is time for parents to roll their sleeves and be involved in quality education provisioning of their children.

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ARE THE UNIVERSITIES PRODUCING THE TEACHERS WE NEED?

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1. INTRODUCTION

Many problems beset the South African school system, including, in many instances, poor management and leadership and the inefficient distribution of resources. But, even where institutions are well managed and teachers have access to sufficient resources, the quality of teaching and learning cannot rise above the ceiling imposed by low teacher capacity. This ceiling may be high in a minority of schools, but in the large majority teaching is often ineffective and learners fall progressively behind the expectations of the curriculum with each passing year.

Recognition of the generally poor state of the Initial Teacher Education (ITE) sector led to its radical reorganisation in 2000. This entailed closing most colleges, merging the remainder with higher education institutions (HEIs), and making ITE the responsibility of HEIs.

The question now arises as to what extent the current system of teacher education is meeting the demands of South African schools. Are we producing teachers better able to address the challenges of schooling? The purpose of the Initial Teacher Education Research Project (ITERP) is to investigate these questions.

A founding assumption of the project is that norms set by regulatory bodies such as DHET, CHE/HEQC and SACE can, at best, provide a broad framework of formal criteria (number of hours, knowledge fields to be addressed, mix of modules, etc.) but they can neither specify content nor guarantee quality. The quality of professional standards is best evaluated by experts in the profession, and therefore attempts to improve the quality of teacher education must start within the field itself. From this perspective, the research findings outlined below are intended to inform the debate about the quality of ITE, commencing within the terrain of initial teacher education, and in particular among campus-based practitioners.

2. CONDITIONS IN SCHOOLS

A number of research programmes, of both large and small scale (Taylor, van der Berg and Mabogoane, 2013), have described the following conditions as endemic in schools across the country:

1. Low levels of English proficiency among both teachers and learners. This places a fundamental limit on academic progress, since English is the medium of teaching and learning in around 90% of schools.
2. Lack of adequate reading pedagogies, resulting in large numbers of learners reaching Grade 5 essentially illiterate.
3. Lack of adequate pedagogies for basic numeracy, resulting in learners up to and beyond Grade 7 using 'stick counting' methods to perform relatively complex arithmetic operations.
4. Low levels of subject knowledge among teachers.
5. The tendency for schools not to recruit and deploy primary school teachers according to subject specialisation, but to assume that all qualified educators are capable of teaching all subjects. Thus, at some stage of their careers, most primary school teachers will be required to teach maths and English. Across all phases, there are too many teachers teaching subjects in which they did not specialise (DBE/DHET 2011: 34-36, 40-42).

These are some of the issues that newly qualified teachers (NQTs) should be equipped to address when taking up positions in schools.

3. RESEARCH DESIGN

The Initial Teacher Education Research Project is framed by four main questions:

Research question 1: What range of practices exists in the ITE programmes offered by HEIs to prepare teachers to teach in South African schools?

Research question 2: To what extent do these practices adequately prepare teachers to teach in South African schools?

Research question 3: How do teachers who qualified from different institutions navigate the challenges they encounter in their first years of teaching?

Research question 4: How can the quality of the curricula offered by ITE programmes be improved?

The project is structured around four components (Table 1). These are designed to complement each other in providing a three-dimensional view of ITE. The components are:

Component 1: A review of the overall coherence and conceptions of teaching which underlie the ITE programmes and curricula in use at five HEIs. This was followed by a detailed examination of the intended and assessed curricula for mathematics and English for teachers specialising in the Intermediate Phase (Grades 4-6).

Component 2: Case studies of a group of students as they move from being students on the five HEIs, through their first two years of teaching. This component will include an exploration of the attained curriculum, i.e. what NQTs actually know.

Table 1: Deliverables for four project components

Project Component		**Deliverable**
Description	**Time**	
1. Content of teacher education programmes at 5 HEIs	June 2012 – July 2014	General description and analysis of BEd and PGCE programmes, including teacher educator conceptualisations of teacher professional identity, programme structure and purpose, admission criteria, curriculum contents and coherence, structure and function of teaching practice, and forms of assessment. Comparative analysis of form and content of teaching practice instruments. Description and comparative analysis of BEd IP **MATHS AND ENGLISH COURSES.**
2. Case studies of NQTs in first two years of teaching	Jan 2014 – July 2015	Report 1: Subject knowledge of NQTs in IP maths and English. Progress of the NQTs in adapting to school life; analysis of the extent to which their training facilitated this process.
	Jan 2015 – July 2016	Report 2: progress of the NQTs in adapting to school life; an analysis of the extent to which their training facilitated this process; changes over the course of the second year.
3. Survey of all final year (BEd and PGCE) students in 2013, tracking them into the workplace for 2 years	June 2013 – July 2014	Report 1: final year students' educational backgrounds, motivations for becoming teachers, perceptions of teacher education programmes, confidence in readiness to teach, teaching practice experiences, and career plans.
	June 2014 – July 2015	Report 2: distribution of NQTs; progress of the NQTs who are employed in SA in adapting to school life; analysis of the extent to which their training facilitated this process; changes in relation to 2013 survey.
	June 2015 – July 2016	Report 3: further progress of the NQTs in adapting to school life; analysis of the extent to which their training facilitated this process; changes over the course of the second year and in relation to 2013 survey.
4. Recommendations for ITE in the IP.	July 2014 – August 2016	Discussion of ITERP findings by teacher educators, government, statutory bodies, teacher unions, donors. Recommendations for Education Faculties, Teacher Educators, Schools, Unions, Government, Donors.

Component 3: A large-scale survey across all 23 HEIs of ITE students in their final year of study (4th year BEd, and PGCE), and subsequently tracking their progress over two post-graduate years.

Component 4: Recommendations for ITE curricula for teachers specialising in the IP.

The present paper describes progress on Component 1.

4. RESEARCH METHOD FOR COMPONENT 1

Five institutions were invited to participate in the study. Their selection was based on five criteria: institutional history, demography, location, programme delivery mode, and the number of graduates produced annually. Collectively, these five HEIs represent the major institutional types which deliver ITE, and in 2012 produced 49% of all BEd graduates in the country and 61% of PGCE graduates (DHET, 2013).

Ethical clearance for the comparative study was obtained from the DHET and from each participating institution. The first draft of the current report was presented to each of the five institutions for correction on matters of fact and comment on questions of interpretation, and the relevant reports amended where appropriate.

The first step in describing the intended and assessed curricula was to undertake a broad overview of all BEd and PGCE courses offered by these five HEIs. The data collected during this phase, as well as during the second phase described below, related to curricula in use in 2012. Since then most HEIs have been redesigning their curricula in accordance with the Minimum Requirements for Teacher Education Qualifications (MRTEQ) promulgated by the Minister of Higher Education and Training in 2011 (DHET, 2011). A senior researcher spent two to three days interviewing faculty members and collecting documents, including course outlines and curricula, course notes and reference lists, and assessment tasks. Information was collected on staffing levels and responsibilities, student numbers in the various courses offered, course components, entrance criteria and the type of teacher the institution is trying to develop. The results, across the 5 HEIs visited, are summarised in section 5 below.

The second step was to look in more detail at course content. In order to render this task manageable, it was decided to focus on the curricula for English and mathematics offered to BEd students specialising in the IP, and on the instruments used to assess the teaching practice component of these course. This involved a further round of fieldwork, interviewing the relevant staff and collecting documents. The results of this exercise and subsequent analysis are summarised in sections 6-8. A full report for each of these three aspects of the curricula offered by the five HEIs studied is available at www.jet.org.za

5. KEY FINDINGS FROM THE OVERVIEW REPORT ON THE FIVE CASE STUDY CAMPUSES

Generally speaking, all initial teacher education programmes at the five case study universities aspire to produce knowing, caring and committed 'reflective practitioners'. Strong subject content knowledge is central to this conception of teacher identity, accompanied by a nurturing attitude and ethical behaviour.

BEd curricula are organised around at least three years of subject content and methodology modules, accompanied by a range of general theoretical and pedagogic modules, as well as language, literacy, ICT, curriculum and teaching practice modules. PGCE curricula are largely concentrated versions of BEd curricula, without subject content modules.

However, the content of modules and hence of programmes varies widely among institutions. Teaching practice is the area with the greatest variation, in terms of both quantity and quality: total time students spend in schools varies between 10 and 35 weeks; at all except one institution, teaching practice takes place mostly in suburban schools; diverse experiences are encouraged but not enforced; most supervisors are not subject specialists; and in at least two institutions it is possible for students to pass teaching practice despite performing poorly in a classroom, or even without being assessed on their classroom expertise. We look in more detail at variation in approach to assessing teaching competence within the ITERP in section 6 below.

ITE programmes have low entrance requirements in comparison with most other disciplines. Students are accepted without any reference to what motivates them to become teachers. Teacher educators' low expectations of the academic quality of students (including weak subject content knowledge, lack of proficiency in English, and generally poor reading and writing skills) are not always counterbalanced by any concerted or structured attempt to transform these poor quality entrants into good quality 'reflective practitioners'. In some institutions, the focus appears to be on quantity (more teachers) rather than quality (better teachers).

Most programmes seem to lack a strong underlying logic and coherence. At one institution, curricula change more in response to changing government policies than in response to research-informed opinions or professional judgements. At others, a similar degree of bureaucratic compliance is coupled with an overemphasis on practice (how) at the expense of theory (why), exacerbated by a lack of staff collaboration and module integration.

However, two institutions' programmes display more structural and conceptual coherence than most: they emphasise the development of deep subject and pedagogical content knowledge, together with strong awareness of the theoretical principles and purposes of education. The basis for this coherence appears to be a clear intra- and inter-programme set of beliefs about initial teacher education, grounded in respected theoretical models and shared by the majority of staff.

Much work remains to be done to mine the wealth of data collected for this Overview Report, including an analysis of variations in how the five HEIs view and use Educational Theory and Professional Studies to shape and direct their programmes. In the meantime, we focus below on the details of the instruments used to assess teaching practice, and the maths and English programmes.

6. KEY FINDINGS FROM THE ANALYSIS OF THE TEACHING PRACTICE INSTRUMENTS

Teaching Practice (TP) assessment instruments are a small part of initial teacher education programmes, but they are nevertheless influential in transmitting messages to students, mentor teachers and university lecturers about what constitutes competence in student teaching and as a newly qualified teacher.

Analysis of criteria specified in TP assessment rubrics

Without exception, all TP assessment instruments included reference to students' subject /content knowledge; teaching and learning strategies; learning and teaching support materials; assessment; language and communication; consideration of learner diversity; professionalism and relationship with learners. However, there exist significant differences in how each criterion presents teaching, and what is expected of students in relation to each one.

Content knowledge

In two institutions, students' understanding of content knowledge is depicted as essential for effective teaching, whereas within others, a sound grasp of content knowledge is only one of many criteria that contribute a portion to an overall credit.

Pedagogic Knowledge

Criteria (and in one case level descriptors) can be distinguished according to whether they present teaching as a collection of technical presentation skills, a generic practice (with reference to general pedagogic knowledge) or a specialised practice (with reference to Pedagogic Content Knowledge, PCK). Four of the five instruments analysed contained criteria that referred mostly to students' presentation skills and their ability to draw on a general pedagogic knowledge base. The level descriptors of one instrument described what students' teaching competence would look like if informed by a consideration of PCK.

Situational / Contextual Knowledge

The analysis found very little provision for recognising the way in which student teachers respond to the limitations, challenges and opportunities within the context of their school placement.

Conceptions of professionalism

The three ways in which conceptions of teacher professionalism are typically conveyed through TP assessment instruments are through interpersonal relationships within a school setting, students' appearance, and their ability to make considered and reasoned pedagogic judgements in relation to specialist knowledge. There tended to be a greater emphasis on interpersonal relationships and appearance in four of the institutions.

Structure of TP assessment instruments

In analysing the structure of the TP assessment instruments, three factors were considered: how they portray the respective roles of the mentor teacher and university lecturer, how the rating scale or level descriptors signify what constitutes distinctive or unacceptable levels of teaching competence, and the mechanism by means of which a pass/fail decision is reached.

Who assesses what?

Some institutions require that university staff members and school based teachers should seek consensus, and bring their particular perspectives together to enhance the overall assessment. Others require that school-based teachers assess students' extra mural involvement, inter-personal relationships, and general professionalism, while university tutors assess the extent to which students draw on university coursework to inform pedagogic decision making. In this way, assessment of the substance of student teaching is determined by the structural arrangement of who assesses what.

The use of explicit or implicit rating scales and level descriptors

In four of the institutions, students are assessed on a four or five point rating scale. While the use of a checklist of criteria along with a simple rating scale may seem like a user-friendly way to structure the assessment of student teaching, it relies on a wide range of assessors (all supervising teachers and a large number of university tutors) being able to interpret each criterion at different levels of competence.

One university provides explicit descriptors to define what constitutes each level of competence against every criterion. The TP assessment instruments enables student teachers to access what they are doing, what they're not doing, and what they should be doing in order to teach more effectively. It also provides more guidance to assessors in unpacking what constitutes competent teaching at each level and against each criterion.

The atomistic or holistic assessment of student teaching

When the overall mark awarded to the student is an arithmetic sum of ratings against a list of criteria, a notion that teaching is reducible to a collection of skills is transmitted. In contrast, a conception of teaching that involves both cognitive and performance dimensions is conveyed by an assessment rubric that plots a student teacher's level of knowledge, understanding and thinking against the effectiveness of her classroom performance.

Conceptions of teaching conveyed in TP assessment rubrics

The study considered how combinations of design features work collectively to convey particular conceptions of teaching. While the three categories described in the bullets below are idealised abstractions, they are useful in gauging the extent to which the design features in TP assessment rubrics convey particular conceptions of teaching:

- When teaching is understood as a *skills-based endeavour*, the routines, procedures and skills needed for managing a classroom are emphasised in TP assessment instruments. Atomistic criteria are generally listed as an end in themselves. Teachers' dispositions and what they can do count more than students' understanding of a principled body of knowledge and its application for sound judgments.
- Teaching as a *generic applied science* draws on general pedagogic knowledge to inform classroom practice, drawing attention to a strong teaching and learning imperative. The teacher's understanding of content knowledge is not portrayed as a precondition for effective teaching, but is one of numerous considerations.
- A conception of teaching as a *complex and specialised practice* is conveyed by the use of a network of criteria that reveal the relationship between appropriate pedagogic choices, the content to be taught and the learning needs of those to be taught. Students' understanding of

the content knowledge is a non-negotiable condition for effective teaching both as a condition for enabling access to conceptual knowledge, and as the grounds upon which pedagogical choices can be justified.

In general, the TP assessment rubric from one institution tended more towards portraying a conception of teaching as a complex and specialised practice, while the other four tended to portray teaching more as a generic practice. If university-based coursework presents teaching as an integrated, complex practice but student teaching is assessed as a collection of discrete skills or against generic competencies, then coherence within the teacher education programme is unduly compromised. The use of assessment rubrics that do not adequately support student teacher professional development in planning conceptually strong and well executed lessons not only misses an opportunity to support students' professional development, it may also perpetuate the prevalence of technicist guidance provided to them during their practicum sessions.

7. KEY FINDINGS FROM THE REPORT ON ENGLISH COURSES FOR BED IP TEACHERS

English courses offered

English courses offered to prospective IP teachers on the five case study campuses are described in terms of three kinds of knowledge (Banks, Leach & Moon, 1999). First, Subject Knowledge English consists essentially of literature, media studies, and language/linguistics. School Knowledge is the knowledge and skills specified in the particular curriculum to be followed in schools, and Pedagogic Knowledge includes knowledge of approaches to teaching a language, and strategies for teaching speaking, listening, reading, and writing. The latter two components are often difficult to distinguish, and in what follows we group them together. Interviewees at all five HEIs mentioned the low levels of English proficiency and of academic writing ability exhibited by many students, and for this reason all offer some support for academic reading and writing, which we describe below as Academic Literacy (AL).

Table 2 summarises the courses offered by the five institutions (labelled A-E) to students specialising as English teachers, in terms of these knowledge components.

Table 2: English Courses for IP BEd English specialists

	A	B	C	D	E
Academic Literacy	1 year course: New Lits for Teachers	2 semesters: Academic and Computer Literacy	No AL, but some attention to it in Level 2 Eng modules	2 semesters: Academic Literacy	2 year long courses: Academic Literacy
Subject Knowledge	4 year courses: Eng Lang and Lit	6 semesters: Eng Lang and Lit 1 – 3	5 semesters: Eng Lang and Lit	6 semesters: Eng Lang and Lit	4 year-long courses: Eng Lang and Lit
School and Pedagogic Knowledge	2 year courses: Language Method 1 and 2	2 semesters: Eng as Medium of Instruction. 4 semesters: Eng Method	2 semesters: Language Method (one semester each for HL and FAL)	2 semesters: English Method (FAL)	HL: 4 year- long courses: Eng Method

Aside from the fact that all five HEIs offer some or other form of Academic Literacy, the most striking feature of Table 2 is the variation in both duration and content of the other components. Thus, Institutions A and E both offer 4 full years of Subject Knowledge, while Institution C offers only 5 semesters. Regarding School and Pedagogic Knowledge, Institution E provides specialist English teachers with 4 year-long courses, while the other 4 HEIs offer only between 2 and 4 semesters.

Table 3 summarises the English courses for BEd IP teachers who do not specialise in English. It is disturbing to note that, despite the ubiquitous complaint that many students enter university with weak English proficiency, and despite the fact that the overwhelming majority of IP teachers will teach through the medium of English, three of the HEIs in the ITERP sample (A, B and D) provide no Subject Knowledge English for students not specialising in this subject, while Institution D offers no School or Pedagogic Knowledge in English either.

Table 3: English courses for IP teachers not specialising in English

	A	B	C	D	E
Academic Literacy	1 year course: New Literacies for Teachers	2 semesters: Academic & Comp Lit: 1 for all students + 1 for weak readers	No Academic Literacy courses	2 semesters: Academic Literacy	2 year courses: Academic Literacy
Subject Knowledge	None	None	2 semesters: One for Eng Lang; one for Eng Lit	None	HL 2 year courses: Eng Lang & Lit. FAL 2 year courses: Eng Lang & Lit (non-credit, elective).
School and Pedagogic Knowledge	1 year course: Language Method	2 semesters: English as LOLT (FAL)	2 semesters: English Method HL and FAL	None	HL 2 year courses: Eng Method. FAL 2 year courses: Eng Method (non-credit, elective).

Table 4 summarises the number of credits carried by the courses listed in Table 2 and Table 3.. Here too the variation across HEIs is striking, with English courses for specialist English teachers constituting only 15% of the overall degree at Institution C, while the comparable figure for Institution B is 34%.

With respect to those IP teachers who have elected not to specialise in English, the question must again be asked whether their formal exposure to English Subject and Pedagogic Knowledge (between 5% and 7.5%) is adequate.

Table 4: Proportion of BEd degree made up by English courses for IP teachers

Elective	A	B	C	D	E
IP English Specialists	120 (25%)	162 (34%)	72 (15%)	120 (25%)	HL: 72 (15%) AL: 5 (1%)
IP English Generalists	30 (6%)	28 (6%)	36 (7.5%)	24 (5%)	HL: 28 (6%) FAL: 29 (6%) AL: 5 (1%)

Observations

The full Report on English courses offered to IP teachers at the five case study campuses provides a rich source of information and analysis, and in the space available below we can do little more than allude to some of the most important issues.

English for academic purposes

The academic literacy courses offered to all IP student teachers at each of the five institutions in the study contribute to very different constructions of literate teachers, as a result of the different learning focus of each course. Some aim to fill gaps in student teachers' syntactic and lexical knowledge of English; others aim to support development of the ability to read and write academic texts and to undertake research. While the need for 'gap filling' for some students is acknowledged, if this is the sole or main focus of academic literacy programmes student teachers are unlikely to gain sufficient epistemic access to 'socially powerful' theoretical knowledge (Shay, 2012).

New literacies for teachers

Only two institutions offer courses (both subject and pedagogic in one institution and pedagogic in the other) that enable students to engage substantively with New Literacy Studies in which literacy practices are considered 'cross culturally, in different domains, in different discourses and as they vary in relation to different sign systems and different technologies' (Janks, 2010, p. 117). When literacies are produced and used in such diverse ways within and across communities in South Africa and globally, this lack of engagement with new literacies in several institutions is a cause for concern.

English as subject specialisation / English as subject for the 'non-specialist'
The subject courses offered to IP English specialists at each of the five institutions contribute to very different constructions of teachers of English, as a result of the breadth and depth of study (more courses at more levels offered in some institutions than others), differences in content foci (at two extremes, mainly canonical literature on the one hand and mainly descriptive grammar on the other) and the texts (including film texts) and genres chosen by lecturers. Literature for children and adolescents, as part of the subject knowledge of an IP English teacher, is backgrounded or ignored at several institutions and is a cause for concern given the importance of developing learners' interest in reading and the contribution of reading to lexical and syntactic knowledge.

The opportunities for IP student teachers not specialising in English to study English as subject courses, which could contribute to their development as literate teachers, vary from non-existent (at institutions A, B and D) to limited (institution C) to more adequate (institution E).

Learning to teach English as home or additional language; learning to use English as LoLT
Even in the two institutions which offer more School and Pedagogic Knowledge courses than do the other three, the allocation of time and course credits is significantly less than for English as Subject for IP English specialists. While depth of Subject Knowledge is centrally important in teacher education, it appears that across all five institutions, there may be insufficient focus on equipping student teachers to guide IP learners to become proficient readers and writers / producers of texts in a range of genres and modes. In particular, little or no attention is given to reading pedagogies across the sample, a skill which is in dire need in the school system, as described in section 2 above.

In only two of the five institutions is substantial time allocated to microteaching and lesson planning. These two institutions are also the only ones that foreground the CAPS documents in their School and Pedagogic Knowledge courses and that teach IP specialists on their own for a one year course.

The opportunities for IP generalists to study courses with a focus on School and Pedagogic Knowledge vary from non-existent (at university D) to limited (at universities A, B and C) to adequate (university D).

The language and literacy challenges experienced by many learners in the transition from learning in their home languages(s) to learning in English and in developing their knowledge of English as subject, together with the challenges associated with the linguistic complexity of classrooms in many urban areas, appear to be insufficiently addressed across all institutions, although some pay more attention to addressing these challenges than others.

Capacity
The resources, particularly human resources, available at the five institutions appear to differ markedly to the detriment of what some institutions (particularly universities C & D) are able to offer to students in terms of formative feedback on their work, opportunities for microteaching and opportunities for lecturer modelling of good teaching practices for the classroom.

Curriculum coherence
At some institutions interviews with lecturers revealed lack of familiarity with what is offered to IP English specialists, in both subject and pedagogic knowledge courses, across the four years of a BEd curriculum. This is a cause for concern in regard to curriculum development and curriculum coherence.

Concluding observations in relation to government policy
(i) MRTEQ specifies that all new teachers should be proficient in the use of at least one official language as a language of learning and teaching (LOLT). For the IP, this is likely to be English (as a home or additional language) for the majority of the country's learners (with Afrikaans the alternative). This may be one reason why some institutions, particularly university D, but also to a lesser extent universities B and E, foreground the syntax and lexis of English in their academic literacy courses and English as subject courses. A question to be asked is whether student teachers

who require courses to build their proficiency in English should be placed on an extended curriculum so that becoming more proficient in English is not at the expense of acquiring the knowledge of English as subject and pedagogic knowledge for teaching English competently.

(ii) MRTEQ specifies that all BEd students are required to develop 'intellectual independence' and 'some level of research competence' in order to provide a basis for postgraduate studies and for further professional development. In the data from the five institutions it is evident that developing independent and critical thought and research competence is addressed at three of them in courses for English specialists in the latter part of the degree (Institutions A, B and E) and from first year in two of them (Institutions A and E). Information from a fourth year Professional Studies course at Institution E indicates that all BEd students undertake a research project and this raises the question of whether 'developing research competence' is located in parts of the BEd programme at institutions C and D for which data were not obtained or whether this specification in the MRTEQ is not addressed at these two institutions. Nevertheless, most BEd and some PGCE programmes at all five institutions include a research module or an independent study, which are not confined to the Intermediate Phase or to maths or English.

(iii) There are three specifications from MRTEQ for *all* IP teachers that appear to be ignored, or inadequately addressed in some or all of the BEd programmes at the five institutions:

- All IP teachers must be skilled in identifying barriers to learning within their specialisations(s), as well as in curriculum differentiation for multiple learning levels within a grade. There is no indication in the data analysed that attention is paid to these two aspects of pedagogy at any of the institutions. This may be because these are addressed in a general way in courses such as 'inclusive education' but the neglect of a disciplinary (subject) focus can be questioned.
- All IP teachers must specialise to teach languages (comprising First Language Teaching in one of the official languages and First Additional English Language teaching). The first language may be any of the eleven official languages and thus data about this aspect of the BEd curriculum may not have been gathered (from Institution E there is data that all students are required to study three languages – English, Afrikaans and isiXhosa – for two years). However, it is clear that not all IP teachers specialise in teaching English as first additional language at any of the five institutions, with only universities B and C offering a methodology course to all IP BEd students in which the focus is on teaching and learning English as LOLT (university B) or teaching and learning an additional language (Institution C).
- All IP teachers must have a sufficiently broad background knowledge to understand the requirements of all subjects in the IP curriculum. Where there are no English as subject courses for all IP students as is the case at universities A, B and D, (though such courses were to be added at Institution B in 2014), or English methodology courses (the situation at Institution D) it is difficult to imagine how student teachers can acquire such knowledge.

8. KEY FINDINGS FROM THE REPORT ON MATHEMATICS COURSES FOR BED IP TEACHERS

Maths courses offered

The maths courses offered to prospective IP teachers specialising in mathematics are summarised in Table 5. Three features of Table 5 are noteworthy. First, the numbers specialising in maths are generally small and highly variable, both across institutions and within institutions from one year to the next. Thus, at Institution E, 58 first year students have elected to specialise as maths teachers, while in the fourth year only 8 students have chosen maths as an elective. Second, there is no agreement on the entrance requirements for maths teachers. Institution A demands 65% on a test given to all first year students, Institution B requires students to have obtained a pass at 50% in Mathematics in the NSC exam, while at Institution C students are permitted to specialise as maths teachers if they scored as low as 30% on Maths Literacy in the NSC. Finally, the proportion of the BEd degree taken up by maths courses varies from a low of 13% at Institution E to as much as 25% at Institution B.

Table 5: Maths courses for IP BEd Maths Specialists

HEI	Student numbers (approximate proportion of all IP students)	Entrance Requirements	Maths Credits	Percent total credits
A	15 - 25 (25%)	Must achieve at least 65% in the first year Maths course that is compulsory for all first year students	100	21%
B	60 (33%)	M 50% ML not allowed	128	25%
C	100-200 (±10%)	Pass (30%) in M or ML	108	23%
D	150 (17%)	M 40% or 50%	120	24%
E	Variable from 58 (52%) in 1st year to 8 (9%) in 4th year	M 40% & test ML 60% & test	64	13%

Maths courses offered to IP teachers not specialising in the subject are shown in Table 6.

Table 6: Maths courses for IP teachers not specialising in Maths

HEI	Approx number of IP students not specializing in maths per year	Maths credits	% of total credits
A	60 – 75	40	8%
B	120	16	3%
C	1600	12	2.5%
D	750	68* (ML)	13%
E	55-80	19	4%

* IP students not specialising in maths did courses in mathematical literacy and mathematical literacy teaching methodology

This table presents another disturbing picture: while most teachers will, at some stage in their careers, be required to teach maths (see point 5 in section 2 above), preparation for this task is woefully inadequate.

Content of courses for teachers specialising in maths

At all the institutions studied, prospective IP mathematics specialists are required to take courses that deal specifically with mathematics content as well as methodology courses which explore the pedagogy associated with teaching IP mathematics. Figure 1 indicates the approximate number of contact periods of these courses at each of the institutions[1], and indicates the nature of the mathematics content of these courses. With regard to the content, this does not indicate the level of cognitive challenge posed by the content, merely the level at which the content is generally encountered in the education system. Thus, the content labelled 'Maths IP, SP' consists of counting; the arithmetic operations; fractions, ratio and proportion; and some work on the shape and size of geometric figures.

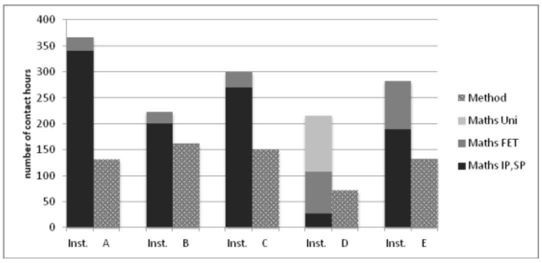

Figure 1: Maths courses for BEd students specialising in IP maths

Institutions A, B, C and E focus largely on the mathematical content from the intermediate and senior phase curricula (grades 4 – 9). However in most cases this is done at a greater level of conceptual depth than would be done by learners at school and includes a focus on the specialised knowledge of mathematics that teachers would be likely to need. At institution D, although the

[1] In the case of the distance education institution contact hours were estimated as being equivalent to approximately half the allocated hours for the course as most institutions assume approximately equal self-study and contact time.

focus of the mathematical content is on topics traditionally covered by university students, these tend to be dealt with at a low level of cognitive demand.

There is a large degree of variability in the methodology courses. Although all method courses include reference to mathematical content, work from the field of mathematics education research and the practice of teaching, the degree to which each of these is foregrounded in the courses studied varied.

Content of courses for teachers not specialising in maths

Maths courses provided to students not specialising as maths teachers are shown in Figure 2.

The exposure to either mathematics or mathematics methodology courses for these 'non-specialists' is low and varies considerably between institutions. At Institution B, student teachers do not do a methodology course, and the one mathematics course that they do focuses on mathematics for everyday life rather than on the specialized knowledge of mathematics required by teachers. At Institution C, student teachers only have a single methodology course.

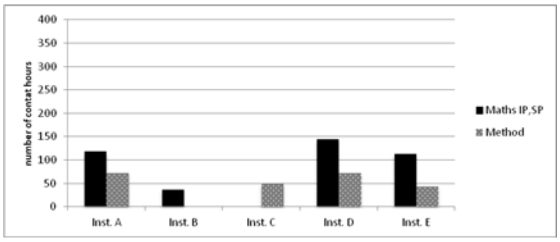

Figure 2: Maths courses for BEd IP teachers not specialising in maths

At Institution D, where prospective IP teachers who are not specializing in maths are offered the most contact periods in maths courses, the courses they do are mathematical literacy courses. Although the mathematical content covered in the mathematical literacy course is aligned with IP mathematics the methodology course focuses on the approach to teaching Mathematical Literacy as an FET subject which differs substantially from the approach required to teach Mathematics as an IP subject.

At Institutions D and E where learners do both mathematics and methodology courses, the nature of the mathematics questions is weighted in favour of lower cognitive demand tasks. Many of the lecturers at these institutions commented that a large proportion of the student teachers had an inadequate grounding in the mathematics they would need to teach, thus necessitating a focus on getting the basic mathematics right in both the mathematics and methodology courses.

Concluding comments

The research suggested an emerging commonality in the mathematics content courses for prospective IP mathematics specialists across four of the institutions. These courses deal mostly with mathematical topics taught to IP and SP learners, but work on them at a deeper level and with a focus on specialized mathematical knowledge a teacher would need to know. These courses align well with the codified version of "mathematics for elementary school teachers" exemplified in textbooks of the same name from the USA.

In contrast there is much greater variability in the methodology courses for prospective mathematics specialists as well as in the offerings at all levels for prospective IP teachers who are not specializing in mathematics. There is some concern, given that most IP teachers will end up teaching mathematics at some level, about the depth and breadth of mathematics and methodology courses that are made available to those who are not specializing in mathematics.

9. CONCLUSION

The purpose of this study is not to evaluate individual institutions, but to describe curricula and practices across the terrain of initial teacher education, with an in-depth focus on the range and depth of maths and English courses provided to BEd students specialising in Intermediate Phase teaching. The insights provided by ITERP, in turn, are intended to contribute to an informed discussion about the design and delivery of ITE curricula most suited to reforming the country's very weak school system.

The IP years (Grades 4-6) are a critically important period, when most pupils move from learning in their mother tongue to using English as medium of instruction, and all must make the transition from arithmetic based on counting to becoming proficient in the more sophisticated tools of mathematics. Currently the majority of learners are at least two years behind curriculum expectations by the time they reach Grade 5, in both language and maths.

The BEd degree forms the bridge between generally poorly prepared matriculants exiting the school system and newly qualified teachers embarking on a career of teaching. University education faculties thus occupy a key node in the system. This is the point that holds the most promise for breaking the cycle of mediocrity which bedevils schooling and exerts a heavy brake on both the personal development of most citizens and the production of knowledge and skills needed for a more vibrant economy.

The findings of the research study described above reveal a very wide variation in all dimensions of the curricula examined. And while there are some excellent practices, it is clear that, as a whole, none of the five institutions studied is rising fully to the challenge posed by the country's low quality school system, particularly with respect to those student teachers not specialising in maths or English.

Regarding mathematics, there is a question as to whether students specialising in the subject are sufficiently equipped to lay the firm foundations in number facility, problem modelling and abstract reasoning required to enter the field of mathematics, science and technology. But, however effective they are as teachers, there are far too few of them to make a significant difference at the system level. Here government can play an important part in attaching conditions to the generous Funza Lushaka bursary programme to ensure a bigger pipeline for maths teachers in the IP, in helping provinces to take up Funza Lushaka graduates and other newly qualified teachers more rapidly, and in holding principals and School Governing Bodies responsible for more effectively utilising teachers and their specialisations. However, in the end, the quality of teachers emerging from the pipeline depends heavily on the quality of their university education. In this regard, the teacher education sector seems to be far from a solution to the problem of poor quality teaching in mathematics.

The situation with respect to the language of teaching and learning, predominantly English, is of particular concern. While the specifications of new MRTEQ regulations are likely to make a difference for the better in mandating more attention to languages, they are unlikely to have a significant effect on the quality of English proficiency among NQTs across the system. Policy is too easily subverted to be of much effect if, at the same time, teacher educators fail to become concerned enough about these problem to give them concerted attention.

This requires a very serious discussion among teacher educators in all sub-disciplines, but particularly in English and mathematics. As a matter of urgency the sector needs to reach a greater degree of convergence concerning the proficiency, in both subject knowledge and pedagogy, required by teachers, the curricula most likely to achieve these standards, and how the outcomes should be assessed.

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DEVELOPING, VALIDATING, AND MEASURING *CONTENT KNOWLEDGE FOR TEACHING:* AN EXAMPLE FROM PHYSICS

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In carrying out tasks of teaching, teachers enact specialized knowledge that content experts who are not teachers do not use (and most likely do not have). How do we operationalize such a construct, validate it, and measure it in distinct ways (in teacher assessments, classroom observations, and teaching artifact analysis)? What is the relationship between these measures and student learning?

In this talk, a multi-institutional, ongoing effort (supported in part by National Science Foundation grant 1222732) to pursue these questions will be described, the project framework will be shared, sample assessments items will be illustrated, and preliminary results from a pilot study involving 222 high school physics teachers will be discussed. Implications for teacher education programs will be highlighted.

The concept of content knowledge for teaching (CKT) originated with the work of Shulman (1986) and was more fully developed by Ball and colleagues (Ball, Thames, & Phelps, 2008). CKT is premised on the idea that teachers need to understand subject matter content in ways that are specific to teaching, such as understanding challenges that specific content might present to students and how students may represent their understanding in non-standard forms, knowing how to ask questions or provide explanations that can move understanding forward, etc. (Ball & Bass, 2003).

The majority of work has been in mathematics, though related work has been done in English language arts (ELA) and science. Validation efforts have followed the strong tradition of the measurement of abilities, which assumes that individuals have traits that are stable over some range of contexts (Carroll, 1993). Therefore, the common research question has been whether relatively broad measures of CKT (e.g., elementary mathematics) are related to general measures of practice (samples of classroom observation) and student learning (annual achievement tests) (e.g., Hill et al., 2008).

This presentation brings the perspective of a multi-institutional research effort that explores CKT in a single science domain, energy in the mechanics part of the first high school physics course (CKT-E). This approach allows us to understand with precision teachers' content knowledge of energy and CKT-E of a single domain, how they enact instruction in that domain, and what their students learn in that domain. This approach allows us to explore the fundamental and relatively unexplored question that underlies CKT—what does a teacher know about the teaching of a particular content area, and how is that knowledge related to instruction and student learning in that same content area?

The talk will present the conceptual framework, measures, and initial findings from a four-year project that has now completed the first year of a two-year data collection. In particular, I will describe the construction and refinement of assessment items that probe the specialized content knowledge that teachers employ to support students' productive scientific engagement with the domain of mechanical energy. In designing CKT-E assessment items, the project focused on the tasks of teaching and energy targets of our domain framework.

The project assumes that scientific understanding includes both knowledge about content and practices of science, consistent with the Next Generation Science Standards (National Academy of Sciences, 2012). We argue that teachers face complex, content-specific challenges that are unique to teaching. Therefore, we are striving to assess knowledge that is relevant for the following tasks that a teacher faces to support student learning of specific energy targets, all described in the project's domain framework:

- anticipating student thinking around science ideas;
- designing, selecting, and sequencing learning experiences and activities;
- monitoring, interpreting, and acting on student thinking;
- scaffolding meaningful engagement in a science learning community;
- explaining and using examples, models, representations, and arguments to support students' scientific understanding; and
- using experiments to construct, test, and apply concepts.

We designed 20 assessment tasks, including selected-response and constructed-response formats, to address authentic challenges to teaching energy. Each item contains a rationale detailing the item design and justification for both the keyed answer and the distractors. The intensive development process has included work with a small development team of teachers, a pilot study of ~200 teachers, scoring of the pilot, item revision and full field-testing with ~300 teachers. This process has helped us address the following research questions:

- To what extent do written assessments capture different aspects of the CKT-E framework?
- What aspects of the domain framework are most appropriately addressed through constructed-response formats?
- Can constructed-response items be coded reliably and provide insight that selected-response items cannot?
- What is the evidence with respect to the dimensionality of a CKT-E assessment?

Below is a sample item, which will be described in the presentation.

Ms. Patel knows from her previous experience that students often have difficulties with energy conversions. Several students in her class have expressed the idea that whenever potential energy decreases, kinetic energy increases by the same amount. She wants to present a series of scenarios for her students to consider that will start with their current ideas and then progressively challenge their ideas in a constructive way.

Determine a sequence for presenting the following four scenarios that would build Ms. Patel's students' understanding of energy conversions in a logical progression that is practical in the classroom, starting with their current ideas.

Describe your reasoning for each choice in the sequence.

A. A block slides across the floor to a stop.

B. A metal ball speeds up as it rolls down a smooth track.

C. A tennis ball that has been submerged and is then released so it is rising in water.

D. A hockey puck sliding on ice hits a horizontal spring and compresses it.

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THE FIRST YEAR GENERAL CHEMISTRY COURSE: GREAT CHALLENGES AND GREAT POTENTIALITIES

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Abstract–The first year general chemistry course is considered particularly challenging. It poses the challenges inherent to the secondary school – university transition and, simultaneously, the typical challenges of chemical education, largely related to the nature of chemistry and its interpretation models. The challenges are widely acknowledged and explorations of ways to address them constitute one of the most active areas within chemistry education research. The first year chemistry course is also a fertile source of potentialities, because it sets the foundations of the ways in which students will consider and approach chemistry afterwards.

The paper offers a broad overview of identified challenges, highlighting their main features and presenting some of the explored addressing options, with particular emphasis on approaches suitable for interactive teaching or aimed at stimulating students' active engagement. It also highlights the potentialities stemming from good levels of conceptual understanding attained in the first year.

Keywords: Epistemological access, language-related difficulties, language-visualization interplay, secondary school–university transition, visualization.

1.1. INTRODUCTION

The first year general chemistry course is considered particularly challenging. It has been so for many years and in many contexts. Students' pass-rate may be quite low. In periods and contexts with high selectivity, the pass-rate could be down to 25% or less (for instance, from the author's direct experience, 12 out of 49 chemistry students passed the course at the first attempt in the 1966-67 academic year, at the university of Pisa, Italy). Even in situations with less strict selectivity criteria (e.g., in contexts where the bare-pass mark is 50%, versus 60% in Italy), the pass-rate may be comparatively low. For instance, at the University of Venda (UNIVEN, South Africa), the pass-rate has remained unsatisfactory in recent years, despite several supporting measures, including numerous tutorial sessions.

The challenges of the course are widely acknowledged by educators. Explorations of ways to address them constitute one of the most active areas of chemistry education research, producing a wealth of information. Besides educational research in its more or less "traditional" forms, there have also been initiatives aimed at joining efforts across countries and cultures to promote improvements through collaborations. For instance, the *International Centre for First Year Undergraduate Chemistry Teaching (ICUC)* posed the teaching of first year chemistry courses at the centre of investigations and international collaborations. In the words of its founders (Castro-Acuña & Kelter, 2010), ICUC:

> is based on the fundamental construct that chemistry teachers from all countries and cultures have made important contributions to our global educational practice, and we must continue to encourage and honor this worldwide work.

The challenges of the first year general chemistry course can be considered from various different perspectives, among which:

- As a component of the overall transition from secondary school to university. Like the other first year courses, the first year chemistry course involves all the challenges inherent to this transition: major changes in the study approach (e.g., because of the greater independence expected from the learners) and in the epistemological ways through which the content needs to be approached.

- As a course posing the typical challenges of chemical education in a magnified way, because of often corresponding to the first students' encounter with "real chemistry". These challenges are largely related to the nature of chemistry as a science characterised by fundamental interplays: interplay between macroscopic and microscopic descriptions, interplay between *qualitative* and *quantitative*, and interplay between *general* and *particular*. The interplays – determined by the fact that chemistry is the science of substances and that the properties of substances depend on the properties of their molecules – pose substantial learning challenges because of their inherent complexities.
- As a course "looking" simultaneously in two directions: the past, i.e., the previous instruction, from which students have often inherited imprecise views and misconceptions, and also learning habits that are not adequate for the tertiary level; and the future, for which the first year course poses the foundations, particularly important for those students who will encounter other chemistry courses in their learning career.
- As a course often posing the "practical" challenges of large-enrolment groups, where the teacher has to try and actively engage a high number of students simultaneously, sometimes with the addition of the un-conduciveness stemming from inadequate physical spaces and overcrowded venues.

The next sections offer brief overviews for each of these aspects.

The first year chemistry course does not involve only challenges. It is also a fertile source of potentialities, because it sets the foundations of how students will consider and approach chemistry afterwards. This is important both for future chemistry professionals and for other scientists who will use chemistry information in their professional careers. For the foundations to be apt to foster interest in (or even passion for) chemistry, it is crucial to attract students' attention to primary issues: what is chemistry, what chemistry can do, why it is interesting to investigate certain themes, how we approach experiments and reflect on the observations, and other key aspects of chemistry as a science. For students to be able to approach future courses comfortably, it is necessary to ensure that all the basic concepts are clearly understood and their implications recognised and deeply internalised.

This paper aims at providing an overview of the major challenges and potentialities of the first year general chemistry course. The previously-recalled perspectives are utilised as a convenient framework enabling a first-approximation grouping of observations, considerations and inferences. Both the cross-contexts character and significant contextual features are highlighted when relevant. The educational potentialities of the course are viewed as the "other side of the coin" with respect to the challenges and, therefore, are intrinsically embedded in the outlines of addressing options and their expected outcomes. A variety of explored addressing options are outlined and discussed, on the basis of more than twenty years direct experience with the first year general chemistry course. Particular emphasis is given to novel – or even unconventional – approaches suitable for interactive teaching, or aimed at stimulating students' active engagement both in the learning process and in the very addressing of the challenges they experience. Illustrative examples are provided to substantiate the discourse and make it concrete.

Following the active interest by researchers, the existing literature on the challenges posed by the first year chemistry course and its various aspects is very abundant. To be at least basically meaningful, a literature review for each of them would – alone – exceed the space suitable for an article. Therefore, only few examples are cited, to offer a hint of the attention that each issue has attracted.

1.2. THE TRANSITION FROM SECONDARY SCHOOL TO UNIVERSITY

The transition from secondary to tertiary education is a vast focus of educational research, in view of the difficulties frequently experienced by students entering universities. The transition implies major changes in study approaches and in the ways in which the content is approached. The "new" approaches require more attention to concepts, and the ability to relate concepts to each other, to the solution of problems and to experimental observations. They also require greater study independence. All this demands active mental engagement from the learner. When learners have acquired passive study-attitudes in previous instruction, the need for active engagement demands a huge paradigm shift in their habits.

Investigations of the difficulties of the transition have been carried out in many contexts (e.g., Chipere, 1993; Nyapfeme & Letseka, 1995; Mammino, Mathibeli & Mutambala, 2000; Markic & Eilks, 2008). Cherif & Wideen (1992) view it as a transition between two cultures and conclude that "It should come as no surprise that for many students a year is required to adjust to the new college/university setting". The different "cultures" are marked by changes both in some concepts' features and in the attitude toward science concepts: "In high school students were often taught that what was printed in the text was the truth, only to find it being challenged or changed by the time they reached university". The opinions of interviewed students offer interesting insights into the reasons for the gap in sciences courses: "High school science courses are centered around facts, while in university science courses are centered around theories and ideas as well as facts"; "While there is little challenge in high school science courses, there is a great deal of challenge in university science courses".

Students entering universities are increasingly underprepared for the requirements of university studies. Although most of the considerations and examples in this paper are based on direct experience in a disadvantaged context (UNIVEN), there is an increasing "globalisation" of factors for which students entering universities are often not ready for it. Many universities organise and advertise special programs to assist in the transition phase. Some educators propose approaches engaging both the secondary and the tertiary levels. For instance, Higgins, Mullamphy & Belward (2009), consider the problem of "the drop in standards of students entering first year university mathematics in Australia"; acknowledge that the common response "to reduce the difficulty level of the first year mathematics courses… has had limited success, with students passing first year mathematics but lacking preparation for the higher years". An analogous description could apply to first year chemistry courses in many contexts. Higgins, Mullamphy & Belward came to the conclusion that "If realistic change is to be made in bridging this gap, then the problem needs to be addressed at both the tertiary and secondary level" and designed a program to bring "mathematics into high schools" that proved "'to be a small but significant start in helping to bridge the secondary-tertiary gap". An analogous experiment (endorsed by OCED and OCCSE) had been carried out in the early Sixties in Italy, with "pilot" chemistry courses in selected secondary schools; students who took those courses went smoothly through first year chemistry courses; regrettably, the experiment did not have a continuation beyond the planned years of "pilot" testing.

The difficulties regarding learning and communication skills are often comprehended under the concept of inadequate *epistemological access*. The major factor is inadequate language mastery, which is now-a-days reaching worrying levels not only in second-language-instruction contexts (Mammino, 2005, 2006, 2007 & 2009; Mtshali & Smillie, 2011), but also in mother-tongue-instruction contexts in which the extent of the theoretical study of the mother tongue at pre-university level has decreased sharply in the last decades (Mastrocola, 2010). The problem mostly concerns the ability to read complex sentences, to understand complex discourses, and to write about something in a logically organised way, using grammatically correct sentences and selecting a wording consistent with the nature of the scientific information involved (Mammino, 1995). This has huge hampering effects on science learning, because understanding concepts depends on understanding the language through which they are expressed and because of the general fundamental importance of language in the science discourse (Bruner, 1975; Munby, 1976; Carré, 1981; Davies & Green, 1984; Muralidhar, 1991; Sutton, 1992; Wellington & Osborne, 2001; Norris & Phyllis, 2003; Fang 2006; Brooks, 2006; Mammino, 2014a). Remedial measures have already been introduced in some contexts; for instance, in Italy, several universities have introduced Italian language courses for incoming students, to upgrade the mastery of the mother tongue to the complexity levels that are required for university studies (Mastrocola, 2010). The integration of science learning and language learning, combining English and mother tongue, can be a viable option to upgrade the epistemological access in contexts like UNIVEN, or other institutions in South Africa (Mammino, 2012). It is practically impossible to compensate, within the general chemistry course (or other first year courses), all what a student has not learnt previously, but should be part of the acquired knowledge and skills necessary to approach university contents. A period when the student learns how to approach chemistry at a basic literacy level (how to understand a chemistry text instead of memorising it, how to write about chemistry concepts, how to understand the logic of a problem-solving procedure – all of this utilising a limited number of fundamental themes) can be the most effective remedy to bridge the gap (Mammino, 2012).

Other components of the epistemological-access inadequacies of students entering the first year are often determined by language-mastery inadequacies, as these hamper the development of other skills (Mammino, 2010a). The outcome may comprise inadequate of poor visual literacy, inadequate familiarity with essential features of the scientific approach, and inadequate familiarity with mathematics and its roles in the other sciences. Again, approaches integrating language and chemistry (or science) learning can be viewed as potentially effective (Mammino, 2012).

Inadequate language-mastery is often a major cause of the frequent all-pervasive passive attitude equating learning to passive memorization, divorced from understanding. Secondary instruction rarely opposes the development of passive attitudes, and in some contexts fosters it. The shift from passive attitudes to active engagement is not easy for the learner. Interactive teaching options since the first year courses constitute the best choice, by implicitly presenting the shift as a component of the overall secondary-tertiary transition. Furthermore, the advantages of interactive teaching (enabling early identification of existing problems – from misconceptions to inadequacies in specific skills – and real-time responses) have paramount importance. Stimulating students' participation and active engagement may require the design of unconventional approaches, tuned to the attitudes and responses in a specific group and in a specific time; some examples are given in Mammino (2011).

1.3. THE CHALLENGES OF CHEMISTRY LEARNING

The first year chemistry course poses the typical challenges of chemical education in a magnified way, because students often encounter "real chemistry" for the first time. The challenges are largely related to the nature of chemistry as a science characterised by fundamental interplays: interplay between macroscopic and microscopic descriptions, interplay between *qualitative* and *quantitative*, and interplay between *general* and *particular*. The interplays – largely determined by the individuality of substances and by the fact that the properties of substances depend on the properties of their molecules – pose substantial learning challenges because of their inherent complexity and their inherent relationships with crucial aspects of the scientific method.

The interplay between the macroscopic and microscopic descriptions is the most amply investigated (e.g., Gabel, Samuel, & Hunn, 1987; Gabel, 1993; Smith, 1996; De Posada, 1997), because of its fundamental role in chemistry, where observed properties and behaviours are interpreted in terms of what atoms and molecules do. Visualization plays important roles in the familiarisation with the microscopic level of atoms and molecules (Tasker & Dalton, 2006 & 2008; Gilbert, 2005 & 2008; Mammino, 2008), and the interplay between language and visualization can largely enhance the benefits of visualization, above all in situations in which students' visual literacy is not fully adequate and they need guidance to read images (Mammino, 2010b & in press). Visualisation and its interplay with language are also effective interaction tools, e.g., for the introduction of molecular formulas and the 3-dimensional structure of molecules through collaborative drawing of representations on the basis of essential geometry information (Mammino, 1999). Fig. 1 (Mammino, 1994 & 2003) shows an example concerning the nature of chemical reactions. The teacher draws the first image on the board, with only reactants present; then starts drawing the second image, showing two water molecules formed, and asks the students to complete it, individually, on their notebooks. Most students copy the two water molecules on the products side, but do not delete the corresponding oxygen and hydrogen molecules from the reactants side. This prompts a discussion, until students identify which molecules, and how many for each element, should be deleted from the left hand side. The exercise proceeds with the subsequent formation of more water molecules and corresponding deletion of reactants molecules. In the first exercise of this type, reactants are proposed in stoichiometric proportions. When the main concepts (formation of products and parallel disappearance of the reactants in certain proportions) are acquired, a new exercise considers a situation with one of the reactants in excess; the way it illustrates that part of the reactant in excess remains unreacted, because the other reactant is exhausted, is quite effective, as the students reach this conclusion "manually", through their drawing.

The interplay between *quantitative* and *qualitative* aspects is extensive in chemistry, where the qualitative component (the nature of individual substances) is all-permeating. It can be highlighted on many occasions. For instance, the qualitative features of chemical reactions (which types of atoms, which types of molecules) and the quantitative ones (how many of each type) both play essential roles for conceptual understanding and for applications in stoichiometric calculations. Systematically reading chemical equations in these terms ("x moles of X react with y moles of Y to give p moles of P and q moles of Q") facilitates the internalisation of the association of qualitative and quantitative aspects.

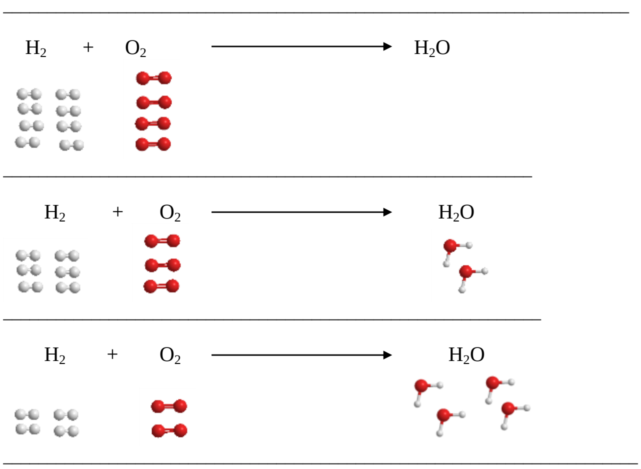

Figure 1. Stepwise illustration of what happens during a chemical reaction, utilising visualizations suitable for in-class interactions (collaborative building of the representations.

The distinction and interplay between *general* and *particular* are fundamental method-related aspects. They require the ability to distinguish between what is valid in general (for all the cases of a given type) and what is valid for particular cases (where often the *particular* refers to something that is different for different substances). Students often experience difficulties with the distinction, likely because their attention has never been explicitly attracted to it, and because of the impact of inadequate language mastery (Mammino, 2001). Typical examples are statements such as "a solid melts at 273 K" or "a liquid boils at 100°C", frequently encountered at first year level. The impact is not limited to the expression level, but has also implications for problem solving, even in further courses. In the second year physical chemistry (chemical thermodynamics) course, a non-negligible number of students assume that any solid melts at $0^{o}C$ and any liquid boils at $100^{o}C$ on solving problems on the enthalpy or entropy changes accompanying multi-step processes (e.g., by treating nitrogen as if its melting point were $0^{o}C$). When difficulties with the distinction are diagnosed, it becomes necessary to stress the difference frequently, in different contexts. For instance, it can be part of the short in-class questions utilised to check students' existing conceptions (Mammino, 2013a), by asking questions like "at what temperature does a solid melt?". The nearly unanimous answer "$0^{o}C$" provides the opportunity to stress that different substances have different melting points, and also the importance of checking whether we are talking of something that is true for all the cases, or something that is true only for a specific substance or a specific case. Examples from the surroundings (all the things that are solid in one's environment) are particularly effective because of their concreteness. They also contribute to counteract the dichotomy between students' awareness of everyday experience (they obviously know that lots of things are solid around us and that the room temperature is above $0^{o}C$) and their perceptions of what they expect to be correct in the chemistry classroom ($0^{o}C$ as melting point for any solid).

1.4. A COURSE BETWEEN PAST AND FUTURE

The first year chemistry course is a course "looking" simultaneously in two directions: the past, i.e., the previous instruction, from which students have often inherited imprecise views and misconceptions; and the future, for which the first year course poses the foundations, important above all for those students who will encounter other chemistry courses in their learning career. Experience in a given context makes a teacher aware of the possible inherited misconceptions, thus enabling timely suitable interventions at early stages in the course. Direct experience with the teaching of more advanced courses also highlights aspects that are often not completely understood at first year level. Combining the two perspectives (awareness of the past and of the future) enables higher systematicity in the interventions within the first year course. A high number of examples could be considered; some are briefly recalled in the next paragraphs. The general underpinning (or methodological and philosophical perspective) is that of using rigour as a pedagogical tool (Mammino, 2000a) and simultaneously training students to rigour in chemistry (Bradley, Brand & Gerrans, 1987) to ensure clearer understanding.

Misconceptions may concern mathematical tools that are important in chemistry, such as the direct and inverse proportionality concepts. Experience at UNIVEN has shown nearly generalised misconceptions based on previously provided definitions for which two quantities, x and y, are directly proportional if y increases as x increases and inversely proportional if y decreases as x increases. Consistently with these definitions, many students identify dependences such as quadratic, logarithmic or exponential as direct proportionality, because for all of them "y increases as x increases", and identify a straight line with negative slope as inverse proportionality because "y decreases as x increases". The importance of correcting these misconceptions in a convincing way since the first year level is stressed by the frequent permanence of these errors in second and third year courses. The combination of language and visualization offers the best tool to clarify these concepts (Mammino, 2014b).

Definitions play fundamental roles in the sciences. An important aspect, requiring adequate stressing, is their operational role: a definition must provide all the information that is necessary for the identification of the object or situation that is being defined (Mammino, 2000b). The awareness of this is rarely acquired in pre-university instruction. The previously mentioned definitions of direct and inverse proportionality constitute a clear example, as they do not provide criteria to distinguish between direct or inverse proportionality and other types of relationships also corresponding to "y increases as x increases" or "y decreases as x increases". Several other definitions inherited from the past require deep analysis, whose most apt place is the first year course. For instance, the definition of molecule as "the smallest part of a compound that maintains the properties of that compound" requires critical analysis, because it would exclude the molecules of elements (H_2, O_2, etc.), thus not providing criteria for one to be able to recognise all molecules. The more rigorous definition of molecule as a "stable grouping of atoms bonded to each other" (or simply "a stable grouping of atoms") provides a sound criterion, which can be stressed through visualization of molecular structures, becoming integral part of the familiarization with the world of molecules.

The definition of catalyst as "a substance that speeds up a chemical reaction without taking part in the reaction" requires critical analysis, because the catalyst does take part in some steps of the reaction (intermediate steps).

The definition of oxidation number as "a number that indicates the number of electrons lost, gained or shared as a result of chemical bonding" requires critical analysis, because the concept of "electrons lost" or "electrons gained" applies only to ionic compounds, and the oxidation number surely does not indicate the number of shared electrons. The last aspect is clearly highlighted by drawing the Lewis structure of any molecule of elements (H_2, F_2, etc.) and recalling that the oxidation number of each of the two atoms is zero, but the number of shared electrons is two. The use of visualization to explain a rigorous definition of oxidation number and its operational character is outlined in Mammino (2014b).

If the operational character of definitions is not adequately established in the first year course, definitions without operational character may surface in subsequent courses. For instance, second or third year students may provide the definition of chemical equilibrium as "a chemical reaction is at equilibrium if the chemical potentials are equal at both sides"; however, this is not operational, because chemical potentials of individual species are not measured directly in the laboratory (while concentrations are). Altogether, familiarising students with the meaning and roles of definitions contributes to a better understanding of the first year material, to the correction of misconceptions, and to set sound bases for future chemistry courses.

The statements of laws may also require critical analysis. For instance, the memorised statement of the Hess law that most students have inherited from previous instruction states that 'the heat accompanying a chemical reaction is the same whether the reaction occurs in one step or in many steps". Although this is literally true, it does not respond to reality for most of the cases in which we apply the Hess law. We apply it as a "formal" tool, i.e., the set of chemical reactions that we utilise to obtain the reaction whose enthalpy change we want to calculate is a "formal" set, and has nothing to do with the steps through which the reaction actually occurs; it is an algebraic exercise, not the chemical reality (Mammino, 2013b). The inherited previous statement leads students to believe that those steps are real. For instance, after an exercise in which the enthalpy of combustion of propene was calculated utilising the known enthalpies of the following reactions.

a) $C_3H_{6\,(g)} + H_{2\,(g)} \longrightarrow C_3H_{8\,(g)}$

b) $C_3H_{8\,(g)} + 5\,O_{2\,(g)} \longrightarrow 3\,CO_{2\,(g)} + 4\,H_2O_{\,(l)}$

c) $H_{2\,(g)} + ½\,O_{2\,(g)} \longrightarrow H_2O_{\,(l)}$

A quick survey showed that students believed these to be the actual steps through which the combustion of propene occurs.

Many other themes and concepts of the first year chemistry course could be analysed in similar ways. A number of them have been objects of individual studies. For instance, the inherited perceptions of atomic orbitals as something like "houses" or "rooms" for electrons, and the misconception considering the spin as related to a rotation of the electron around its axis, have been analysed in Mammino (2013c).

Some interventions to better elucidate first year concepts may be prompted not by diagnosed misconceptions, but by the requirements of more advanced courses (a sort of "feedback" from the future). For instance, teaching the process technology course (introduction to chemical engineering, a third year course at UNIVEN) has highlighted the importance of stressing conservation and non-conservation aspects in chemical reactions since the first introduction of the reaction concept.

Analysing what is conserved (the total mass, the mass of each element, the moles of each element) and what is not conserved (the mass of individual substances, the moles of individual substances) favours a better understanding of what happens in a chemical reaction even in the first year, and provides bases for future courses (Mammino, 2005b).

1.5. EDUCATIONAL IMPLICATIONS OF LOGISTIC CHALLENGES

The first year chemistry course is often a large-enrolment course, above all when the course is not individualised in view of different degree options, but is comprehensively offered to all students registered for science-related degrees (as is the situation at UNIVEN). Educational research has investigated the challenges of large-enrolment classes and the possible adaptations of educational options to meet the needs of these classes without renouncing important benefits, including the benefits of in-class interactions. Writing may become a teacher-student interaction tool simultaneously available to many students and enabling follow-ups that benefit all students (Cooper, 1993; Mammino, 2013a). Experience within a specific context enables a teacher to "invent" approaches that can be suitable to attract students' attention and stimulate participation even in large-enrolment classes in disadvantaged contexts, by responding to the specific features of each specific group (although somewhat changing with the changing students' population from year to year) (Mammino, 2011).

1.6. DISCUSSION AND CONCLUSIONS

The main objectives of the first year general chemistry course comprise students' familiarization with chemistry and its interpretation models (including the microscopic world of atoms and molecules), and the acquisition and possibly deep internalization of fundamental concepts, to build a sound foundation for further chemistry courses, or for the use of basic chemistry information in other professional activities.

The challenges and potentialities of the first year chemistry course are common to all contexts, although concrete features may differ – even widely – from one context to another. They relate mostly to the transition from secondary to tertiary instruction. In recent years, the difficulties are enhanced by inadequate acquisition of basic concepts in previous instruction, and inadequate development of fundamental learning tools, first of all language-mastery.

The ways of approaching the challenges may be different in different contexts. However, the analogies between several diagnosed problems and between observed trends (including the lowering of secondary instruction levels, or the fast deterioration of language-mastery levels, affecting many contexts) point to a phenomenon that, although possibly not yet world-wide generalised, concerns a large portion of the world educational contexts. Thus, the search for effective addressing approaches, and for their continuous optimisation, can be viewed as a common effort, which is continuously enriched by interchanges of experiences.

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AN EXPLORATION OF THE FOUNDATIONAL PROVISION MODEL IN FIRST YEAR MATHEMATICS IN SCIENCE AND ENGINEERING PROGRAMMES.

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Abstract–The changes and transformation in South African higher education and the Mathematics FET curriculum have challenged first year lecturers to review curricular content. The review also comprises a reflection on teaching strategies, use of technology and interventions to support student learning and academic progress. The provision of grants to provide additional resources and interventions has provided opportunities to widen access and deliver tailor-made content in various fields of studies. The number of enrolments in the first year mathematics modules has increased in the past five years but the quality of foundational knowledge and skills has been a concern for all lecturers. Basic numeric skills and critical thinking ability have been identified as inefficient preparation for successful study in first year science modules and need to be addressed at entry level. The University of Johannesburg has designed a semester module in mathematics as a bridging component before students in the four year degree commence, with three semesters to complete the first year curriculum. This investigation compared the success of students in the two streams (three year programme in one module and four year programme in three modules) for the first semester Mathematics and their progress in the last first year modules when students from both streams share the same classes. Appropriate inferential statistics were employed in the comparison of the 2011 – 2013 cohorts. It will be shown that the interventions implemented in the four year degree can be considered as effective in developing the students' academic competency in mathematics relative to mainstream students in Science and Engineering.

Keywords: Mathematics NSC Curriculum; Mathematics Intervention; First Year Mathematics; Critical Thinking; Effective Study Management; Student Academic Support; CAPS

1. INTRODUCTION AND PURPOSE

The changes and transformation in South African higher education and Mathematics FET curriculum have challenged first year lecturers to review curricular content. The review also comprises a reflection on teaching strategies, use of technology and interventions to support student learning and academic progress. The provision of grants to provide additional resources and interventions has provided opportunities to widen access and deliver tailor-made content in various fields of studies.

This investigation comprises a literature review, as well as a statistical analysis to substantiate the challenges faced by first year Mathematics lecturers in terms of larger class groups, lack of prior mathematical skills due to an inadequate matric syllabus and innovative support.

The CHE report (2013, p.43) on new degree duration with inclusion of foundational support raises the poor graduation rate of BSc students (23%) and many students 'dropping-out' with no qualification at all. This research investigates the contribution of an extended Mathematics model to provide students with a comparable opportunity to continue with degree studies.

2. BACKGROUND AND LITERATURE PERSPECTIVES

2.1 Theoretical framework

This investigation will investigate the literature perspectives that influence the performance of first year students in Mathematics on entering the university curriculum. High failure rate has been the norm in most Mathematics first year courses and prevents many students from progression in

Science, Engineering and other programmes (Bunting, 2004, p.73-94) and Jacobs (2010, p. 59-70). Many colleagues at universities are sceptical of the products that schools provide to higher education (first year students) and extending curricula to assist students with transition. The financial loss and resource waste with failing students have been investigated by Scott (CHE, 2013) and urges institutions to design models to combat the drop out of students and promote success rate.

The authors of this paper are of the opinion that the foundational provision model followed by the Faculty of Science has an influence on the successful performance of first year Mathematics students. The theoretical framework that underlies this quantitative inquiry relates to the literature perspectives and research goals to achieve via descriptive, exploration and predictive measurement. The descriptive nature of the research represents an attempt to describe recording of student results after school and at university level, and the incorporation of the literature review on the performance in first year Mathematics. The exploratory nature of the research represents exploration of the curricula (school and university) and the predictive nature of the research represents the prediction of academic success when students exit the foundational provision phase.

2.2 Adaptation of the curriculum

The South African secondary school curriculum, and especially the Mathematics content, has been changed with every new minister since 1994 (Jacobs, 2010). In November 2014, the National Senior Certificate (NSC) will be written on the newly implemented Curriculum and Assessment Policy Statement (CAPS) (DoE, 2011). Changes in curriculum imply new textbooks and resources, with training and up-skilling of teachers, also impacts on the higher education sector where students enter into first year classes. The preparedness of students has been debated widely and will impact on Science, Engineering and Health Science faculties where content follows on the foundations laid down in the school curriculum.

University Mathematics lecturers have been exposed to entering students with changes in school content, creating constant review of first year curriculum. With the removal of crucial topics such as Geometry in the FET Mathematics curriculum-NSC (Jacobs, 2010 and DoE, 2008) from the school syllabus, these learners have been left lacking in their ability to analyse and carry out proofs, such as those embedded in the scientific method of solving Geometric problems. Without a sound knowledge and skill of analysis and applying theorems to solve complex problems, first year students find themselves at a loss when it is expected at higher education level. Experienced lecturers have reported that students in Physics and Engineering programmes are severely affected as they need these critical thinking tools, as well as geometric concepts in their problem solving.

Depth in a topic is sacrificed for newer, easier topics (Kriek, 2008) such as Financial Mathematics and Statistics, which learners find easy. Absolute Values and Reciprocal Trigonometric Functions which had also been removed in the National Curriculum Statement (NSC), are also topics used extensively in the traditional first year mathematics syllabus. Engelbrecht, Harding & Phiri (2009, p. 297-299) have been expressing concerns that this substitution of challenging themes would provide more opportunity for good grade 12 results.

Kriek (2008) and Jacobs (2010) have found that the level at which algebraic techniques is assessed at the end of grade 12 has declined, with ill prepared students enrolling for University mathematics. University Mathematics lecturers investigated first year performance over years and found that students are not prepared to start at the level of mathematics required of them (Engelbrecht, et al. 2009, p. 297-299). For the past ten years universities have been planning and applying interventions, various teaching strategies and tutorial support in their first year mathematics programme to enable students to better cope with the topics covered (CHE, 2013).

In these interventions and support programmes the university curriculum starts with a review of the school content and re-teaching of the important foundational principles from a skilled, mathematical perspective (UJ, 2014). By intervening at the earliest stage possible in the mathematics time-line of students (Jacobs, 2010), many obstacles can be overcome to ensure success on the part of the student. Kurian (2008) indicated that "effective management and leadership is an essential characteristic of a successful school. Institutions that perform poorly require visionary and innovative managers to turn those institutions into centres of excellence".

In order to improve academic performance, extensive student support needs to be provided. In South African, according to the Education White paper 6 (EWP6), "Inclusive Education and Training is about acknowledging that all children and youth can learn if they are provided with effective support" (DoE, 2001). "The best predictor of student retention is motivation" (Simpson, 2004) which can be enhanced by good teaching and support. Students can be supported by means of passionate teaching, tutoring and extra lessons, as well as being guided by coaching and advice by a caring educator, who is a good ambassador for effective teaching (Tanenbaum; Cross; Tilson and Rodgers, 1998). "Learners need to have access to mathematical knowledge and its structures needed for them to understand their world and decipher 'unknown information' about situations (Mwakapenda, 2008) which is the real role of the good university lecturer.

Finally, the criticism of Parker (2006, p.62-63) that 'the idea of transferability of everyday knowledge into mathematics' is absent in the NSC, thus placing the transfer of mathematical knowledge and skills to other disciplines at the forefront of importance of good content control.

2.3 Skilled teaching

Kilpatrick, Swafford and Findell (2001) have performed extensive research into the structures needed to promote the learning of mathematics. These structures are conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. The importance of procedural fluency and conceptual understanding (Sullivan, 2010) are actions which are familiar to teachers. In addition, strategic competence and adaptive reasoning might be less familiar actions but can be learnt. However, there seems to be a challenge when it comes to teaching styles to support this, according to Suh (2007).

South Africa has about 24 500 schools and needs a minimum of four to five mathematics teachers per school (this would be 98000 to 122500 qualified Mathematics teachers) and the Department of Basic Education reported that more than a 100 schools have no Mathematics in grade 12, contrary to critics that claim that 327 schools in SA have no Mathematics teacher (Mail and Guardian, 2014). This country desperately needs skilled teachers who are not only qualified in their area of expertise, but also have a love for teaching (Tanenbaum, et al., 1998) There is a deficit of teachers who make it their goal for learners to grasp the concepts and who also inspire them to develop their own self-motivation to succeed. "Empirical studies have shown that the quality of teacher-student relationships tend to decline after students enter junior high school and worsen thereafter " (Freeman; Anderman and Jensen, 2007).

Mihaly; McCaffrey; Staiger and Lockwood (2013), state that "…teachers matter more to student achievement…." than any other aspect of schooling. The importance of the "right" teacher creating successful learning opportunities can only be accomplished through a high level of skills and knowledge as far as teaching is concerned, according to Mihaly, et al. (2013). Smit (2001) emphasises that "the role of teachers cannot be overlooked if policy and educational change should have the desired effect".

McGrath; Sayres; Lowes and Lin (2008) maintain that "at the heart of the challenges for FET teacher training is the need to respond to the new curricula, content and learners. These clearly require new pedagogies, including a radical shift in approaches to learner support". It is essential that teachers be suitably trained in order that they are capable of skilfully delivering the required programmes. Teachers are the largest single occupational group and profession in the country (DoE, 2007). Their role has strategic importance for the intellectual, moral, and cultural preparation of our people, and processes need to be put in place "intended to strengthen the role of teachers".

2.4 Motivation of students

Educators 'must continually work on inspiring students to become enthusiastic and motivated learners. Such students are engaged, active participants in their own learning' (Parker, 2006). Students need to be inspired enough to ask questions and they should be question-driven, rather than answer-driven (Rothstein & Santana, 2011). New questions generate new ideas and theories which extend the field and grow their depth of comprehension and application. Students need to be stimulated in such a way that their interest is captured and they are prompted to think.

In a report by the Institute for Higher Education Policy (2013) it is argued that answers often lead to an end in merely thinking. The ultimate accomplishment is when an answer leads to further questioning, and these questions in turn lead to further questions. When learners have questions, then they are really thinking and also learning. Teachers should strive to draw questions from students. Our traditional schooling system does not encourage self-thinking and questioning.

In a study by Rich (1997) it is noted that "mega-skills" are needed for successful living in the twenty first century. "Mega -skills includes disciplined work habits, caring attitudes, and the ability to cope, as well as to create one's own opportunities". He ascertained that students need a Life Skills program which runs parallel to their studies in order to cope with the stresses of their academic life. Rooth (1998) emphasis the essence of Life Skills for successful living and learning as it include, amongst others, emotional skills, coping skills, health and hygiene skills, communication skills, and interpersonal skills. Mastery of these skills is what leads to self-empowerment, and then personal growth can occur naturally.

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2.5 Maths Curriculum-CAPS

The new curriculum in the NSC namely the Curriculum and Assessment Policy Statement (CAPS) (DBE, 2014) is still lacking in the level of mathematical skill required for first year university mathematics. The curriculum came into effect in January 2012 for Grades 7 to 9 and Grade 12. Even though geometry has been re-introduced into the curriculum, the level at which certain topics are tested is not adequate for deep understanding of the section of work. The depth of understanding by students is lacking. Even when they follow a procedure, they battle. It is to be understood that they therefore lack understanding on a deeper cognitive level (Felder and Brent, 2005). Students resist detail in mathematics and the teaching at school level is generally not conducive to self-thinking and innovation (Jacobs, 2010).

2.6 Value of Grade 12 results

The higher education sector has found that the grade 12 marks have been inflated (Nel & Kistner, 2009, p. 963). Jacobs (2010, p. 68-70) expresses concern that applications to university are done with grade 11 results and these marks differ substantially from the final grade 12 marks that students submit when they register in their first year. Their inflated marks give them entrance into a program they would perhaps previously never have qualified for and miraculously, on receipt of their matric certificate, they suddenly qualify for these degrees. The drop-out rate of SA universities has been discussed by Scott, Yeld and Hendry (2009), the CHE report (2013) and remains at almost 30% in the first year of studies (Jacobs 2010, p. 70)

Jacobs (2010) tabulated grade 12 results from 2006 to 2009. In 2006 and 2007 25 000 learners passed the previous Higher Grade. In 2008, 89 778 passed in and 85 491 in 2009, but where there is no longer any differentiation in levels. Brombacher (2004,1) and Volmink (2010) found that the average Higher Grade pass rate between 2001 and 2007 was between 6.7% and 7.6 % in comparison to 19.8 % in 2008 and 15.8 % in 2009. Professor Jonathan Jansen (Educational specialist and VC) called it matric fraud (Beeld, 31 December 2003, p.8). "South Africa placed 50th out of 50 countries in terms of quality, participation rate, completion rate and level of competency" (Jacobs, 2010).

The value of the National Benchmark tests has also been debated and although there seems to be merit in using the test with NSC results it seems like university management are reluctant to lose numbers, and enrolment plans drive the incoming numbers, rather than quality and success of students (Jacobs, 2010). The National Benchmark Test has a Mathematical subtest which has been applied in different placement and selection batteries. The results will be provided below and could be used with the NSC results.

3. PROFILING THE UNIVERSITY OF JOHANNESBURG

The University of Johannesburg, in Johannesburg, was established in 2005 when the former Rand Afrikaans University (RAU) merged with the Witwatersrand Technikon and two Vista campuses. It is a comprehensive university with four campuses, nine faculties and over 50 000 students.

3.1 Increased enrolment

As mentioned above, the curriculum has been changed considerably, but not in isolation. The public higher education has been transformed from an elite system with students from good schools to a mass system, and where the sector had 495,356 students in 1994, the numbers escalated to 899,120 in 2011. In the Faculty of Science the profile changed from 264 African and 314 White students in 2001 to 925 African and 108 White students in 2013 (Jacobs and Jacobs, 2014). The Indian and Coloured representation stayed fairly stable over the years and 104 students in 2013. The number of enrolments increased during the years, but given the lack of qualified teachers, the students enrolled and dropped-out ("revolving door") as soon as the first tests and examination were taken down. In the CHE report (2013, p.41) it has been stated that 20% of African and 44% of White students graduate in regulation time. The attrition rate is 40% by the end of regulation time and "…more students have been lost to failure and dropout than have graduated – more than twice as many in the case of African and diploma students" (CHE 2013, 43). The concern would be the low completion rates for Engineering degrees (23%); BSc (23%); Engineering diplomas (5%) and Science diplomas (14%).

3.2 Extended modules

The University of Johannesburg has designed a foundational provision model where students enter Science programmes with the first six months of predominantly school mathematics curriculum, in order to better prepare students for proper first year mathematics. Lecturers find that even standard mathematical procedures are not correctly carried out by students, or unreliable methods are used, which no longer work in the context of more rigorous problem solving. The interventions address these short-comings in adequately preparing students for first year mathematics.

Lecturers find that it takes a few months for these students to realise that they are not quite as capable as what their matric results may claim. Students need to be convinced rather quickly to buy into the program to avoid failure. They also need convincing that they will not be receiving inflated marks and that a pass has to be earned. There is some resistance, but with firm guidance, most students co-operate.

3.3 Interventions

Over and above the change in curriculum and time the extended programme provides interventions to support students towards academic success:

3.3.1 Many of our students fit the profile of the **under-privileged**. They are ill-equipped financially to cope with the challenges of student life. These students have poor nutrition, which directly affects their academic performance. The university relies on sponsors to feed them. Support is also provided in the form of psychological intervention and/or counseling and guidance.

3.3.2 Rigorous **on-going assessment** is crucial to the success of this model. Students need to be persuaded to work on their mathematical skills continuously and the only reliable means is to assess them during almost every lecture. Lecturers find that testing students at the end of a lecture on the new work just covered in that lecture forces students to make it a priority to concentrate, engage and ask questions, knowing they will be assessed before they leave. The benefits of this rigorous assessment far outweigh the administrative hurdles associated with the marking of these assessments. Students are also verbally reminded to commit mathematical concepts to long-term memory. Lecturers find that students generally cannot rely on prior knowledge. They seem to forget the processes which are meant as building blocks for more complex problem solving.

3.3.3 The department of Mathematics relies heavily on the support to students provided by its **Mathematics Learning Centre**. Tutors are available to assist students all day, every day, to assist students who struggle to understand concepts quickly. Tutors are selected for their mathematical ability as well as their communication and teaching skills, by a process of interviews in conjunction with practical mathematics teaching demonstrations. These tutors receive training throughout the year. A logbook is kept of students who make use of the services of the tutors. This service provides one on one assistance to students. In 2013, up to 1600 students per term (64 000 per year) made use of these tutors and the centre (UJ, 2013).

3.3.4 Lecturers and tutors with a **passion for teaching** are selected to present modules. The university finds that knowledge and mastery of mathematics is not enough to get students to a level of understanding of the subject. The teaching aspect of the subject is crucial for successful advancement to the next level. Students require teachers, as opposed to lecturers, who have the success of their students at heart and who constantly innovate in order to adapt to the new student which each year brings forth.

3.3.5 **Technology** is used to appeal to the modern student who is technologically driven in a natural way. UJ uses its own internal website to communicate with, inform and assess students. Students log onto uLink with their student number and receive e-mails of new announcements pertaining to each subject, which lecturers have posted on uLink. The majority of students are comfortable with the use of uLink and those who arrive at university with little knowledge of computers very quickly learn to acquire the skills necessary to participate. Use of uLink is not an option, but a necessity, since the student portal is also used for assessments. Lecturers are also able to post notes of the content on uLink. This particularly useful for topics such as Logic, which is very comprehensive writing and wordy. Students can print out these notes for class and then simply add any comments as the lecture progresses. This leaves more time for the application of the topic in the form of exercises and examples.

4. FOCUS OF THIS INVESTIGATION

This research paper focused on the comparative academic achievement of first-year students in the Faculty of Science at the University of Johannesburg with specific emphasis on the Mathematics modules. The research question is: “Does the foundational provision model in first year mathematics prepare students to pass the main stream module that follows in the second year?” The main objective of this research was to compare the success of students in the three year programme (one module) and the four year programme (three modules). The hypothesis formulated suggests that the interventions implemented in the Four Year Degree programme can be considered as effective in developing the students’ academic competency in mathematics relative to mainstream students.

5. METHODOLOGY

The academic achievement of the three year degree Mathematics students was compared to the academic performance of the four year degree Mathematics students. The curricula of the two programmes are identical; the offering of the mainstream in one module when students exists school are compared with students entering a fundamental module in the first semester and then entering the two semesters (an expanded offering of the main steam one module) before they all enter the final first year module (MAT1B).

5.1 Participants and sampling

Purposive sampling was used with final results of students after completion of the one Mathematics module (mainstream) and final results of students after completion of the three semesters in the four year (extended programme) option for Mathematics 1A. Both these groups streamed into the second semester module 1B and all attend the same class and write the same exam in Mathematics1B.

Table 1 provides a demographic analysis of the participants.

Table 1: Demographic Analysis of Participants

Variable		3 yr (Mainstream) (n=405)	4 yr (Extended) (n=204)
Gender	F	30.6%	40.7%
	M	69.4%	59.3%
Ethnic Group	African	72.1%	91.7%
	Coloured	6.2%	2.0%
	Indian	2.7%	0.5%
	White	19.0%	5.88%
Gr 12 Profile	Ave APS	36.41%	32.39
	Ave Mathematics	74.85%	62.89%
	NBT Mathematics	44.29%	36.74%

5.2 Reliability and validity of the collected data

The date used in this research was the biographical data and grade 12 results as captured on the universities' student data system. The data is reliable and valid as students' results and finances are processed from the same system. The module results were captured from the formal mark system (ITS) and are audited by external auditors and will thus be reliable and valid. The researchers validated each item and removed the students with complete data sets (e.g. international students and students repeating only one of the modules).

5.3 Empirical data

In the dataset, over and above the comparison of the Grade 12 Mathematics results, investigation into the comparison of the achievement in Mathematics 1B, in the second semester (as mentioned above).

A paired-samples t-test, including Pearson's product moment correlation coefficients, were conducted on the two pairs of first and second semester examination and final module marks, for the 846 students who enrolled for the different modules. Tables 3 and 4 below summarise the respective paired samples statistics, correlations and test findings in respect of the two sets of paired differences.

Table 2: Correlations

MODULE		Gr 12 Math	MAT1A01	MAT1AE1-3	MAT1B01
Gr 12 Math	Pearson Correlation	1	.344**	.373**	.356**
	Sig. (2-tailed)		.000	.000	.000
	N	609	405	204	609
MAT1A01	Pearson Correlation	.344**	1	.b	.542**
	Sig. (2-tailed)	.000		.	.000
	N	405	405	0	405
MAT1AE1-3	Pearson Correlation	.373**	.b	1	.353**
	Sig. (2-tailed)	.000	.		.000
	N	204	0	204	204
MAT1B01	Pearson Correlation	.356**	.542**	.353**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	609	405	204	609

** Correlation is significant at the 0.01 level (2-tailed).

b. Cannot be computed because at least one of the variables is constant.

Inspection of Table 2 shows the Pearson correlation for Mathematics1A and Mathematics 1B (r = 0.356**) is statistically significant ($p < .001$). Furthermore, Mathematics 1AE1-E3 and Mathematics 1B (r = 0.353) have a statistically significant relationship ($p < .001$).

In Table 3 the statistics are shown. In the **Mathematics** modules (both programmes) are statistically significant ($p < .001$). The first semester **Mathematics** (mainstream) has as expected lower average of 60.10 (*SD* = 9.521) than the combined results for Mathematics (extended) average of 62.07 (*SD* = 6.977). In the second semester when students from both programmes enter the same modules the values are statistically significant ($p < .001$).

Table 3: Group Statistics

Item	Program	N	Mean	SD
Gr 12 Math	MS	405	74.85	9.277
	EXT	431	61.38	7.804
MAT1A01	MS	405	60.10	9.521
MAT1AE1-E3	EXT	431	58.97	7.81
MAT1B01	MS	405	58.41	10.159
	EXT	205	50.65	9.722

An independent samples t-test was conducted to enquire whether there is a significant difference between the performances of the mainstream and extended in the one module in the second semester.

Table 4: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	**Sig. (2-tailed)**	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MAT1B	Equal variances assumed	3.120	.078	9.024	607	.000	7.765	0860	6.075	9.455
	Equal variances not assumed			9.150	422.510	.000	7.765	0849	6.097	9.433

In Table 4 the independent samples t-test revealed a statistically significant difference between the mainstream and extended (t (422) = 9.150, (p = .000),

d =.390), with the marks of **Mathematics** mainstream (three year) (*M* = 58.41; *SD* = 10.159) better than the marks of the extended (four year) (*M* = 50.65; *SD* = 9.722).

Levene's test indicated equal variances for Mathematics1B (F = 3.120, p =.078, so degrees of freedom were 607.

Table 5: Proportion of Variance In Mathematics 1b Explained By Mathematics 1a (Mainstream and Extended)

Model	R	R^2	Adjusted R^2	SE	Change Statistics				
					ΔR^2	ΔF	$df1$	$df2$	Δp
1	.542[a]	.294	.292	8.547	.294	167.814	1	403	.000
2	.353[b]	.125	.120	9.140	.125	28.750	1	202	.000

a. Predictors: (Constant), MAT1A01
b. Predictors: (Constant), Ave MatE1-E3

Table 5 shows that MAT1A results accounted for 29.2% of the variance in Mathematics 1B (ΔR^2 = 0.292; *F* = 167.814; *df* = 1, 403; *p* = .000), and that the MATE1-E3 average accounted for 12.5% of the variance (ΔR^2 = 0.120; *F* = 28.750; *df* = 1, 202; *p* = .000). Thus the MAT1A and MATE1-E3 modules contributed significantly towards the explanation of student achievement in Mathematics 1B, but the mainstream MAT1A accounted for 6.5% of the total variance in Mathematics 1A.

5.3 Empirical synthesis

The empirical investigation among the 836 first year mathematics students generated the following noteworthy findings:

- Table 3 indicates that of the initial 431 extended students only 205 continued with Mathematics 1B (second module) which indicates a 47.6% progress;
- In Table 4 the independent samples t-test revealed that as expected the mainstream (with a mean of 58.41) indeed performed better than the extended group (with a mean of 50.62);
- In Table 5 the variance indicates the contribution that MAT1A or 1AE1-E3 results made towards performance in MAT1B. The 29.2% variance in Mathematics 1B in the main stream (MAT1A) and the 12.5% in the extended (MAT1E1-E3). As expected the main stream 1A should prepare students well to be able to pass MAT1B but there is also a good prediction that students that passes the MATE1-E3 modules would be able to pass MAT1B.
- Thus the extended programme provides students with comparable opportunities to pass first year Mathematics and the modules that follow.
- The model and interventions in the extended programme are providing students with attributes that add to their confidence, work ethics and enough time to mature to transfer the foundational mathematical concepts in other disciplines.

6. CONCLUSION

Based upon the significant (statistically and practically) achievement in the second semester module in Mathematics, the influence of the interventions on student success in Mathematics needs to be emphasised. The research question was: "Does the foundational provision model in first year mathematics prepare students to pass the main stream module that follows in the second year?" The above data- analysis indicate that indeed the foundational provision model prepares students to have an equal opportunity to be able to pass the following module.

The smaller groups, learning centre, active tutorials and highly motivated lecturers are proven to be adding to the attitude and performance of students who started off with a deficit. This paper provided evidence of two streams of students entering the first year Mathematics modules with different background, varying school profiles, excellent and poor teachers and many other factors are provided with an equal chance of passing mainstream modules after applying constructive interventions.

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FACTORS ATTRIBUTED TO POOR PERFORMANCE IN GRADE 9 MATHEMATICS LEARNERS SECONDARY ANALYSIS OF ANNUAL NATIONAL ASSESSMENTS (ANA)

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Abstract–This article is about the factors associated with learners' poor performance in grade 9 mathematics Annual National Assessments (ANA). The study used a qualitative research approach to illuminate factors associated with this problem. Participants were purposefully selected from four schools with poor pass rates. Data was generated from different sources for triangulation, namely questionnaires, interviews and document analysis. After the analysis, coding and categorizing of data, the following factors were identified as the main causes of learners' poor performance answering: content related factors - these are factors that relate to the mathematics children learn, how they learn it and how it is disseminated to them; didactic factors - these are factors that are due to the instructional approaches and how these enhance or inhibit learners' mathematical knowledge acquisition; systemic factors - these are factors that the educations system impose on the learner and they include the school environment, the administration and the general educational support as well as the social factors- which are related to the child home and community environment and how that impacts on the child's learning of mathematics.

Keywords: ANA, Didactic factors, Systemic factors, Social factors, Content related factors.

INTRODUCTION AND BACKGROUND

The Department of Basic Education (DBE) has identified ANA as a vehicle for improving the quality of education in the lower grades. Previously, external assessments were done only in grade 12. The DBE has now shifted the focus on the lower grades. In this regard, ANA is used as a critical measure for monitoring progress in learner achievement in these grades. The data on learner achievement in ANA is useful for informing education policies, designing and implementing intervention programs aimed at improving classroom learning and teaching, identifying and supporting learners with learning barriers, providing effective methodological support to schools and the provision of training and professional development opportunities for underperforming schools and teachers (DBE, 2013). Both the 2012 and 2013 ANA results show that South African learners are not performing well in Grade 9 mathematics (see table 1). Achievement in mathematics declined across the grades with progressively steeper declines from Grade 6 to Grade 9. According to DBE (2013), grade 9 learners "demonstrated a fairly limited repertoire of necessary basic skills and knowledge, a signal warranting particular attention, given that this is a critical transition grade into the Further Education and Training (FET) Band of the school system". This is alluded to by Spaull (2013) whose report reveal that 76 per cent of Grade nine learners in 2011 still had not acquired a basic understanding about whole numbers, decimals, operations or basic graphs.

Table 1: National average percentage marks for mathematics in 2012 and 2013 (DBE, 2013).

GRADE	MATHEMATICS 2012	MATHEMATICS 2013
1	68	60
2	57	59
3	41	53
4	37	37
5	30	33
6	27	39
9	13	14

The average % of all the provinces is shockingly below 17% (see table 2). Less than 4% of the learners in all the provinces (except WC at 6.8%) achieved more than the acceptable achievement mark of 50%.

Table 2: Achievement in Grade 9 mathematics by province in 2012 and 2013 (DBE, 2013).

PROVINCE	AVERAGE MARK (%)			ACCEPTABLE ACHIEVEMENT (≥ 50%)		
	2012	2013	verification	2012	2013	verification
EC	14.6	15.8	12.9	2.6	3.3	1.2
FS	14	15.3	14.8	3.1	4.1	2.2
GP	14.7	15.9	14.6	3.7	5.2	3.0
KZN	12	14.4	12.2	1.9	3.4	1.8
LP	8.5	9	10.1	0.5	0.9	0.5
MP	11.9	13.7	13.9	1	1.8	1.6
NC	13.2	12.6	12.9	2	2.4	2.5
NW	11.2	13.3	12.7	1.4	2.3	1.4
WC	16.7	17	16.5	5	7.2	6.8
National	**12.7**	**13.9**	**13.0**	**2.3**	**3.4**	**2.1**

The results also paint a gloomy picture in terms of the levels. Learner achievement in South Africa is expressed in terms of seven levels as shown below:

Table 3: Seven key Levels of achievement, (DBE, 2012).

RATING CODE	PERCENTAGE	DESCRIPTOR
LEVEL 1	0–29	Not achieved
LEVEL 2	30–39	Elementary achievement
LEVEL 3	40–49	Moderate achievement
LEVEL 4	50–59	Adequate achievement
LEVEL 5	60–69	Substantial achievement
LEVEL 6	70–79	Meritorious achievement
LEVEL 7	**80–100**	Outstanding achievement

About 88% of the learners performed at the not achieved level in Grade 9 Mathematics (see table 4 below). About 2% of learners performed at high achievement levels. This is a worrying trend.

Table 4: Percentage of grade 9 learners in achievement levels in Mathematics by province (DBE, 2013).

PROVINCE	L1	L2	L3	L4	L5	L6	L7
EC	84.9	7.5	4.3	1.9	0.8	0.4	0.2
FS	86.9	5.6	3.4	1.9	1.1	0.6	0.5
GP	84.8	6.1	3.9	2.3	1.4	0.9	0.6
KZ	87.3	5.8	3.5	1.9	0.9	0.4	0.2
LP	95.9	2.2	1.1	0.5	0.2	0.1	0.1
MP	91.1	4.6	2.5	1.0	0.4	0.2	0.2
NC	91.8	3.9	2.0	1.1	0.7	0.4	0.2
NW	90.5	4.7	2.5	1.1	0.6	0.4	0.3
WC	83.1	5.7	3.9	2.8	1.9	1.3	1.2
National	**88.4**	**5.1**	**3.0**	**1.6**	**0.9**	**0.5**	**0.4**

THEORETICAL FRAMEWORK

This research report is based on the theory of constructivism. Llewellyn (2005) describes constructivism as a philosophy about how an individual learns, one in which the learner is embedded in active engagement and is constantly constructing and reconstructing knowledge. In constructivism, the responsibility for learning therefore lies with the learner. Emphasis then is placed on the learner being actively involved in the learning process.

AMESA compiled a report on the standard of the 2013 grade 9 ANA question paper following a request by the DBE for an independent opinion. The report indicates that the question paper presented a sound spread of content areas as required by the NCS (see table 5).

Table 5: Content area coverage in 2013 on ANA grade 9 Mathematics exam (AMESA, 2013).

Content area	Suggested %	Actual
Numbers, Operations and Relationships	15%	13%
Patterns, Functions and Algebra	35%	35%
Space and Shape	30%	19%
Measurement	10%	14%
Data Handling	10%	19%
TOTAL	**100%**	**100%**

Although there was a minimal deviation in terms of the questions that were set, AMESA (2013) reports that the paper was of a good standard and tested the knowledge and skills which a Grade 9 mathematics learner should have. It was a well- balanced paper, catering for a wide range of ability levels**.** The paper was generally in keeping with the Grade 9 ANA framework in terms of cognitive and difficulty levels; and the questions were well thought provoking, formulated clearly and unambiguously. According to AMESA, second language learners would have been able to understand most terms/concepts. The committee was of the opinion that there was adequate time allowed for the question paper; and that learners had enough time to complete the question paper (AMESA, 2013).

Based on the criteria (content coverage, cognitive level balance, language and time) of its analysis, the committee concluded that the paper was set at an appropriate, acceptable standard and must be regarded as fair. Learners who were taught well and worked hard should have had little difficulty in solving most of the problems in the paper.

If the standard was fair, the question then is why the learners perform so dismally. The poor performance of learners countrywide can therefore not be attributed to a difficulty paper set beyond the scope of the learners. The interest in this paper is to seek possible reasons for poor performance by learners. Of concern is the fact that the learning deficits that learners acquire in this grade will grow over time to the extent that they become insurmountable and preclude them from following the curriculum at higher grades, especially in subjects like mathematics and science. According to Spaull (2013), all of the available evidence suggests that many South African children are acquiring debilitating learning deficits early on in their schooling careers and that this is the root cause of underperformance in later years. Poor mathematics results at the primary and secondary level in South Africa severely limit the youth’s capacity to exploit further training opportunities. Intervening early to prevent, diagnose and correct these learning deficits is the only appropriate response. It is for this reason that this study was undertaken.

This study aims to investigate the factors associated with learners’ poor performance in grade 9 mathematics ANA, given the strategic importance of Mathematics for a world that has a technological slant and the critical transition that Grade 9 provides into FET Band. The study addressed the following research questions: *What are some of the factors that attribute to South African grade 9 learners’ low performance in the Annual National Assessment exanimation?*

RESEARCH DESIGN AND METHODOLOGY

The study used a qualitative research approach within an interpretive paradigm to investigate the factors associated with learners’ poor performance in grade 9 mathematics ANA. Data which were selected were on the basis of learners’ lowest pass rates. The data collected was interpreted in the context of the research question, thus locating the study in the interpretative domain. The sample consisted of 40 learners (10 from each school) together with their respective mathematics teachers. The learners were randomly selected in each school. Data was generated from a combination of sources to allow for triangulation. These sources ranged from interviews, document analysis and questionnaires.

With permission from the Department of Education, the researchers contacted the principals of the schools to access the grade 9 ANA Mathematics results. Districts, provincial, and national results were accessed from the internet and regional office. Permission was also sought to interview and administer questionnaires to both teachers and learners. For ethical reasons, the schools were coded S1 to S4, teachers T1 to T4, and learners L1 to L40. The limitation of this research report is that the sample used was rather small and therefore the results may not be taken as a true representative of the South African schools as a whole.

FINDINGS AND DISCUSSION

Interpretive descriptive analysis method was used in the analysis of data (Luneta, 2011). The researchers provided descriptions of the learners' and teachers' responses to questionnaires and interviews. The responses were then categorised according to the emerging themes and patterns based on the causes of the learners' difficulties encountered when responding to ANA questions. Document analysis on the work given to learners was also done. The causal factors were categorized in terms of categories, namely; content related factors (C1), didactical factors (C2), systemic factors (C3) and social based factors (C4).

Table 6: Category of causal factors

Category	Type	Description
C1	Content related factors	Factors related to the content taught to learners.
C2	Didactical factors	School based factors as a result of teaching and learning methods or strategies
C3	Systemic factors	Factors associated with policy
C4	Social based factors	Factors associated with society

Content related factors:

This relates to all factors related to the mathematical content taught to learners. This also includes the pedagogic content knowledge of teachers, which is how well a teacher understands common mistakes that learners make and how to correct them as well as the teacher's capacity to teach the subject matter.

This study established that learners' poor performance may be due to the quantity and quality of mathematical content taught to learners. The department provide schools with annual teaching plans and pace setters (wok programmes) to guide teaches in terms of when and what should be taught as well as when, how and what to assess. In an ideal teaching learning situation, the teachers' preparations, teachers' files, and learners' written work give an evidence of how much content knowledge was taught. Unfortunately there were no lesson preparations in the four schools where this research was conducted. Teachers had policy documents which were in their files but not used accordingly, for example pace setters were not used for lesson preparations and presentations. Without lesson preparations and not using pace setters, it was therefore not easy to determine when and how much was taught. The researcher solely depended on learners' books to analyse how much content was learned during the first term of 2014. The table below show content topics to be taught and the allocated time for the first term in grade 9.

Table 7: Topics and allocated time to be taught during the first term in grade 9 mathematics (DBE, 2011b, p. 37).

Term 1	
Topic	**Time**
Whole numbers	4,5 hours
Integers	4,5 hours
Common fractions	4,5 hours
Decimal fractions	4,5 hours
Exponents	5 hours
Numeric and geometric patterns	4,5 hours
Functions and relationships	4 hours
Algebraic expressions	4,5 hours
Algebraic equations	4 hours
Revision/Assessment	5 hours
TOTAL: 45 hours	

An analysis of whether these content topics were taught was done using learners' books as there were no teacher preparations.

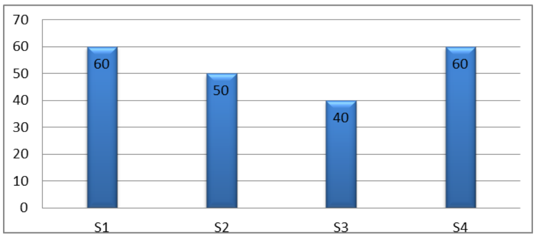

Figure: Schools' mathematics content coverage for term 1 in percentages

The figure shows that S1 and S4 managed to complete about 60% of the topics they were supposed to teach. S2 completed about 50% while S3 completed about 40 %. The number of mathematics lessons given by teachers was therefore less than the official number they were expected to teach. This indicates that time on task is a problem. In all these schools, revision was not done although there was provision of this in the term plan. A quarterly assessment however was done with question papers being set by the district. These assessments must have given learners problems considering the content coverage in term 1. This pathetic state of teaching is aggravated by not using period attendance registers, resulting in no evidence of number periods attended per week and quarter. The gleaning of learners' books therefore gave an evidence of low content coverage (see figure 1). This means low numbers of periods were taught which in turn compromised content coverage, content emphasis and content exposure. Content coverage refers to the extent to which mathematics topics were covered or taught in the classes (Carnoy et al., 2011). Content emphasis refers to the relative amount of time each class spent on each of the various topics that relate to the content. Content exposure refers to the overall amount of time students spent engaged in doing mathematics. Interviews with teachers revealed the following factors which contributed to low content coverage: departmental meetings, time provision in the timetable, school and cluster meetings, marking learners' work, corrections, and the need to address gaps.

It was therefore not surprising that most of the learners interviewed indicated that the questions on ANA exams were difficult. This was affected by the number of periods taught which affected content coverage. Three of the teachers interviewed blamed the previous grades for not teaching enough content. They complained that they had to spend valuable time preparing learners with mental mathematics and some sections which should have been mastered in their previous grades. If learners had not mastered basic skills and the content taught in the previous grades, then the new content will be difficult to master.

Some of the learners indicated that not enough class activities were given to them and the activities were simpler compared to the exam questions. Some teachers admitted giving simpler tasks to learners. The reason was that it was far much easier to mark them and be able to give the maximum number of tasks required per week as required by policy. This also shows that the cognitive demands made by teachers of learners in the classrooms are low. According to Carnoy et al. (2011), cognitive demand refers to the "cognitive or conceptual level at which the learners in the class are engaged with the mathematic content covered". When assessing learners on a daily basis, questions should be selected from all the four cognitive levels, namely knowledge, routine procedures, complex procedures and problem solving. The four cognitive levels used to guide all assessment tasks is based on those suggested in the TIMSS study of 1999 (DBE, 2011a). Each balanced test written by learners should include questions from all these cognitive levels. A balanced test should have 20% of knowledge questions (questions which needs straight recall or one step), 45 % of routine procedures questions(questions which requires learners to perform well known procedures , simple applications and calculations which might involve many steps), 25 % of complex procedures questions (questions with problems that involve complex calculations and/or higher order reasoning which requires conceptual understanding), and 10 % of problem solving questions (questions that need higher order understanding and processes). Concentrating only on knowledge based questions is failing the learners because an examination includes questions from all the four cognitive levels.

Didactical Factors

This refers to all factors within the school context, including factors as a result of incorrect teaching and learning methods or strategies. A report by the OECD (2005, p. 2) concludes that, second only to learner background factors, "factors to do with teachers and teaching are the most important influences on pupil learning". This is alluded to by Barber and Mourshed (2007, p. 12) who argue that "the main driver of the variation in pupil learning at school is the quality of the teachers".

Teachers complained about time provision in the time table. According to Taylor (2007) strong evidence exists showing that adherence to basic educational policies and processes can have an impact on good teaching and learning**.** Taylor (2007) further argues that issues around the maximisation of contact time with learners in class, the presence of both learners and teachers at school and in class, makes a positive impact on educational. Analyses of the timetables of the four schools reveal a minimal usage of contact time for teaching and learning as per policy. These schools use a 35 minute period system with one double period per week, resulting in mathematics being allocated 210 minutes per week. According to DBE (2011b, p. 8) the instructional time in the Senior Phase for mathematics is 4, 5 hours which is 270 minutes (see table 7). This means about an hour of mathematics teaching is lost per week. This is a lot of time lost per term and per year. This results in a chronic and systemic reduction of teaching and learning in class. Unfortunately this study was unable to determine how much time was spent on teaching mathematics as there were no period attendance registers signed by educators. If the amount of work given to learners is used as a yardstick of the time spent on teaching, coupled with the allocated time per week, it is evident that not enough time as required by policy is spent on teaching and learning.

Learners complained that often teachers are fast. Interviews reveal that this pace was a result of teachers' anxiety to keep pace with the work schedule and finish the syllabus. This fast pace makes leaners not to understand mathematics. Learners then become anxious and develop negative attitude towards mathematics. According to Khatoon and Mahmood (2010), negative attitude towards mathematics may have its roots in teaching and teachers, with maths anxious teachers resulting in maths anxious learners at times. Such teaching is characterised by an over-reliance on traditional instructional activities such as drills, memorization, textbook method teaching, one correct method of solving a problem, and concentrating more on basic skills rather than concepts (Khatoon & Mahmood, 2010)**.**

Teachers complained about lack of resources. Learners had no calculators which made it difficult to perform and solve some mathematical problems. According to Taylor and Reddi (2013), lack of resources like models, pictures, drawings, graphics, calculators and charts is acontributory factor to learners' negative artitude towards mathematics. Mathematics classrooms should have a mathematics feeling and touch. Learners should see mathematics around them. The classroom is also a place where positive or negative attitude towards mathematics can develop and flourish.

Performance was affected by ineffective leadership. Mathematics HOD's never call meetings with teachers and learners' work is neither supervised nor moderated. Meetings facilitate communication and the flow of important information. Teachers believe regular meetings may assist them with curriculum issues, specific questions around subject content, improvement of their style of teaching. It seems HOD's lack the technical capacity to manage the department. Teachers articulated a need for effective assistance, guidance and mentoring in most aspects of teaching, but specifically around issues of lesson planning and assessments. This was supposed to be provided by their HOD's who allegedly are failing them.

Another contentious issue which was discovered when analyzing documents is that workbooks provided were not used. Teachers were only using activities which are in the textbooks. Exemplar question papers provided were also not used. This seemed problematic because exemplars and workbooks have questions on the four cognitive levels. Failing to use these resources resulted in teachers giving learners only simpler classwork activities whereas in the examinations learners faced challenging questions.

Systemic factors

This relates to all factors associated with policy. Mathematics as a subject has its own policy which relates to the assessments, number of periods to be taught and other relevant aspects related to it. The NDP report highlights a number of institutional and systemic factors such as the management of the education system, the competence and capacity of school principals and heads of departments, teacher performance and accountability, as factors preventing progress in South Africa's schooling system (NPC, 2012, p. 38).

Teachers felt the system is putting too much pressure on them in terms of the quantity of the work to be taught and the quantity of tasks to be given. They complain that the tasks to be given per week are too many considering that corrections and teaching have to take place. Teachers are expected to give at least four tasks per week. This proves to be challenging because they are teaching other subjects with overcrowded classes which also have tasks to be controlled as well.

Teachers complain about the syllabus that is always changing. They complain about teaching new content which they themselves do not know. Teaching a content which a teacher does not understand is a recipe for failure as alluded to by Taylor and Taylor (2013) who posited that learners will not do well in mathematics when their teachers who were supposed to guide did not know the subject themselves. Teachers indicated challenges in topics such as transformations, measurement as well as shape and space. Although workshops are sometimes conducted, there is not enough time to engage with the content. Usually workshops are conducted after school hours for about 2 hours or more to which teachers claimed that they are usually too tired with the day's work. Some of the workshops are conducted during holidays with many of them having gone back home as they are from other provinces like Limpopo. Because of the lack of adequate training, teachers may not adequately discuss mathematical problems with learners as has been alluded to in other studies.

The teachers interviewed reveal that the policy which states that a child may only be held back once per educational phase is also contributing to learners' poor performance. The South African Admission Policy for Ordinary Public Schools (1998) limits grade repetition to a maximum of one year per school phase (DBE, 2008). This forces schools to promote learners to the next grade without them having mastered the necessary mathematics knowledge and competencies as demanded by the curriculum. Teachers are therefore forced to promote mediocrity by this policy. While there is a cap on the number of repetitions allowed in the schooling system, the policy cautions that this limit should not be construed as promoting automatic promotion.

The problem is also number of Mathematics Curriculum Implementers (CI's) visiting the schools. The teachers revealed that CI's are not coming to their schools for support. Upon investigations, it was found that only four CI's are serving the whole region with 348 schools, an average of 87 schools per CI. This situation is not conducive for effective monitoring.

Social based factors

Learners are social beings. They are born and live within a particular society. Sometimes society has its own views and attitude towards mathematics. One of the most views of society towards mathematics is that it is a difficult subject **(**Khatoon & Mahmood, 2010).

Learners in this study also attributed their failure to the fact that mathematics is naturally difficult, and therefore there was nothing they could do to pass. This social factor is a mathematical myth which may induce or reinforce negative attitude in some learners.

This study also established that learners do not receive assistance from parents or family members. It is impossible for learners at the school where this research was conducted to receive parental support in terms of mathematics education. This is because most parents are illiterate. Even teachers complained that learners' performance in tasks like projects, assignments and investigations is poor because of parental support at home. Mji and Makgato (2006) propose service learning to close this gap. Service learning involves learners assisting other learners while meeting their own learning objectives. In mathematics, this would involve a learner assisting another learner with math skills. With service learning, there are three key elements to a successful program: exposure provides the learner with exposure to another learner struggling to learn the same skills, the experience needs to meet a community need for it to be valuable to the learner, and the learner also need to have the time to provide reflection. Mji and Makgato (2006) found that learners who participate in a service learning experience have a great motivation toward their own subject involvement.

Another social factor is the ridicule of learners who get wrong answers by their peers in class. This is alluded to b**y** Khatoon and Mahmood (2010) who argued that a learner may develop a strong dislike for a certain subject where other learners habitually ridicule him or her in front of his/her peers. The classroom should be a place where learners learn without fear of making mistakes. Mistakes should be viewed as a vehicle for meaningful learn.

CONCLUSION

This study has established that learners' poor performance in grade 9 mathematics ANA can be attributed to the didactic obstacles they encountered in their previous or present grade, to systemic problems, to social problems or to content related problems. The dismal poor performance of grade 9 Mathematics in ANA is therefore a symptomatic of state of mathematics teaching in the senior phase (grades 7 – 9) or perhaps even in the junior phases in South Africa. Over the years, the DBE has paid more attention to the FET Band, especially grade 12, and neglecting other phases. It is possible that this neglect has also contributed to this poor state of teaching and learning of mathematics in grade 9. Immediate attention should be given to all the junior phases. Maximum energy should be channelled to these phases. Interestingly, during the apartheid era, external examinations, with certificates being awarded, were written in standard 5 (now called grade 7) and form 3 (now called grade 10). Perhaps it is now time for the DBE to reintroduce this assessment and certification policy for it will encourage both learners and teachers to work very hard.

From the findings in the previous section of this study, the following recommendations are made:

RECOMMENDED TIPS FOR THE DBE

From the findings of this study, it is clear that there is the need to improve the pedagogic content knowledge of teachers. The DBE should therefore embark on serious in-service training of mathematics teachers to equip them with skills for teaching mathematics in schools. Teachers should be in-serviced in the use of learner-centred teaching methods that are appropriate and that make the learning of mathematics meaningful. According to Spaull (2013) a large proportion of South African teachers still have below-basic content knowledge in the subjects that they teach – largely as a result of the ineffectiveness of in-service teacher training initiatives. A system of identifying which teachers need what help is urgently required. The DBE should first aim to ensure that every teacher in the system has the basic content knowledge required to cover the curriculum that they currently teach. The DBE should then implement a nation-wide system of diagnostic teacher testing and capacitating for mathematics teachers. Teachers should be reassured that these tests are primarily for diagnostic rather than punitive purposes. They should be developmental in nature with the ultimate aim of not vilifying and demeaning teachers and the teaching profession, but to increase the capacity and dignity of teachers.

There should be an increase in the managerial, administrative and technical capacity of the districts bureaucracies. CI's should be based at circuit level instead of district levels. This will make it easier to establish an efficient monitoring of curriculum coverage. The result will be an improvement in the quantity and quality of assessment tasks given to learners. Monitoring will ensure making optimal use of teaching and learning time because of regular class attendance by teachers and learners.

The DBE should help improve the competence and capacity of mathematical HOD's. HOD's should be appointed purely on merit. They should always be held accountable for their schools low performance. According to RESEP and Oxford Policy Management (2012, p. 37) most educational systems appears to suffer from both a lack of top-down oversight and a lack of bottom-up accountability, which means that there is little consequence for non-performance and therefore little emphasis on results. There should therefore reinforcement of the HOD's subjects' supervision.

The department supplies schools with exemplars and support materials like assessment guidelines and annual teaching programme. Through the CI's with the assistance of the principals and the HOD's, monitoring should be done to ensure that these documents are used. Strict monitoring should be done to ensure that teachers are teaching the right content and asking appropriate questions in terms of all taxonomy levels.

The department also supplies schools with workbooks. Workbooks are viewed as an important intervention strategy for improving performance of learners in national and international assessments of literacy and numeracy. According to DBE (2013) report, the purpose of the workbooks is to "provide good quality activities; ensure that learners are given adequate opportunities to consolidate their skills through written responses; guiding teachers to improve their teaching; provide a variety of activities to reinforce mathematical concepts and skills, literacy/ language skills; help teachers to monitor learner performance in key activities; and prepare learners for the formats used in various standardized assessments". This study found that some schools are not using these work books. The DBE, through the CI's, the principals and their HOD's should ensure that these workbooks are used effectively and efficiently.

The CI's should conduct a comprehensive audit of the identified underperforming schools and determine the causes of poor performance. They should facilitate, through the assistance of the mathematics HOD's, the setting of annual targets, improvement plans and intervention strategies. They should improve teacher supervision by doing quarterly inspection with quarterly reports being compiled by schools. CI's should monitor compliance with CAPS. They should ensure that there is proper timetabling and utilization. They should also ensure that all schools have time tables that comply with curriculum policy and that mathematics is afforded maximum minutes as per policy.

Lastly, the DBE should consider reducing the teacher - learner ratio and the number of subject a teacher teaches. This will make provision for the employment of extra educators to reduce the burden of teaching many subjects and learners, as well as of controlling many tasks. Class sizes impact on learner performance. Small classes allow teachers to give more attention to individual learners. In South Africa, for every teacher there are 33 learners, compared to Botswana where the ratio is 1:22, which is one of the lowest teacher/learner ratios in the world (DBE, 2008).

RECOMMENDED TIPS FOR TEACHERS

The core business of schools is learning and teaching, and the core task of principals is to ensure their school ethos is conducive to these priorities. Principals need to provide leadership on the curriculum, as well as administration and management. Mathematics HOD's and teachers should therefore protect the teaching time. They should ensure that a proper adherence to prescribed contact time between educator and learner attendance takes place. They should ensure that schools have time tables that comply with curriculum policy. Teachers should always be in class teaching. The value of safeguarding and maximizing contact time between educator and learner within a prescribed time allocation is simply priceless. Teaching and learning time is indispensable for syllabus coverage and the eventual learner performance. If teachers and learners are on time, on task, teaching and learning, success is guaranteed. Such things as syllabus backlogs and catch-up programmes are automatically eliminated. It is therefore essential that educators' absenteeism and class absconding be totally removed from schools.

Schools should ensure that period registers are established to have evidence of period attendance per week and quarter. This will ensure that classes are attended and there is full content coverage.

They should always check the rate of syllabus coverage per fortnight through the submission of fortnightly syllabus coverage reports.

There should be monthly subject meetings. These meetings should take the form of monthly reviews, performance assessment and analysis of learner results. Such analysis should be used for assisting learners with mathematical challenges.

Teachers should acquire a good knowledge of the subject matter. This will result in teachers teaching competently and confidently. A display of subject incompetence by a mathematics teacher causes the learners to lose confidence first in the teacher and then in the subject.

Teachers should ensure that learners should understanding rather than memorization. The problem many learners have with mathematics is that many rules and concepts are memorized. Some of them memorize steps of solving problems without understanding. Rules, problem solving and concepts should not be memorized. Teachers should therefore help improve learners' conceptual understanding.

Principals should ensure that their schools are mathematically well resourced. Resources are used in class to stimulate and maintain learners' interest in mathematics learning as well as facilitate their understanding of mathematical topics. They help in the formation of concepts in learners' minds. Mere telling without exposing the learners to the concrete materials does not enhance learning. It is therefore recommended that models, pictures, drawings, graphics, manipulatives and charts should be used in explaining mathematical concepts and relations.

Teachers should ensure that mathematics homework and classwork, as well as all formal tasks are set, completed and marked. The process of giving learners written work, checking that it has been done and then marking it in order to assess whether learners have understood what has been taught, needs to be a ritual that is performed every day in every mathematics class. Corrections should always be done, and learners should immediately receive feedback. Teachers should use the results of these tasks to monitor learner performance and to identify those learners who are struggling and who may need additional support. Teachers should always do item analysis of each task to determine problem areas and plan remedial strategies. When learners make mistakes it is important to interrogate their thinking. This is best done by asking them to explain the process they followed to reach their answer. This unpacking process will help learners to become aware of their thinking process and often helps identify misconceptions formed about a particular mathematical operation.

Teachers should improve their test and class activity setting skills. According to Luneta (2013, p.43), wrong questioning techniques can cause learners to make mistakes. Teachers should therefore set questions using exemplars and questions from work books. Questions should be spread over the four cognitive levels as required by policy (Knowledge 20%, Routine procedures 45%, Complex procedures 25% and Problem solving 10%). This will make it easier for learners to face examination questions.

In mathematics, regular practice in performing the tasks that will be tested is key activity. Teachers should give learners plenty of work. They need to leave the mathematics classroom exhausted from the hard work that they have been doing with their minds, not bored from listening to long explanations from their teachers. Mathematics is learned by doing, hands on.

Principals should build competent bureaucracy, and increase accountability at all levels of management of schools. Mathematics' supervision should be improved. Mathematics' HOD's should utilize subject policies which are clearly articulated to teachers. Every mathematics teacher should know what and when to teach, what, when and how to assess as well as what and when to submit for moderation. The culture of accountability should be cultivated and strengthened, while the culture of blame-shifting should be done away with. Efficient leadership and management in a school promote accountability and a healthy working environment. Such a school is also characterized by a clear vision, mission and goals resulting in vibrancy and functionality. This creates a fertile background for effective teaching and learning that will result in complete content coverage. The absence of the above mentioned characteristics in a school results in a dysfunctional school. Both teachers and their HOD's should have clear, structured, personal and subject improvement plans, outlining the steps they will take to help learners who are underperforming.

RECOMMENDED TIPS FOR LEARNERS TO SUCCEED IN MATHEMATICS

Learners should always be punctual and attend all the periods. They should never skip a period unless if there is a serious problem. Missing a single period is a recipe for disaster.

They should improve their conceptual understanding. Mathematics is built around concepts and learners should be made aware that conceptual understanding will go a long way in making it easier for them to understand rather than memorizing mathematics problems, which will in turn result in meaningful mathematics understanding.

Learners should practice daily. They should work all the problems in their workbooks and textbooks. Learners should know that there is no substitute hard work. They should resist the temptation of copying answers from their classmates. They should be made aware that the more problems they work out on their own, the more comfortable they will be during class and during exams. Learners should not get discouraged if they sometimes fail to get correct answers. Learners should always try to get help when necessary. If a learner comes across a problem, he or should immediately consult his or her peers or mathematics teacher. A delay will result in frustrations, and consequently a negative desire and attitude towards mathematics will develop. They should be made aware that persistence always pays off when it comes to mathematics.

If the DBE, the teachers and learners can implement all the recommended tips, surely learners' competency in grade 9 mathematics will improve.

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MATHEMATICS STUDENT TEACHERS' APPROACH TO, EXPERIENCE OF AND ATTITUDES TOWARDS MATHEMATICAL MODELLING

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Abstract–This paper interrogates the thinking and planning strategies of Mathematics student teachers, when faced with a mathematical modelling challenge for the very first time. Mathematical modelling is the process of generating mathematical representations in attempting to solve real life problems. Modelling has the proven ability to develop learners' reasoning, communication and problem solving competencies. Literature cautions against the unpreparedness of Mathematics teachers in teaching modelling to learners. The second aim of the Curriculum and Assessment Policy Statement (CAPS, 2011, p. 8) emphasises mathematical modelling as "…an important focal point of the curriculum. Real life problems should be incorporated into all sections whenever appropriate." A traditional textbook problem was converted into a modelling task and eight groups of third year mathematics student teachers at the University of Johannesburg were confronted with this challenge. The groups' strategies, nature of engagement and proposed solutions were monitored, while their attitudes towards the teaching of mathematical modelling were also researched. The aforementioned richly contributed to guidelines aimed at the effective integration of modelling into the new mathematics curriculum and into the formal education of mathematics teachers.

Keywords: Mathematical modelling; Problem solving; Attitudes towards mathematics; Mathematics teacher education.

1. BACKGROUND CONTEXT AND PURPOSE

Fennema and Franke (1992) accentuate four components of mathematics teachers' knowledge, namely knowledge of mathematics, of mathematical representations, of students and of teaching and decision making. The first two components, according to Shulman (1986), emphasise mathematical content knowledge (MCK) and the last two components pedagogical content knowledge (PCK). Although a profound understanding of MCK is essential, it is regarded as insufficient in effectively teaching mathematics (Turnuklu & Yesildere, 2007).

Mathematical concept formation and learning initially depend on the classroom environment and learner activities, with teachers' attitudes, knowledge, judgements and beliefs heavily impacting on this. "It has become an accepted view that it is the [mathematics] teacher's subjective school-related knowledge that determines for the most part what happens in the classroom", confirms Chappman (2002, p. 177). Teacher attitudes and beliefs about mathematics are a vital part of their subjective and pedagogical knowledge (Opt't Eynde, De Corte & Verschaffel, 2002). Teacher education programmes therefore have a huge role to play in steering and shaping prospective teacher beliefs and attitudes in an appropriate manner.

Authentic problem solving is increasingly used to great effect in enhancing learners' mathematical competencies and mathematics teachers' PCK and MCK (Buchholtz & Mesrogli, 2013). What's especially comforting is that the relationship between mathematical modelling and authentic learning has been proven (Kang & Noh, 2012). Modelling has been incorporated into schools' mathematics curricula of several countries, expecting mathematics teachers and learners to operate in a "culture of mathematising as a practice" (Bauersfeld (1993), in Stillman, Kaiser, Blum & Brown, 2013, p. 9). It is now also a theme of South Africa's Curriculum and Assessment Policy Statement (CAPS, 2011) for mathematics, geared at the Further Education and Training (FET) phase.

The second aim of the curriculum statement (CAPS, 2011, p. 8) specifies as follows: "Mathematical modelling is an important focal point of the curriculum. Real life problems should be incorporated into all sections whenever appropriate. Contextual problems should include issues relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible". Julie (2002) agrees that mathematical modelling let learners realise the relevance of mathematics as a subject.

Ng (2013) and Ikeda (2013) both caution against the unpreparedness of mathematics teachers in teaching modelling. They put forward pleas that mathematics student-teachers should be formally exposed to modelling tasks during their education. Not only should these prospective teachers eventually model modelling, but they should also be able to cultivate a climate conducive towards mathematical modelling in their classrooms.

The *first goal* of this study is to identify and analyse the thinking and planning strategies of third year mathematics student-teachers, who are exposed to and involved in a mathematical modelling activity. The *second goal* is to explore these student-teachers' experiences of and attitudes towards the aforementioned. The authors intend to deduce a set of guidelines aimed at the effective integration of mathematical modelling into the pre-service education of Grade 10-12 mathematics teachers.

2. LITERATURE PERSPECTIVES: MATHEMATICAL MODELLING AND ITS DIVIDENDS

2.1. Theoretical framework

There continues to be much disagreement about the potential influence that teacher education has on teacher learning (compare Boaler, 2000; Lampert, 2001 and others). Some critics question whether teachers learn anything of value in their pre-service education programs, while others claim that the effects of these programs have been nullified once teachers enter more conventional school settings. The authors of this paper are of the opinion and assume that the pre-service education of mathematics teachers, especially in the current South African school context, has a fundamental influence on their practices, beliefs, attitudes and early effectiveness. It is of course not the only aspect that shapes their role as mathematics teachers, but it has a vital initial influence.

Aligned with the abovementioned assumption, the theoretical framework that underlies this inquiry relates to two complementary sets of literature perspectives. The first set of underlying perspectives is the Learning to Teach Secondary Mathematics (LTSM) framework (Peressini, Borko, Romagnano, Knuth and Willis, 2004, p. 68). This framework views learning-to-teach activities and processes in mathematics through a situative lens, based on two assertions. The first claim is that *how* a learner acquires a particular set of knowledge and skills and the specific teaching context (*situation*) in which it happens fundamentally influence what is eventually learned (Greeno, Collins and Resnick, 1996). The second claim is that teachers' knowledge, beliefs and attitudes interact with teaching-learning situations, implying, in the words of Adler (2000, p. 37) that mathematics teacher education is "…usefully understood as a process of increasing participation in the practice of teaching, and through this participation, a process of becoming knowledgeable in and about teaching".

The second set of underlying perspectives is underscored by the Vygotskian idea of the Zone of Proximal Development (ZPD), originally defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1986, p. 86). Chaiklin (2003, p. 40) summarises the core message of Vygotsky's ZPD with what learners are able to do via collaborative support today, they should be able to do independently tomorrow.

For the purpose of this paper, the three assumptions underlying ZPD particularly appeal to the authors, since they align well to the purpose and methods of this research on mathematical modelling. Chaiklin (2003, pp. 40-41) highlights them as the "generality assumption" (the ZPD is applicable to learning in all subject domains), the "assistance assumption" (learning is enhanced by the support of a more competent 'other'), and the "potential assumption" (learners usually display 'built-in' developmental properties and an 'automatic' readiness to learn).

The *Learning to Teach Secondary Mathematics* (LTSM) framework and the *Zone of Proximal Development* (ZPD), in their combination, serve as the theoretical lenses through which this specific study is viewed.

2.2. Conceptualising model, modelling and mathematical modelling

A model is a visualisation of something that cannot be directly observed via a description or a resemblance (Kang & Noh, 2012). Lesh and Doerr (2003) regard models as theoretical or conceptual systems that are used in an abstract form for a specific purpose. Models are social initiatives and should be reusable in different situations (Greer, 1997). Whereas the end-product is known as a *model*, the cognitive activities preceding it, which involve and require reasoning can be labelled as *modelling*.

Modelling is a cyclical process involving (1) the creation of a provisional model, which stems from (2) a series of interactive activities, which should be (3) continually tested and refined in order to improve or verify it (Kang & Noh, 2012). The modelling process can, at any stage, incorporate various forms of language, like computer programmes, sketches, drawings, tables, spreadsheets, and others.

Aligned to the abovementioned, *mathematical modelling* is the process of generating mathematical representations in attempting to solve real life problems (English, Fox & Watters, 2005; Greer 1997; Ikeda, 2013). A mathematical modelling process (cycle) consists of four sequential phases (Balakrishnan, Yen & Goh, 2010, p. 237-257), namely "mathematisation" (representing a real-world problem mathematically), "working with mathematics" (using appropriate mathematics to solve the problem), "interpretation" (making sense of the solution in terms of its relevance and appropriateness to the real-world situation) and "reflection" (examining the assumptions and subsequent limitations of the suggested solution). These representations are then validated, applied and continuously refined (Ang, 2010).

2.3. Three levels of modelling tasks

The International Community for the Teaching of Mathematical Modelling and Applications (ICTMA, in Stillman, Gailbrath, Brown & Edwards, 2007, p. 689), fittingly distinguishes mathematics applications from modelling. Applications attempt to link mathematics to reality: "*Where can I use this particular piece of mathematical knowledge?*". Mathematical modelling tasks focus on the antithesis, linking reality to mathematics: "*Where can I find some mathematics to help me with this problem?*"

Galbraith and Clatworthy (1990), later supported by Kang & Noh (2012), acknowledge three different levels of mathematical modelling tasks. Traditional problem solving fits the description of a so-called level 1-problem. Such problems are already carefully defined, no additional data is required to formulate a model and the problems require specific mathematical procedures. Problems at level 2 have a slight vagueness as insufficient information needed to successfully complete the task is given. Level 3-problems are the most authentic and open-ended type, characterised by unstructuredness and a challenging level of complexity (Ng, 2013).

2.4 The dividends and necessity of mathematical modelling exposure

It was rationalised and deduced (in Section 1 above) that:

Teacher education programs play an important role in steering and shaping prospective teacher beliefs and attitudes in an appropriate manner.

Authentic problem solving can be used to great effect to enhance learners' mathematical competencies and teachers' PCK and MCK.

A strong positive relationship exists between mathematical modelling and authentic learning.

Mathematics teachers (worldwide) are generally underprepared to teach modelling and student-teachers should be exposed to the topic during their education.

Modelling is since 2011 a prescribed theme in the CAPS document. According to the National Curriculum and Assessment Policy Statement Grades R-12 (2012, p. 6), two essential abilities that mathematics learners should gradually develop are to "identify and solve problems and make decisions using critical and creative thinking", and "to demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation". Suitable modelling tasks are exactly the kind of exposure that learners nowadays require to empower them in striving to attain the two aforementioned CAPS ideals.

Research in Singapore (Ng, 2013) and South Africa (Julie, 2002) reveal that teachers' lack of prior experience in problem solving and their (sometimes too conventional) beliefs about mathematics are major obstacles, when they are exposed to modelling activities. "The teachers generally perceive mathematics to be formula-based involving linear track solutions", remarks Ng (2013, p. 346), implying that they are mostly severely challenged by the open-endedness of modelling.

In this regard teacher education programmes have a prominent responsibility to fulfil. Julie (2002, p. 7), supported earlier by Kang & Noh (2012), phrases it in the following manner:

There is no doubt that this realisation can only be effected through mathematics teacher education programmes which, in addition to developing mathematical modelling pedagogical content knowledge, aim at developing mathematical modelling as content. After all, it is during the engagement with mathematical modelling as content that windows of opportunities are opened for dealing with relevance relevantly.

3. RESEARCH DESIGN AND DATA COLLECTION

3.1 Research paradigms and methods

The research paradigm refers to the researchers' worldviews, as reflected in a matrix of beliefs, perceptions and underlying assumptions (Foucault, 1972), which guided them in approaching the research problem. The paradigm influenced the researchers' decisions regarding the data collection instruments, selection of participants and methods of analyses, among others. Alongside the positivist, post-positivist, critical theory and pragmatist worldviews, the constructivist-interpretivist approach (Giacobbi, Poczwardowski & Hager, 2005; Onwuegbuzie & Leech, 2005) was chosen as primary research paradigm underlying this study.

The inquiry aims to understand participants' experiences of, attitudes towards and perspectives on the personal and group dynamics that are forged during their exposure to and involvement in a mathematical modelling activity. The chosen paradigm enabled the researchers to collect data on the lived experiences of the participants, via their individual and/or shared exposure to and involvement in problem-solving activities (Charmaz & Mitchell, 1996; Cresswell, 2009).

Besides the qualitative constructivist/interpretive approach, the inquiry also incorporates a quantitative dimension. This dimension relates to an attempt to measure participants' attitudes towards the mathematical modelling activity, as well as towards the subject mathematics. It was conducted from a post-positivist stance (Heppner & Heppner, 2004), which presumes that an external reality exists independent from the researchers, and although this reality cannot be known fully, attempts at measuring it would be possible.

3.2 The mathematical modelling experiment

In striving to realise the goals an in-class experiment was conducted during the last week of the first semester of 2014. The experiment was carefully planned and modelled on a similar pilot study, involving 48 mathematics teachers and 57 mathematics student teachers, conducted just more than a decade ago in 2003 at the Nanyang Technological University in Singapore (Ng, 2013, pp. 339-349). Thirty-eight (38) third year Mathematics student-teachers, in more or less even sized-groups, were exposed to a mathematical modelling activity, during which their own views of their group's problem-solving strategies were collected. Afterwards, data in respect of their lived experiences and attitudes towards mathematics and mathematical modelling were also gained. The experiment was conducted in a one hour 50 minutes contact session during the scheduled Mathematics time slot on the timetable.

The participants had little formal mathematics teaching experience - approximately five weeks of school practice in total through the two and a half years of their studies so far. They have also never been exposed to modelling tasks before, and neither to the teaching of such tasks. Care was taken to divide them into eight relatively comparable groups, each containing four to six members, based on their performance in the 3rd year Mathematics course. Proportional stratified sampling was employed to randomly assign them to the groups, in such a way that each group at least had a high(er), a moderate and a low(er) achiever.

The session kicked off with a 20 minute presentation (by one of the researchers) on the goal and nature of the research and experiment. The inclusion of mathematical modelling in CAPS, what modelling entails, phases of a typical modelling cycle (as outlined in section 2.2 above) and the ethical measures taken to safeguard the confidentiality of collected data and the anonymity of each participant, were the main components of the presentation. Individual written participant consent was obtained, also in respect of their feedback, the day after the experiment.

The selected modelling task on "Traffic flow" (Stewart, Redlin & Watson, 2012, p. 661) was an adaption of one of their textbook problems. The task can be categorised as a level three challenge (compare section 2.3), typified as open-ended and incomplete. It involves data collected by a city's Traffic Department on traffic flow in a busy section of the city's street network. Participants were requested to recommend the best location for a Day Care Centre for toddlers to the Department of Town and Regional Planning, based on the traffic flow data provided.

Taking into account the complexity of the task, the inexperience of the student teachers (as modellers) and the relatively limited interaction time, groups were not expected to come up with well-defined solutions to this real-world problem, nor to provide their views on the representativity, validity and applicability of their 'answers'. Groups were merely required to report on the strategies and methods that they employed. The experiment and group interactions were carefully monitored by the researchers and each group recorded their strategies, processes and suggested solutions on a predesigned worksheet.

The researchers initially also planned that each group should critique their suggested solutions, based on three generally accepted criteria of Ng (2013, p. 342), namely *representation* (how well their suggested solutions solve the problem), *validity* (suggestions on how to improve their solutions) and *applicability* (whether their solutions can be used in other contexts). As the experiment unfolded, it was realised that the aforementioned was definitely a bridge too far.

3.3 Collection and analysis of data on participants' demographics, experiences and attitudes

The day after the experiment (described in section 3.2 above), during the last contact session of the first semester, individual participant feedback was collected. A self-designed questionnaire was used for this purpose.

3.3.1 Demographical data

Section A of the questionnaire's contains a number of demographical items (gender, ethnical group, home language, age and Gr 12 performance in Mathematics), enabling the researchers to construct a participant profile. The last two items of the section gained information on participants' exposure to mathematics in their Gr 12 year and the main reason(s) underlying their decision to study towards becoming mathematics teachers. Collected data were captured in a Microsoft Excel worksheet and then analysed via the frequencies and descriptive statistics options of the Statistical Package for the Social Sciences (SPSS, version 22).

3.3.2 Participants' attitudes towards mathematics as subject

The Attitudes Towards Mathematics Inventory (ATMI, Tapia & Marsh, 2004) is an internationally recognised instrument, used for gaining learner attitudes towards Mathematics as subject.

Schackow (2005) tailored the ATMI towards mathematics student- and practising teachers, making it appropriate for this study. The ATMI has four underlying dimensions, namely *value* (whether mathematical skills are worthwhile and necessary), *enjoyment* (whether mathematical problem-solving and challenges are enjoyable), *self-confidence* (expectations about doing well and how easily mathematics is mastered, or not) and *motivation* (the desire to learn more about mathematics and to teach it). Only two ATMI dimensions, enjoyment (ten items) and self-confidence (15 items), were incorporated into the questionnaire (Section B). Each of the 25 items uses a Likert-type response scale, ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*). All item responses in each dimension are added, yielding total scores for the enjoyment (maximum 50) and self-confidence (maximum 75) dimensions. Analysis of ATMI data, including validity and reliability measures, were also performed via the Statistical Package for the Social Sciences (SPSS, version 22).

3.3.3 Participants' perceptions of mathematical modelling

Section C of the questionnaire focusses on participants experiences of and current attitudes towards mathematical modelling. All four questions were open-ended. The final question collected concrete suggestions from participants on how they might be supported during their education in becoming more effective modellers and teachers of modelling.

Individual feedback per question was consolidated into a worksheet and hence analysed via the constant comparative method (Jacobs and Du Toit, 2006:305-306), as a directed form of content analysis (Hsieh and Shannon, 2005:1281). Appropriate participant views per category, by quoting their direct words, are integrated in the findings.

3.3.4 Trustworthiness, validity and reliability

Strategies to maintain the *trustworthiness* of the experiment included selected credibility, transferability, dependability and confirmability measures, originally prescribed by Lincoln and Guba (1985). A thorough description of the experiment, its planning and implementation, the properties of the participants and the data collection instrument and methods enhances transferability. A dense description of the methodology employed in the constant comparative and directed content analysis methods promotes dependability and rigour. The credibility of the research is augmented through a proper interrogation and triangulation of the findings by both researchers, while the original records were maintained for follow-up purposes.

The creators of the Attitudes Towards Mathematics Inventory (ATMI), Tapia and Marsh (2004, p. 18-19) report that the survey shows a high degree of internal consistency (Cronbach's alpha was in the region of .88), while its factor structure "…covers the domain of attitudes towards mathematics, providing evidence of content validity". The researchers conducted a pilot study (involving three third year mathematics students, who weren't participants) on the questionnaire, confirming its perceived sight *validity*. Three Cronbach's alpha coefficients were hence calculated in respect of the two ATMI dimensions, Enjoyment and Self-confidence, and the participants' total ATMI score (the sum of the two dimensions). The coefficients are portrayed in Table 1 below and confirm that the quantitative items of the questionnaire have high internal consistency (*reliability*).

Table 1: Reliability of the Attitudes Towards Mathematics Inventory (ATMI)

ATMI dimension	Cronbach's alpha
Enjoyment (7 items❶)	.745
Self-confidence (15 items)	.922
ATMI total (25 items)	.917

❶ The original Cronbach's alpha value was .718 for all ten items in the Enjoyment dimension, but after the removal of items 1, 2 and 10, the alpha value for the remaining seven items increased to .745

4. EMPIRICAL FINDINGS

4.1 Demographic profile of the participants

Table 2 (on the next page) displays elements of the demographics of the participants. The majority can be characterised as *male* (63%), *black* (76%), *indigenous language* speaking (74%), *23 years or younger* (61%), and having scored *60% or more* for Mathematics in matric (79%).

Participants' motivation to become mathematics teachers

Their responses to the question: '*What is the main reason(s) underlying your decision to become a mathematics teacher?*' indicate participants' intentions in sustaining their relationship with the subject mathematics. Main feedback categories are their interest in mathematics and the resulting curiosity and challenges it generates; the opportunity to make a difference to learners in disadvantaged communities, who lack good mathematics education; and to positively contribute to South Africa's' educational challenges.

4.2 Participants' attitudes towards mathematics as a subject

Sweeting (2011, p. 53-54) categorises teacher attitudes towards mathematics as subject (represented by their total ATMI score out of 200) on five levels, which she respectively labels as "strongly negative, negative, neutral, positive and strongly positive". Using her categorisation in this study, positive scores on the enjoyment dimension (maximum 50) would be *41 or more*. Likewise, corresponding scores on the self-confidence (maximum 75) dimension would be *61 or more*. A positive ATMI total (incorporating just the two dimensions – maximum 125) would be minimum *100*.

Table 3 (on the next page) provides a breakdown of the participants' ATMI scores. The researchers expected the majority of the participants (all of them studying to become mathematics teachers), to portray a positive disposition towards mathematics. Thirty-two of the 38 participants (84.2%) have a positive to strongly positive attitude in respect of their *enjoyment* of mathematics as a subject, while 28 (75.6%) disclosed a corresponding attitude in respect of their mathematics *self-confidence*.

Their *total* ATMI scores (on the two dimensions) unveiled a similar pattern, with the mean score of 109 (out of 125) sufficient reason to describe the group's attitude towards mathematics as positive to strongly positive. Although the ATMI is a self-rating survey (which is definitely a limiting factor), the strong relationship between a positive attitude towards and achievement in mathematics has been well documented in many studies (compare Brown, McNamara, Hanley & Jones, 1999; Dowker, Ashcraft & Krinzinger, 2012; Durandt & Jacobs (2013); Ismail & Anwang, 2009; Khatoon & Mahmood, 2010; Sweeting, 2011, and several others).

Table 2: Demographic profile elements of participants (n=38)

Profile variable		N	%
Gender	Female	13	34.2
	Male	24	63.2
	No response	1	2.6
Ethnic Group	Asian, incl. Indian	2	5.3
	Black	29	76.3
	Coloured	1	2.6
	White	6	15.8
Home Language	Afrikaans	3	7.9
	English	6	15.8
	Indigenous	28	73.7
	European	1	2.6
Age in years (Avg= 23.3 yrs)	Up to 21 years	10	26.3
	22 or 23 years	13	34.2
	24 to 26 years	11	28.9
	27 years and older	3	7.9
	No response	1	2.6
Math mark in Gr 12 (Median = 60-69%)	50 – 59%	7	18.4
	60 – 69%	12	31.6
	70 – 79%	8	21.1
	80% +	10	26.3
	No response	1	2.6

Table 3: Distributions of ATMI enjoyment, self-confidence and total scores

ATMI dimension		N	%
Enjoyment (Mean = 44.7)	46–50	13	34.2
	41–45	19	50.0
	36–40	6	15.8
Self-confidence (Mean = 64.3)	68–75	12	32.4
	61–67	16	43.2
	53–60	6	16.2
	52 and lower	3	8.1
Total ATMI score (Mean = 109.0)	113–125	13	35.1
	100–112	18	48.6
	87–99	5	13.5
	75–86	1	2.7

Group strategies and proposed solutions to the modelling challenge

4.4.1 Solution styles and complications

All eight groups succeeded in representing the real-world problem mathematically. Five groups used more than one style to present the data in a mathematical context. All eight groups made use of graphical illustrations, one group adding a histogram, two groups a double bar graph and three groups a two-way table.

Most groups experienced difficulty in introducing variables and in matching them to unknown quantities. Initially, the majority of groups introduced two variables, one for the number of cars entering and another for the number of cars leaving the city's street network. They later realised that the number of cars entering an intersection (from various directions) must equal the number of cars leaving that intersection. In setting up their mathematical models, four variables (for example x, y, w and z) were required. The variables represent the number of cars (from all four directions) traveling along a specific street. Most groups felt unfamiliar working with four variables.

The researchers had to intervene and guide most groups in setting up a first and even a second mathematical equation. Thereafter, all groups could formulate the third and fourth equation. Four of the groups attempted to solve the system of linear equations. Only one group eventually provided a probable solution, while another group introduced a more sophisticated mathematical strategy, involving matrices.

4.4.2 Task interpretations

An interrogation of their submitted worksheets revealed that half of the groups made a recommendation as to the most appropriate location of the Day Care Centre. One group argued in favour of the intersection with the highest traffic flow (being more convenient for working parents), while two groups supported exactly the opposite (an intersection with the lowest traffic volume). Another group juxtapositioned convenience (for parents) versus safety (for toddlers) and thus recommended a medium busy intersection. Only three groups found time to critique their solutions (models) and also made suggestions to improve their own models. In the researchers' opinion, the open-ended nature of the modelling task was perhaps the biggest challenge to the participants.

Participants' experiences and suggestions to enhance their modelling skills

The participants provided feedback on their lived experiences of the modelling experiment and also made suggestions that could enhance their abilities to implement mathematical modelling tasks.

Their experiences were dominated by the overwhelming open-ended nature of the modelling problem and its consequential challenges. Participants reported that group members struggled to agree on an idea and to get everyone's point of view across. As a result the groups found it extremely difficult to construct mathematical equations to represent task contains. Even after formulating and attempting to solve the equations (as reported in 4.4.1), the interpretation of their findings was confusing as some participants were not convinced about their validity. Participants' feelings and attitudes toward mathematical modelling fluctuate from extremely negative to tremendously positive. Besides the challenging nature of the task, participants acknowledged the opportunity to experience mathematics in the real-world.

A number of suggestions to assist pre-service mathematics teachers in becoming good modellers and effective modelling teachers were made. The crux of their suggestions revolves around the provision of guidelines on how to approach mathematical modelling problems, more frequent exposure to modelling activities (and to examples with their solutions), more group work opportunities, more time on tasks and the challenge to present a lesson on mathematical modelling.

5. CONCLUSION

The literature is filled with references to the positive relationship between mathematical modelling and authentic learning. The theme of modelling is since 2011 a theme in South Africa's Curriculum and Assessment Policy Statement for the Further Education and Training phase.

The underpreparedness of mathematics teachers to teach, but also to grasp modelling is a global phenomenon. Several calls for the exposure of mathematics student-teachers to modelling tasks during their education are made. Not only are prospective mathematics teachers expected to model mathematical modelling, but they should also be able to cultivate a climate conducive towards modelling in their classrooms.

In this inquiry, a group of third year Mathematics student-teachers was exposed to a mathematical modelling activity, thereafter their experiences were explored. The study revealed that it was not only a very challenging ordeal for the participants, but that it was indeed very difficult for them to link the 'world out there' (reality) to the mathematics of the classroom. The question, '*Where can I find appropriate mathematics to help me solve this problem*?' encapsulates their predicament.

However, although this first 'taste' of modelling might have been extremely perplexing, it was also thought-provoking, inspiring and motivational for them. Their feedback suggests that they 'want more', although they realise that 'it won't come easy'.

In preparing prospective mathematics teachers more optimally to grasp and also to teach modelling, several suggestions were made by the participants. The researchers have no doubt in their minds that (based upon the study's theoretical framework) mathematics student-teachers should formally acquire modelling knowledge and skills during their education. This should ideally happen in teaching contexts (situations), which let them experience for themselves that mathematics teaching isn't a formula-dependent, linear-track endeavour, but indeed much more authentic, open-ended and even thrilling.

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MATHEMATICS STUDENT-TEACHERS' EXPERIENCES OF MENTORING AT A TEACHING SCHOOL IN SOUTH AFRICA

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Abstract–This paper addresses mathematics student-teachers experiences of mentoring at a teaching school (TS) in South Africa. The research question was: What are post-graduate certificate in education (PGCE) mathematics student-teachers' experiences of mentoring at a TS? A case study using a qualitative research design was adopted with three data collection methods, namely interviews, lesson design analyses and reflection reports. From the population of 15 PGCE mathematics student-teachers, a sample of five was purposefully selected. The findings indicate that student-teachers acknowledged their responsibilities with regard to the effectiveness of learning. They experienced problems with time-management pacing them when presenting lessons and found the use of the resources challenging. Student-teachers started valuing reflection and considered classroom management important. They considered administration as part of a teacher's job and acknowledged that the environment of the TS contributed to their growth. The article adds to research on the role of TSs in South Africa.

Key-words: Teaching school (TS); mentoring; student-teachers; relational; developmental; contextual.

1.1 INTRODUCTION

In April 2011, the South African Department of Education (DoE) released a technical report, Integrated Strategic Planning Framework for Teacher Education and Development in South Africa for 2011-2025 highlighting challenges being experienced in teacher education and development, especially by teachers. Only 13.1% of the 2650 education students in the senior phase at higher education institutes and 12.1% of the 5 899 education students in the further education and training (FET) registered for Mathematics at all higher education institutions in South Africa in 2009, even though the need profile was 49% and 21% respectively (DoE, 2011, p.52). Other challenges include a lack of access to quality teacher education and development (TED) opportunities for prospective and practising teachers; a mismatch between the provision of and demand for teachers of particular types; the failure of the system to achieve dramatic improvement in the quality of teaching and learning in schools; a fragmented and uncoordinated approach to TED; the tenuous involvement of teachers, their organisations and other role-players in TED planning; and inefficient and poorly monitored funding mechanisms. In order to meet these challenges, this report's main outcome was to set guidelines in improving the quality of teacher education and development in order to improve the quality of teaching. In particular, the aims were to define "innovative, collaborative relationships among the key stakeholders for the improvement of teacher development"; to make "institutional arrangements for the delivery of key components of teacher development, such as teacher education"; to establish "a network of viable, accessible Teacher Education Institutions (TEIs) [and] Teaching Schools" (DoE, 2011, p. 3); and to address the "imbalance between the current registration profile and the needs profile" (DoE, 2011, p.66).

In order to improve the quality of teachers and teaching of South Africa it is important to draw on the experiences of other countries (DoE, 2011, p.5)), in particular the Finnish education system, one of the best performing education providers in the world. According to the PISA international testing program, this system's had a ranking of 2 in a Mathematics literacy test in 2006 (Tuovinen, 2008). They conduct methodologies and practice teaching throughout the entire duration of the teacher education programme within TSs, which are "organically linked with the departments of education of the university" (DoE, 2011, p.111). However, post-graduate certificate in education (PGCE) student- teacher training at the University of Johannesburg is delivered in a highly theoretical mode, while work integrated learning (WIL) is only occurring in short block periods during the year, namely three weeks in the first semester (March) and seven weeks in the second semester (August-September). Hence, the university has the responsibility for ensuring that their education programme is accessible to aspirant teachers, is of high quality and leads to meaningful development for teachers. In particular, the university will need to "implement innovative mechanisms to strengthen the work integrated learning component of their teacher education programme, e.g. through the effective use … of teaching schools" (DoE, 2011, p.3)

Against this background, the University of Johannesburg was approached by the DoE to conduct a broader study on the establishment of TSs in South Africa. In particular, this paper focusses on a pilot study toward the broader study, namely to examine the experiences of mathematics student-teachers with regard to mentoring at a TS school in South Africa, so as to explore the relational, developmental and contextual dimensions. The question arising from the above is thus: *What are post-graduate certificate in education (PGCE) mathematics student-teachers' experiences of mentoring at a TS?* Hence, a literature inquiry with regard to three dimensions of mentoring, namely relational, developmental and contextual dimensions was conducted.

1.2 MENTORING IN A TS

TSs are "schools in which a major part of student pedagogical practice is conducted are linked organically with the departments of education" (Moon, Vlasceanu, & Barrows, 2003, p.89). In particular, TSs are local schools consisting of supervising teachers contracted by universities to specialise in the supervision of student-teachers, by guiding teaching practice, develop pedagogy and curriculum planning. These schools integrate teaching practice into all levels of teacher education time, thus integrating theoretical studies and practice from the beginning to the end of a student-teacher's studies. In particular, TSs are teaching laboratories, where student-teachers can engage in learning-from-practice, such as by observing best practice, participating in micro-teaching exercises and taking subject methodology courses.

Beyene, Anglin, Sanchez and Ballou (2002, p.87) argue that "definitions of mentoring range from the simple and romantic images of Greek mythology's Mentor to the complex, multivariate processes of structured human interaction within institutional contexts". In particular, Donaldson, Ensher and Grant-Vallone (2000) view mentoring as a one-on-one, lasting relationship between a more knowledgeable person and a less knowledgeable person fostering professional development. According to Hyde and Edwards (2013, p.2) "the guidance, support and wise advice of a mentor is vital in providing pre-service teachers with appropriate learning experiences so that they develop effective skills as teachers of mathematics". In this paper mentoring refers to the developing assistance and care of an experienced mathematics teacher to an unexperienced mathematics PGCE student-teacher.

Lai (2010) reviewed literature and has found that mentoring is conceptualised with respect to its relational, developmental and contextual dimensions as indicated in diagram 1.

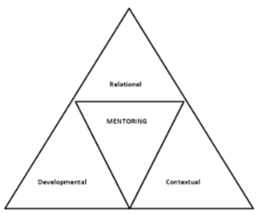

Diagram 1: Dimensions of mentoring

These dimensions form the conceptual framework of this paper. The relational dimension is the "mutually beneficial relationship in which both the mentor and the protigi grow as a result of their relational connection" (Beyene et al., 2002, p.87), thus, the relationship between the mentor and the mentee. According to Beyene et al. (2002) two qualities are central to all relationships, namely empathy and mutuality. In addition, the conception of mentoring emphasises the role of a mentor as emotional supporter and critical friend (Bradbury, 2010). Furthermore, Ensher and Murphy (2011) mention three factors impacting on the relational dimension of mentoring, namely commitment, measuring up to a mentor's standards and career goal.

The developmental dimension of mentoring focuses on the mentoring roles aiming to develop student-teachers professionally and personally (Lai, 2010). Here, firstly, the developmental level of the novice teacher is recognised by the mentor who then shifts the novice towards a higher level of development (Wang & Odell, 2002). This does invoke the notion of scaffolding that emerged from socio-constructivist views of learning, especially Vygotsky's (1978) notion of learning in the zone of proximal development (ZPD).

The contextual dimension focuses on cultural and situational features of the mentoring setting. It recognises the powerful influence of the school organisation and culture of teacher learning. According to Feiman-Nemser (2003, p.25) the mentoring of new teachers involves a process of surrounding "new teachers with a professional culture that supports teacher learning", thus enculturation, in which they are helped to fit into a particular school community.

1.3. RESEARCH METHODOLOGY

1.3.1. Research design

Vandeyar (2010, p.87) noted social investigations are bound in the "consideration of how certain phenomena or forms of knowledge are achieved by people in action", which convinced me to adopt a social constructivism theoretical paradigm. Moreover, this paradigm can be tailored to an investigation of how Mathematics student-teachers' experience mentoring at a TS, and the way in which these perceptions inform and shape their development as future teachers.

A case study design using a qualitative method research design was adopted for the study. This design is suitable for people's ideas and experiences are used in order to understand the world under investigation (Rowley, 2002). In particular, case studies allow for the exploration of multidimensional aspects using a comprehensive inquiry (Baxter & Jack, 2008). Furthermore, case studies allow for the use of a collection of evidence from various sources, such as interviews, lesson plans, observations and reflection reports (Rowley, 2002). I established student-teachers' experiences regarding mentoring at a TS qualitatively through interviews, lesson design analyses and reflection reports.

1.3.2. Sample

A purposeful sampling technique (Creswell, 2003) was used to select five mathematics student-teachers from a population of 15 enrolled PGCE mathematics student-teachers at a university in South Africa. Criterion sampling was utilised (Palys, 2008). The TS was chosen for it is approximately 5 km away from the university and allow easy access to students between the university and the TS. All mathematics students enrolled for full-time studies in the PGCE course, which were only five students, were selected. Participation was voluntary, consent was obtained and the anonymity of the participants was protected (Mouton, 2001).

1.3.3. Data collection: interviews, lesson design analyses and reflection reports

One-on-one semi-structured interviews were conducted before the start of the piloting project and after the conclusion of the project. The purpose was to determine mathematics student-teachers' viewpoints on mentoring regarding the relational, developmental and contextual dimensions before and after mentoring. Student-teachers participated voluntarily. Furthermore, lesson designs submitted to mentor-teachers, as well as 11 weekly written reflection reports by the student-teachers, were collected.

1.3.4 Data Analyses

Tesch's protocol of data-analysis (Creswell, 1994) to analyse the data from the one-on-one semi-structured interviews, lesson designs and reflection reports was used. Firstly, the interview was audio-recorded and transcribed. Secondly, the transcriptions were read to obtain a holistic perspective, after which relevant answers were separated from irrelevant answers. Thereafter, Saldana's (2009) method of coding was used, a "heuristic exploratory problem-solving technique without specific formulas to follow" (p.8), where a code in qualitative inquiry refers to a "word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (p. 3). In particular open and axial coding was used. Axial coding "relates categories to subcategories and specifies the properties and dimensions of a category" (Saldana, 2009, p.159). After coding was applied to the data, codes sharing the same characteristics were grouped into sub-themes and grouped together to form the themes (Saldana, 2009). Table 1 represents the themes, sub-themes and codes emerging from the qualitative analysis.

Table 1: Themes, sub-themes and codes

Themes	Sub-themes	Codes
Relational dimension	Caring and nurturing	Caring Teacher's understanding Nurture Observation passion
	Critical emotional support	Support Communication Available Age/Emotional support
	Collaborating within a community of practice	Engagement COP
Developmental dimension	Developing pedagogical thinking	Lesson plan PCK Solutions to problems Solving of problems Methods of teaching Other methods Methodology Higher order questions Assessment planning vs. preparation perception Teaching – conducting lessons
	Inquiry-oriented teachers	Inquiry-based learning Heuristic approach
	Reflecting on practice	Reflection Steps in lesson plan
	Evidence –based practice	Evidence-based practice Resources Content knowledge Knowledge of the syllabus Nature of Maths time allocation evaluation
	Conceptualise everyday phenomena	focus on concepts Conceptualisation
	Scaffolding	Scaffolding guidance
Contextual dimension	Enculturation into the school culture Administration Professionalism Time management Classroom management Discipline Preparation	Enculturation School culture Professionalism Punctuality Time management Too many examples Honesty Preparation Administration Documents Code of conduct Discipline Respect Relation with learners

		Classroom management checking of homework Discipline system Accountability Planning dress code behaviour morals
	Cultural features of setting	Culture Religion Cultural features of setting
	Situational features of setting	Situational features Contextual Intervention Timeframes Classroom environment

1.4 ETHICAL CONSIDERATIONS

The ethical committee of the Faculty of Education of the University granted ethical clearance for the study and permission was obtained from the participating TS to conduct the research.

1.5. RELIABILITY, VALIDITY AND TRUSTWORTHINESS

Qualitative rigour was ensured through a careful consideration of all the elements of trustworthiness. The data was verified by means of data saturation and crystallisation, which allowed for new facets to emerge from the data. Sufficient data sources ensured internal validity or "Truth Value" (Guba, 1981, p.80). Trustworthiness is further enhanced through a repeat of interviews and reflection reports. The research questions, as outlined in the introduction of the study, were used as a framework for the development of the interview questions used in the study. The research questions were broken down into smaller, more appropriate conceptual ideas and these became the concepts to be explored. In this way, the validity of the interview questions is ensured because it is testing the conceptual ideas, which form the basis of the study. To ensure face and content validity, the interview questions were shown to colleagues for comments and responses, to ensure that the constructs were clearly conceptualised. Consequently, the interview questions were amended with regard to terminology and clarity.

1.6. MAIN FINDINGS

The findings from the pre- and post-interviews, lesson design analyses and reflection reports reveal how student teachers experienced mentoring at the TS. In the following protocols the names of the learners are pseudonyms to protect their identity. All the protocols are from the pre-interviews conducted on Saturday, 23 February 2013; post-interviews conducted on Tuesday, 13 August 2013; lesson designs collected on 25 April 2013 – 23 May 2013; and written reflection reports submitted on 28 February 2013 – 15 August 2013.

1.6.1 Findings from the analysis with regard to the relational dimension

Before the start of the pilot project, student-teachers' perceptions on mathematics teaching were that teachers do not have the responsibility to teach learners. Learners should "go out and to do problems [them]selves and come and ask if [they] encounter problems" (Isaac). In the post-interviews, after the TS school project was completed, student-teachers' views have changed on mathematics teaching. Isaac realised that "I thought teaching math's was going to be very easy no challenges just put the equation on the board and I found it to be way more than that" Tshepo also realised that "as a teacher I have so much responsibility, for the learning to be effective … I realised this it's up to me whether the class is going to be effective or not … you must know that you are at work you must do your work that's why you are there".

Before commencement of the teaching project, Fiona held the perception on barriers in mathematics teaching that "maths … its difficult", while Fay viewed "the lack of understanding of the learners" as a barrier in Mathematics teaching. At the end of the project, student-teachers viewed barriers in mathematics teaching from their own experiences, which indicate that they started reflecting. Tshepo found it difficult to relate some mathematics concepts with real life, as she noted that

> "Some of the mathematics concepts you cannot relate them to daily life you have to think hard, what I can include so that they can grasp this thing. It's very difficult sometimes like some of them you don't know what to compare with it with solving for X. Sometimes it becomes very difficult and frustrating"

Dina argued that learners find the understanding of mathematical language difficult if their mother tongue language differs from the language of instruction. According to her "they find it difficult to understand the mathematical language because of their poor … fluency in English". Fiona also felt that language is a barrier, especially the way in which it is used by textbooks. She noted that "the way some textbooks are written … language to a certain level is getting deconstructed and so maybe now once you deal with concepts".

Student-teachers developed self-confidence. Fay noted that "I find myself being more confident to be a teacher than before I went for that practice". Also, Dina realised that "when you are well prepared you feel confident in front of the learners and when you are confident it's easy to manage your class". However, Fay complained that "they should not feel that we are qualified teachers, we are not qualified already". The students were stressed, nervous and frustrated, as Dina reflected: "I was nervous which made me do some new errors while speaking and writing". Initially, student-teachers experienced mentoring as an additional burden, but eventually it changed, as Tshepo stated that "I no longer see this project as an extra job for me, because it help me with many thing like, I have realised my weakness and I am working on it and the mentor teacher is very helpful".

Student-teachers experienced the mentor teachers not only as caring and supportive, but also as role-models. According to Isaac the mentor teacher "is very fair ... she considers your problems if you talk". Tshepo noted that "the mentor-teacher is very friendly, empathetic warm, friendly and supportive". Dina added that "she is really caring because when she addresses us she does not address us as assistants or something like helpers. She refers to us as teachers". Fiona claimed that the mentor teachers are "supportive, friendly, they are welcoming". Fay also noticed that "she show care and kindness to her profession by making sure that every learner understands and follow up with the lesson". At the end Fiona confessed that "you start to care about what you are doing and now you also think about the learners when you do your work … it rubs off on you when you're there how the teachers do … you can see that they care about the work so yah it rubs off on you so it builds on you as a student".

Student-teachers indicated that they prefer to have face-to-face discussions with mentors, rather than e-mails. Tshepo complained that - "the obstacle is sending the lesson plan electronically; I wish to sit down and discuss the lesson plan face to face before I can give a lesson".

The student-teachers were willing to function in a community of practice. Dina mentioned that "I am willing to try any way by asking from others how to approach problems, how to go about solving them. I am going to be hands-on and open-minded to any suggestion". Isaac noted that "you pretty much blend in so you are pretty much part of the community". Student-teachers realised that they cannot work in isolation. Dina noticed that "as a teacher you are not working alone you have to communicate with other teachers from other classes". Student-teachers also have a sense of belonging at the school. Isaac noticed that "you belong to that group … You kind of immediately feel like part of the community".

1.6.2 Findings from the analysis with regard to the developmental dimension

Lesson plan presentation and conducting of lessons improved during the project. Fiona confessed that "I need to make sure that my work is proper in order for them to get the best out of it". She also noted later in the project that "regarding to lesson planning, preparing and conducting of lesson is that I am getting used to it, it is no longer difficult and frustrating like the first time I had to do it". Also, Fay commented that "in the aspect of planning a lesson, in production of the lesson and in completion of the lesson. I have really learnt a lot since I have started this program". The student-teachers realised the importance of preparation as Tshepo noted that "… you must be ready and prepared". Isaac added that "the planning, preparing and conducting has improved and is very interesting, there are a lot of things that I had taken for granted but, this experience is an eye opener". Fay viewed "planning as a building block of lesson presentation. There is an adage that says if you fail to plan, you plan to fail".

Student-teachers found the transferal of content knowledge challenging, but also realised the importance of PCK. Isaac mentioned that "you have to understand that we … just know content, the environment is a new story, delivering content to learners". Fiona also noted that "It's one thing to know it and then transferring it then getting to a place where the learners can also grasp it you know it's not always easy". Gradually, student-teachers realised that they should also utilise other methods, as Tshepo reflected after he conducted a lesson that "I forgot that I do not have to concentrate on one method, I can also introduce other methods". Isaac confessed that "I initially thought it was just about content knowledge but also meaning of that content to learners is required and that is a skill that requires sharpening over time". Fiona acknowledged "I didn't know that you give learners an activity to do but now I know when you are teaching, you give an activity to do". Dina confessed that "it takes time to develop a pedagogical content knowledge, so but it's something that you should work on it if you want to have a successful lesson plan". According to Fiona "practice still remains a key element in teaching so you need to give the children time to work through a lot of problems in order for them to grasp the concepts". She also noted that a teacher should "try to make the concepts less abstract more understandable for the students".

According to the student-teachers the mentor teachers are concerned about results and do not use learner-centered teaching approaches or encourage creativity. Isaac stated that the mentor teacher does "not encouraging creativity or brain activity to come with new ways of doing it". According to Dina "she is the one who is doing a lot of talking in the class, she does not really use the learner centered teaching approach". The school is concerned about their standard and their results. Tshepo believed that "the school is more concern of keeping the image of producing good results of 100% pass rate, so there is a limit creativity " She also noted that

> "at [the TS] I don't think they use the heuristic approach it's all about the standard of the school. So she always told us you must tell them everything they mustn't discover, they know nothing and they don't know how to discover things for themselves you must give all the information you can think of. This is how it must be done here so I thought that maybe because she always tell us that they are always getting a hundred percent so they are trying to keep the standard".

Student-teachers acknowledged the use of various resources, as Dina remarked "the thing I like about that school, it is well resourced. Tshepo acknowledged that "you must also find other textbooks in to find out other methods". Also, Fiona indicated

> "One issue for me during the lesson preparation was the classroom mathematics textbook. It was not easy to construct the lesson using the textbook only. The mentor was helpful in this regard since she created a worksheet that was used to facilitate the lesson. We also do have access to other resources at the university in terms of the internet".

However, student-teachers find the use of white boards challenging. Dina confessed that "some of the teaching materials like the white boards we are not use to it, it needs a lot of practice there". She also stated that "I did present one lesson on there, using PowerPoint, although it was my first time presenting a lesson on a PowerPoint but I did learn next time if I can do it I will do it better".

Student-teachers were lacking basic language skills. A challenge was that English is not their home language, as Isaac argued: "We are not really used to speaking English right. So sometimes I have to clarify … in another language … that is something that can be worked on, the matter of communicating" As a result, the student-teachers appreciated the way the mentor teacher communicates with the learners. According to Tshepo "she uses the question and conversation approach, because in that way she guides her learners how to get answers and information. I like the way how she communicates with the learners in the classroom when she teaches".

Even though the teachers did reflection sessions with student-teachers at the end of each day, the student-teachers did not value the importance of reflection in the beginning. Fay mentioned "after each and every lesson we'd sit down reflect on it talk about it positives and negatives, how did you feel about your lesson today it so that next time you don't do the very same thing … it's just that student-teachers might not actually agree to stay after school … at times I'd feel like she is too much maybe criticising my lesson then maybe you realise that it's necessary". However, later in the project student-teachers acknowledges the importance of reflection. "Having feedback sessions with the mentor, it definitely helps" according to Fiona. Gradually, student-teachers realised that they have to think on the spot. Tshepo commented:

"It made me realise that teaching is very challenging, it is not a small thing where you can say ok, I am going to teach the learners about x times x and expecting things. But you will be surprised to know that it is not everybody that understands what you are teaching. It made me realise it is all about you must think on the spot, it is very challenging".

Tshepo also commented that "teaching does not always proceed smoothly, it is a very challenging profession and it requires a teacher that think and reflect". Fay also realised that she has to reflect everyday as she noticed "by reading my notes I get a reflection on what the mentor teacher's thoughts after the day like she always give us what she did in the class. I get home, I read it, I reflect. Every day I reflect on what I have learnt that day". Tshepo noticed that "I must speak to my presentation. Speak to my lesson plan for the success of the lesson for that day". Dina realised that "we're also supposed to tell … her, to explain to her what happen here, why did this go wrong or what did you do to make this thing right". Eventually, she realised that "the process of designing a lesson plan force you to reflect on what you want to achieve in each class and how best you can do that". Tshepo concluded that

"It really helped to have a detailed plan because it made me visualise each class before I taught it. I imagined the flow from one activity to the next, made sure there was a balance of skills and types of activities, and anticipated places where we might detour from the lesson. Knowing what came next helped me avoid dead zones in class".

1.6.3. Findings from the analysis with regard to the contextual dimension

Student-teachers started realising professionalism includes responsibility and accountability, as Fay noted that "now [she has] to work and get up at 4 o'clock this morning to make sure I will be there". Tshepo also viewed "professionalism … that as a teacher I must be accountable for everything I do during my teaching years … it [is] my responsibility to plan and prepare each and every lesson … professional is that you will be respected and be seen as a responsible person by your co-workers and your work will run smoothly".

Student-teachers started implementing classroom management. Tshepo mentioned that "the way is to be firm in my class and to tell the learners what I want … I tried to … send the learners out of the class … If you talk in my class wait until the lesson is over before you can come back, they said I cannot do that". However, student-teachers found it difficult to manage discipline in the classroom. According to Dina "a challenge for me is classroom management whereby we find learners who are not behaving and you have to, you have to discipline them. So I think I am not very good on disciplining".

Student-teachers were exposed to administration and realised that "managing the paperwork is one of the toughest things a teacher has to do. Record keeping and administration is often time consuming and repetitive and many see it as detracting from the teacher's real purpose to teach" (Tshepo).

Student-teachers felt that they were enculturated into the school system. Isaac commented that "I was almost part of the class, the school culture I was almost part of it". Fiona also noted that "the culture there at the school they do care about the pupils".

Student-teachers acknowledged that the environment at the TS school contributed to their growth. Isaac commented that the school "grooms … the student teacher because it is so formal, it is academically inclined".

1.7. DISCUSSION AND CONCLUSION

A measure to address the challenges experienced in teacher education, as note in the Integrated Strategic Planning Framework for Teacher Education and Development in South Africa (DoE, 2011) is the establishment of TSs, as practiced by the Finnish education system, one of the best performing education providers in the world. Therefore, PGCE mathematics student- teachers of the university were exposed to a TS, as part of a pilot project, to "implement innovative mechanisms to strengthen the work integrated learning component of their teacher education programme" (DoE, 2011, p.3).

This paper examined the experiences of mathematics student-teachers with regard to relational, developmental and contextual dimensions of mentoring at a TS, in South Africa. A TS is a school "in which a major part of student pedagogical practice is conducted" (Moon, Vlasceanu, & Barrows, 2003, p.89). In this paper mentoring referred to the developing assistance and care of an experienced mathematics teacher to an unexperienced mathematics PGCE student-teacher. The relational dimension indicated the "mutually beneficial" (Beyene, Anglin, Sanchez & Ballow, 2002, p.87) relationship between the mentor and the mentee; the developmental dimension of mentoring focused on the mentoring roles aimed to develop student-teachers professionally and personally (Lai, 2010); and the contextual dimension focuses on cultural and situational features of the mentoring setting.

A social constructivism theoretical paradigm was adopted. In particular, a case study design using a qualitative method research design was followed. Student-teachers' experiences regarding mentoring at a teaching school (TS) were qualitatively established through interviews, lesson design analyses and reflection reports. A purposeful sampling technique (Creswell, 2003) was used to select five mathematics student-teachers from a population of 15 enrolled PGCE mathematics student-teachers at a university in South Africa.

The results from the qualitative data addressed the research question, namely: What are post-graduate certificate in education (PGCE) mathematics student-teachers' experiences of mentoring at a teaching school?

The results with regard to the relational dimension indicated that student-teachers' perceptions on mathematics teaching were initially that teachers do not have the responsibility to teach learners. Later student-teachers realised a teacher has the responsibility to ensure that classes are effective. Student-teachers started viewing barriers in mathematics teaching from their own experiences, which indicated that they started reflecting. They developed self-confidence. Initially, student-teachers experienced mentoring as an additional burden, but eventually they viewed it as very helpful. Student-teachers experienced the mentor teachers not only as caring and supportive, but also as role-models. However, student-teachers preferred to have face-to-face discussions with mentors, rather than e-mails. Furthermore, the student-teachers were willing to function in a community of practice, as they realised that they cannot work in isolation. Student-teachers also had a sense of belonging at the school.

It was evident from the analysis with regard to the developmental dimension that lesson plan presentation and conducting of lessons improved. The student-teachers also realised the importance of preparation. However, student-teachers found the transferal of content knowledge challenging, but also realised the importance of PCK by using other methods. According to the student-teachers the mentor teachers were more concerned about results than using learner-centered teaching approaches and creativity. Student-teachers acknowledged the use of various resources, but found the use of white boards challenging. A challenge to student-teachers was that English was not their home language. As a result, the student-teachers appreciated the way the mentor teacher communicated with the learners. Even though the teachers did reflection sessions with student-teachers at the end of each day, the student-teachers did not value the importance of reflection in the beginning. Later, students confessed that having feedback sessions with the mentor, helped, as they have to think on the spot.

The analysis with regard to the contextual dimension revealed that student-teachers started realising professionalism includes responsibility and accountability. Student-teachers also started implementing classroom management. However student-teachers found it difficult to manage discipline in the classrooms. Student-teachers were exposed to administration and considered record keeping and administration time consuming. Student-teachers felt that they were enculturated into the school system and acknowledged that the environment at the TS school contributed to their' growth.

A limitation to this paper is that only the views of student-teachers were taken into consideration. The experiences of the mentor-teachers would have contributed to a more holistic understanding. Guidelines for the improvement of such a programme are also recommended. The pilot project was implemented for a short time, namely one year. Although to a certain extent it was successful and student-teachers experienced it as valuable, I recommend that in order to discover the full extent of the success of such a project, it should be implemented for more than one year to more than one group of student-teachers in various subject disciplines. Furthermore, it should take place in conjunction with lectures at the university and should not be viewed as additional work to student-teachers. Support should also be provided to both fulltime and part-time student-teachers, and not only be restricted to fulltime PGCE mathematics student-teachers.

In conclusion, for a teaching school to be effective, its value should be communicated to all role players. An important value of the TS is that the emphasis of theory becomes much clearer after experience and TSs prepare student-teachers for their future with regard to responsibilities and expectations of a teacher. The article adds to research on the role of Teaching Schools in South Africa.

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MATHEMATICS TEACHERS' ATTITUDES TOWARDS THE SUBJECT: THE INFLUENCE OF GENDER, AGE AND TEACHING EXPERIENCE

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Abstract–Several studies indicate that mathematics teachers' attitudes have a vital influence on their learners' achievement. However, there is scant research on mathematics teacher attitudes in the South African context. The paper explores the attitudes of a group of mathematics educators and the role that their biographical attributes might play. The *Attitudes Towards Mathematics Inventory* (ATMI, Tapia & Marsh, 2004) is a recognised learner attitude detection instrument. Schackow (2005) tailored the ATMI towards mathematics teachers. It has four underlying dimensions, namely *value* (whether mathematical skills are worthwhile), *enjoyment* (whether mathematical challenges are enjoyable), *self-confidence* (how easily mathematics is mastered) and *motivation* (the desire to learn more about mathematics). The participants are 35 mathematics educators, enrolled for the Honours programme in Mathematics Education at the University of Johannesburg in 2014. Cross-tabulations were preceded by internal consistency measures, where after the Mann-Whitney U test detected three significant differences of various effect sizes. The paper is part of a larger research project, which endeavours to collect similar data from mathematics learners (or students) of these participating educators.

Keywords: Attitudes towards mathematics; Measurement of attitudes; Mathematics teacher attitudes; Mathematics achievement.

1. BACKGROUND CONTEXT AND PURPOSE

The relationship between attitudes towards and achievement in mathematics has been and rightfully still is the focus of many studies (Brown, McNamara, Hanley & Jones, 1999; Dowker, Ashcraft & Krinzinger, 2012; Ismail & Anwang, 2009; Khatoon & Mahmood, 2010; Schackow, 2005; Sweeting, 2011; Trujillo & Hadfield, 1999; and others). South Africa's dismal performance in the Trends in International Mathematics and Science Study (TIMSS) and in other international studies of its kind over the last decade, has led to a number of interrogative reports, with 'finger-pointing' findings. In the executive summary of the October 2013-report of the Centre for Development and Enterprise (CDE), the authors (McCarthy & Oliphant, 2013, p. 3) summarise the country's dreadful situation as follows:

> The teaching of mathematics in South African schools is amongst the worst in the world. In 2011, the Trends in International Mathematics and Science Study (TIMSS) showed that South African learners have the lowest performance among all 21 middle-income countries that participated. A recent CDE report further underlines the issue as it found rapid increases in enrolments in private extra mathematics classes, which was partly in response to poor teaching in public schools.

This condemning report and others (compare Spaull, 2014) once again positioned strategies to enhance teaching and learning in mathematics, science, reading, comprehension, quantitative literacy and other key domains in the centre of the national educational research agenda. Numerous potential mathematics achievement-related factors, for example learners' home and family contexts, biographical attributes, study orientations, learning strategies, levels of academic engagement, institutional adaption and the role that technology could play in learning, are being interrogated again, and again. Unfortunately, caution Bayaga & Wadesango (2014), does a rather consistent pattern of findings emerge – again and again.

It has also been shown in several studies (compare Durandt & Jacobs, 2013; Maat & Zakaria, 2010; Mata, Monteiro & Peixoto, 2012; Quinn, 1997; Sweeting, 2011; and others) that the quality of mathematics teaching and the nature of teacher attitudes have a pertinent influence on learners' achievement and eventually also on their dispositions towards mathematics. Oppong Asante (2012, p. 123) cites from a large number of studies, which prioritise the six main factors that were found to affect learner attitudes towards mathematics. In reverse order classroom experiences, parent attitudes and beliefs, learner achievement, the quality of teaching and teacher behaviour build up to the **number one effect**, "teacher attitudes and beliefs" (Beswick, 2007, p. 95). Surprisingly, there is still scant research on practising teachers' attitudes towards mathematics, especially in the South African context.

The *research question* that this paper attempts to address is: What are the attitudes toward mathematics of a group of educators, enrolled for the honours programme in Mathematics Education at a public higher education institution? In particular, how do these participants respond to and score on a widely recognised attitudes towards mathematics survey instrument, in respect of its four attitudinal components? The *goal* of the paper is to explore the attitudes towards mathematics of the aforementioned group, while the influence that selected biographical attributes might have will also be scrutinised.

2. LITERATURE PERSPECTIVES: ATTITUDES TOWARDS MATHEMATICS

2.1 Theoretical framework

2.1.1 The relationship between teaching (teachers) and learning (learners)

The authors support the view of Grossman (1992) that how researchers frame the role of teaching predictably sway their opinions in respect of the influence(s) that teachers exert on their learners. Grossman (1992, pp.171-174) then proceeds to distinguish three (sometimes highly contested) models, which define the relationship between teaching (and envisaged teacher conduct) and learning (and envisaged learner conduct), from each other, namely:

- Kagan's (1992) developmental growth model, which regards learners' mastery of subject-related procedures and routines and therefore teachers' pedagogical expertise as pertinent,
- Shulman's (1986) knowledge growth model, which regards learners' understanding of the subject matter and therefore teachers' content knowledge as the key, and
- Richert's (1990) ethical growth model, which focuses on the exemplary behaviour, motivational and classroom management role of teachers, which of course determine expected learner behaviour.

The <u>first element</u> of the theoretical framework underlying this paper is Grossman's 1992-belief that the three abovementioned teaching-learning models function in a complementary manner. Effective teachers portray pedagogical knowledge and skills, subject content knowledge, exemplary conduct and learner motivation and management proficiencies, among other characteristics. A teacher's conduct, disposition and beliefs therefore have a fundamental influence on her/his learner's beliefs and attitudes.

2.1.2 Teacher beliefs about mathematics

The second component of the theoretical framework that underlies this paper, is the worldview of Schackow (2005) on teacher beliefs. By citing Kagan (1990), Schackow (2005, p. 12) defines teacher beliefs as the subjective ways in which teachers grasp their role(s) in a classroom, their learners, determinants of learning, the teaching environment, and the goals of education. She (2005, p. 11) then quotes Thompson (1992): "Studies have shown that teachers' beliefs about mathematics teaching and learning are mostly formed during their own schooling and are developed as a result of their own experiences as mathematics students. Their conceptions about mathematics and how it should be taught are deeply rooted and are difficult to change".

To Schackow (2005, p. 9) beliefs are primarily rational in nature, but "they play an important role in the development of attitudes and emotions about mathematics." She adds that even when student-teachers' beliefs appear to be aligned with the education program they're enrolled for, their teaching practices might not reflect this.

Schackow's 2005-philosophy on the beliefs of mathematics teachers is the second element of the paper's underlying theoretical framework. The authors deduced that mathematics teachers' beliefs (of which their attitudes are a facet) ominously influence how they interpret and implement mathematics curricula, while it also meaningfully affect their learners' beliefs (and attitudes).

2.2 Attitudes in general and more specifically towards mathematics

Even though mathematics is generally regarded as important, many people have a disposition towards the subject, either positive or negative. Attitudes form a central part of a person's identity. It is quite normal to love, hate, like, dislike, favour, oppose, agree, disagree, argue and persuade. All these are evaluative responses to an object. Hence, attitudes can be defined as a summary evaluation of an object (Bramlett & Herron, 2009). Eshun (2004, p. 2) defines an attitude as "a disposition towards an aspect of mathematics that has been acquired by an individual through his or her beliefs and experiences but which could be changed." Schenkel (2009) maintains that attitudes towards mathematics represent a like or dislike of the subject and they embrace beliefs, abilities and views on the usefulness of mathematics. It is interesting to note that Schackow (2005, in section 2.1.2 above) regards beliefs as rational in nature, with attitudes stemming from beliefs.

2.3 The relationship between attitudes and achievement in mathematics

Dowker et al. (2012) find that primary school learners generally show relatively positive attitudes towards mathematics, and that their attitudes tend to become more 'negative' as they grow older. Through a Malaysian study involving Grade 9 mathematics learners, Anwang (2008) identifies gender, home language, expected educational level, family background and educational resources at home as meaningful influences on their achievement. In the same year, Farooq and Shah (2008, p. 77) confirm that positive attitudes towards mathematics lead towards success, while 'negative' or neutral attitudes generally have the opposite effect. This is reaffirmed by Schenkel (2009), in the following year.

Negative attitudes towards mathematics: (1) are typically a result of recurrent failures during mathematical task execution (Nicolaidou & Phillippou, 2005); (2) tend to inhibit learner intellect and curiosity (Bragg, 2007) and (3) generate less enjoyment and usefulness and lower confidence levels among learners (Shrestha, 2006). However, despite an overwhelming evidence of a positive relationship between the two, Hean, Craddock and O'Halloran (2009), as well as Mata et al. (2012), claim that attitudes don't seem to affect mathematics achievement.

2.4 The effect of mathematics teaching on learners' attitudes

It was fragrantly stated in section 1 that the quality of mathematics teaching and the nature of teacher attitudes have a pertinent influence on learners' achievement and eventually also on their attitudes towards mathematics. Yara (2009) confirms that teachers with positive attitudes towards the subject likewise stimulate favourable attitudes in their learners. Henderson and Rodrigues (2008) and Quinn (1997) regard the main source of negative learner attitudes toward mathematics as inappropriate teaching practices and teacher attitudes. Ma and Wilkins (2002) finally put the vital role of teacher attitudes and beliefs into perspective, when they posit that learners who believe that teachers have high expectations of them tend to have a more positive attitude towards mathematics.

3. RESEARCH DESIGN, PARTICIPANTS AND DATA COLLECTION

3.1 Research paradigm

The inquiry primarily attempts to determine the attitudes toward mathematics of a group of educators, enrolled for an honours programme in Mathematics Education at a public higher education institution? A second goal is to ascertain how the participants score on the four dimensions of a recognised attitudes towards mathematics survey instrument. The research paradigm for this study, post-positivism, is firmly based on the abovementioned goals. The post-positivist paradigm (Taylor & Medina, 2013) is a milder form of positivism, basically following the same principles, but allowing for more engagement between the researchers and the participants, by using a survey (containing both qualitative and quantitative items) as data collection instrument.

3.2 Participants

The participants are 35 mathematics educators and post-graduate students, who are enrolled for the B.Ed. Honours in Mathematics Education programme at the University of Johannesburg in 2014. They study on a part-time basis over two years and are made up of first (n=14) and second year (n=21) subgroups. Table 1 below displays elements of their demographics. The majority are fe*male* (63%), *black* (83%), *indigenous language* speaking (74%), *younger than 40 years* (60%), teachers for *ten years or less* (63%), and *60% or more* for matric mathematics achievers (57%). It's also noteworthy that almost half of the participants (45.7%) are *first-generation* students, and thus the first members of their families to engage in studies beyond matric level.

Table 1: Demographic profile elements of participants

Profile variable		N	%
Gender (n=35)	Female	22	62.9
	Male	13	37.1
Ethnic group (n=35)	Asian, incl. Indian	3	8.6
	Black	29	82.9
	White	3	8.6
Home language (n=35)	Afrikaans	1	2.9
	English	8	22.9
	Indigenous	26	74.3
Age in years (n=35) (Median = 38 yrs)	21 to 29 years	7	20.0
	30 to 39 years	14	40.0
	40 years and older	14	40.0
Years teaching (n=32) (Mean = 9.4 yrs)	Up to 3 years	11	34.4
	4 to 10 years	9	28.1
	11 to 20 years	9	28.1
	21 years plus	3	9.4
Math mark in Gr 12 (n=35) (Median = 60-69%)	49% or lower	3	8.6
	50 – 59%	12	34.3
	60 – 69%	11	31.4
	70 – 79%	7	20.0
	80% or higher	2	5.7

3.3 The data collection instrument and process

A close and open-ended, structured, self-designed section, followed by a section, containing an existing inventory of Likert scale items, made up the questionnaire. The questionnaire was used to collect information from the participants (all of them postgraduate (honours) students), during their second contact session of the year (a two hour session on a Saturday in March 2014).

3.3.1 Section A: Demographical information

Section A contains 14 demographical and opinion-based items. The list of demographical items include gender, ethnical group, home language, age, current teaching responsibilities, generation status, Gr 12 performance in mathematics and years of teaching experience. Reasons underlying their decisions to become mathematics teachers, why they are engaged in postgraduate studies, and thoughts that come to mind when they look back upon their Gr 12 mathematics experience (as learners) constitute the open-ended, opinion-based questions in the section. This enabled the researchers to construct a fairly detailed participant profile.

Collected demographical data were captured in a Microsoft Excel worksheet and then analysed via the frequencies, cross-tabulations and descriptive statistics options of the Statistical Package for the Social Sciences (SPSS, version 22). Individual feedback per open-ended, opinion-based question was consolidated into a worksheet and hence analysed via the constant comparative method (Jacobs and Du Toit, 2006:305-306), as a directed form of content analysis (Hsieh and Shannon, 2005:1281). Appropriate participant views per category, by quoting their direct words, have been integrated into the findings.

3.3.2 Section B: Attitudes towards mathematics

The Attitudes Towards Mathematics Inventory (ATMI, Tapia & Marsh, 2004) is an internationally recognised instrument, used for gaining learner attitudes towards mathematics as subject. Schackow (2005) tailored the ATMI towards mathematics student- and practising teachers, making it appropriate for this study. The ATMI has four underlying dimensions, namely *value* (whether mathematical skills are worthwhile and necessary, 10 items), *enjoyment* (whether mathematical problem-solving and challenges are enjoyable, 10 items), *self-confidence* (expectations about doing well and how easily mathematics is mastered, 15 items) and *motivation* (the desire to learn more about mathematics and to teach it, 5 items). Each of the 40 items uses a Likert-type response scale, ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*). When reverse coding (which applies to approximately a third of the items) was done, all item responses in each of the four dimensions are added, yielding total scores for value and enjoyment (maximum 50 each), self-confidence (maximum 75) and motivation (maximum 25). Analysis of ATMI data, including normality testing and reliability measures, were also performed via the Statistical Package for the Social Sciences (SPSS, version 22).

3.3.3 Ethical measures and participant's consent

After the goal of the research, the nature of the data collection instrument and their rights and responsibilities as respondents have been explained to them, individual written consent was obtained from all participants to safeguard the confidentiality of collected data and the anonymity of each participant.

3.3.4 Trustworthiness, validity and reliability

Strategies to maintain the *trustworthiness* of the data collected via the demographical and opinion-based items (in section A) included selected credibility, transferability, dependability and confirmability measures, originally prescribed by Lincoln and Guba (1985). A thorough description of the study, its planning and implementation, the properties of the participants, the data collection instrument and methods of analysis enhance transferability. A dense description of the methodology employed in the constant comparative and directed content analysis methods promotes dependability and rigour. The credibility of the research is augmented through a proper interrogation and triangulation of the findings by both researchers, while the original questionnaires were maintained for possible follow-up purposes.

The creators of the Attitudes Towards Mathematics Inventory (ATMI), Tapia and Marsh (2004, p. 18-19) report that the survey shows a high degree of internal consistency (Cronbach's alpha was in the region of .88), while its factor structure "…covers the domain of attitudes towards mathematics, providing evidence of content validity". The researchers conducted a pilot study (involving four current B.Ed. Honours students, who weren't participants) on the questionnaire, fine-tuning its perceived sight *validity*. Five Cronbach's alpha coefficients were hence calculated in respect of the four ATMI dimensions (Value, Enjoyment, Self-confidence and Motivation), as well as the Total ATMI score (the sum of the four dimensions). The coefficients are portrayed in Table 2 below and it is interesting to note that in total 13 of the 40 items were removed from all further analyses, in striving to optimise the reliability of the data. The five coefficients in table 2 confirm that the participants' responses to the remaining 27 ATMI items (in Section B of the questionnaire) have high internal consistency (*reliability*).

Table 2: Reliability of the Attitudes Towards Mathematics Inventory (ATMI)

ATMI dimension	Cronbach's alpha
Value (7 items❶)	.840
Enjoyment (6 items❷)	.750
Self-confidence (12 items)❸	.834
Motivation (2 items)❹	.804
ATMI Total (27 items)❺	.889

❶ The original Cronbach's alpha value was .801 for all 10 Value items, but after the stepwise removal of items 1, 2 and 6, the alpha for the remaining seven items increased to .840

❷ The original Cronbach's alpha value was .711 for all 10 Enjoyment items, but after the stepwise removal of items 11, 12, 13 and 20, the alpha for the remaining six items increased to .850

❸ The original Cronbach's alpha value was .822 for all 15 Self-confidence items, but after the stepwise removal of items 22, 25 and 34, the alpha for the remaining 12 items increased to .834

❹ The original Cronbach's alpha value was only .590 for all five Motivation items, but after the stepwise removal of items 36, 38 and 40, the alpha for the remaining two items increased to .804

❺ The Cronbach's alpha value was obtained by removing 13 items from the original list (as recommended by the reliability analyses of the four dimensions of the Inventory) and by using the remaining 27 items

4. EMPIRICAL FINDINGS

4.1 Participants' motivation to become mathematics teachers

Their responses to the question: '*What is the main reason(s) underlying your decision to become a mathematics teacher?*' indicate participants' interest in the teaching profession and their relationship with the subject mathematics. Four main categories of feedback were detected with the most pertinent mentioned firstly.

- The opportunity to make a difference to learners in disadvantaged communities, who lack good mathematics education and to change perceived negative learner attitudes towards the subject ["*It can be fun if taught properly and in a hands on, fun method. I wanted to show pupils this and help all pupils to achieve in Maths*" or "*To identify why in SA learners are performing poorly in Mathematics. Is it because of educators' styles of teaching? Or is it because of learners' misconceptions about the subject?*" or "*To break the misconception that mathematics is irrelevant and uninteresting. To develop in learners the passion for mathematics*"]
- The joy that they get through their engagement in mathematics and the passion that they always had for numbers and aspects of a mathematical nature ["*I am called to be a Maths teacher. Maths is my passion*" and "*Mathematics was always my passion. From small, I loved Mathematics. I was good at Mathematics in school as well as university.*"]
- The personal enrichment and cognitive development dividends gained from being involved in mathematics ["I find Maths a very interesting subject. It allows the development of problem solving skills and critical thinking"].
- interestingly enough, to counteract their initial negative attitudes towards and unsatisfactory achievement in mathematics, and also those of others ["*I had a phobia for Maths and I wanted to end that phobia in my life and help our future generation to have a positive attitude*".]

4.2 Participants' ATMI scores, reflecting their attitudes towards mathematics

Sweeting (2011, p. 53-54) categorises teacher attitudes towards mathematics (represented by their total ATMI score) on five levels, which she respectively labels as "strongly negative, negative, neutral, positive and strongly positive". Her categorisation is based on 20%-intervals, which means that someone who is regarded as *strongly positive* has scored 80%+ of the maximum ATMI total. Likewise, someone with a score from 40 to 59% would be regarded as *neutral*.

Table 3 (on the next page) provides a breakdown of the participants' ATMI scores. The researchers expected the overwhelming majority of the participants (all of them are practicing mathematics teachers, who are also furthering their qualifications), to portray a *strongly positive* disposition towards mathematics. Our expectations were confirmed (and probably exceeded), as more than 90% of the participants in respect of three of the four dimensions (the exception is the *Motivation* dimension, although it is still highly comparable to the others) and the ATMI total displayed strongly positive attitudes. The ATMI is a self-rating survey and although these findings are not entirely unexpected, they are viewed with a subtle scepticism.

4.3 Testing for significant differences between ATMI scores

The Mann-Whitney U test, as appropriate non-parametric statistical technique was used to analyse differences between the medians of the responses of participants in the two gender groups, the two honours year groups, in various age categories, in years of teaching experience categories, and in various matric mark for mathematics categories respectively. The Mann-Whitney test is considered appropriate, because the responses do not follow a normal or t-distribution, they are measurable on an ordinal scale, they are comparable in size and they are independent (responses from one subgroup cannot affect the responses of other subgroups (Milencović, 2011:74). Tables 4 and 5 below present the *test statistics* and *ranks* on the ATMI's **Value** dimension, with age group and years of teaching experience as grouping variables.

Table 3: Distribution and descriptive statistics of ATMI scores

ATMI dimensions and intervals		N=	%
VALUE (7 items) (Mean = 33.69)	29–35	34	97.1
	21–28	1	2.9
	Less than 21	0	0.0
ENJOYMENT (6 items) (Mean = 28.26)	25–30	32	91.4
	19–24	3	8.6
	Less than 19	0	0.0
SELF-CONF (12 items) (Mean = 55.80)	49–60	32	91.4
	37–48	3	8.6
	Less than 37	0	0.0
MOTIVATION (2 items) (Mean = 9.00)	9 or 10	26	74.3
	7 or 8	8	22.8
	Less than 7	1	2.9
TOTAL SCORE (27 items) (Mean = 109.0)	109–135	34	97.1
	83–108	1	2.9
	Less than 83	0	0.0

Table 4: Test Statistics[a] for the Atmi's Value Dimension

	Age group interval 1[b]	Age group intervals 2[c]	Teaching experience intervals[d]
Mann-Whitney U	23.500	22.000	30.000
Wilcoxon W	51.500	50.000	96.000
Z	-1.997	-2.142	-2.322
Asymp. Sig. (2-tailed)	.046[e]	.032[e]	.020[e]
Exact Sig. (1-tailed)	.056	.046[e]	.027[e]

a Grouping variables: Age and Years of teaching experience
b Participants in the age group 21 to 29 years are compared to participants in the age group 30 to 39 years
c Participants in the age group 21 to 29 years are compared to participants in the age group 40 years plus
d Participants, who have up to 3 years teaching experience are compared to participants, who have 11 years or more teaching experience
e Significant at the 95% level of confidence

Table 5: Ranks In Respect of the Atmi's Value Dimension

Demographic attributes	Groups	N=	Mean Rank	Sum of Ranks
Age group intervals 1 [N=21]	21-29 years	7	7.36	51.50
	30-39 years	14	12.82	179.50
Age group intervals 2 [N=21]	21-29 years	7	7.14	50.00
	40 years+	14	12.93	181.00
Years of teaching experience [N=23]	3 years or less	11	8.73	96.00
	11 years+	12	15.00	180.00

The Mann-Whitney test findings firstly indicate that mathematics teachers in this study, between the ages of 21 and 29 years (*Mdn* =33) have a significantly lower (at the 95% confidence level) **Value attitude towards mathematics** as their 30 to 39 year old counterparts (*Mdn* = 34.5), *U* = 23.50, *p* = .046. Cohen's effect size (r = .44) is in the medium to high interval (Milencović, 2011:77), which implies that the finding has moderate (to high) practical significance.

The findings secondly indicate that mathematics teachers in this study, between the ages of 21 and 29 years (*Mdn* = 33) also have a significantly lower (at the 95% confidence level) **Value attitude towards mathematics** as their 40 years and older counterparts (*Mdn* = 35), *U* = 22.00, *p* = .032. Cohen's effect size (r = .47) is again in the medium to high interval, indicating that the finding also has moderate (to high) practical significance.

The findings thirdly indicate that mathematics teachers in this study, who have three years or less teaching experience (*Mdn* = 33) have a significantly lower (at the 95% confidence level) **Value attitude towards mathematics** as their counterparts who have more than ten years of teaching experience (*Mdn* = 35), *U* = 30.00, *p* = .020. Cohen's effect size (r = .48) is very close to the high interval, implying that this finding also has moderate (to high) practical significance.

5. CONCLUSION

The research questions that this study attempted to find answers to were two-fold, namely:

- What are the attitudes toward mathematics of a group of educators, enrolled for the honours programme in Mathematics Education?
- How do these participants respond to and score on the Attitudes Towards Mathematics Inventory, in respect of its four attitudinal components and its total?

It was found that more than 90% of the participants display strong positive attitudes towards mathematics as subject, also in respect of all four dimensions of and the total ATMI. This means that these mathematics teachers, who are currently also enrolled for a postgraduate qualification in Mathematics Education, regard the acquisition of mathematical skills as worthwhile and necessary, enjoy mathematical problem-solving and challenges, have high expectations about doing well in mathematics and also have a desire to learn more about mathematics and fulfil their roles as mathematics teachers.

Significant differences (statistical and practical) were detected between mathematics teachers aged 21 to 29 years and their 30 to 39 year old, as well as their 40 year and older counterparts in respect of the value that they attach to mathematics, with the 'younger' group attaching lesser value. In addition, participants who have three years or less mathematics teaching experience also attach significantly less value to the subject than those who have more than 10 years teaching experience.

The credibility (and truth value) of the ATMI as a self-rating questionnaire has not been ascertained yet. However, the instrument definitely makes a meaningful contribution. Attitudes towards mathematics are complex and dynamic and most certainly also needed to be interrogated via other mechanisms and instruments. The larger research project, which endeavours to collect similar data from learners (or students) of mathematics educators, is a logical next step. This study (and the larger project) aspire to contribute to the number one effect on mathematics learners' attitudes (and also their achievement), namely teacher attitudes and beliefs.

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MOTIVATION STRATEGIES OF EX-MATHEMATICAL LITERACY LEARNERS IN A UNIVERSITY FOUNDATION PROGRAMME

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Abstract–Ex-Mathematical Literacy learners are currently excluded from directly gaining admission to undergraduate studies in Commerce and Technology at most South African Higher Education Institutions (HEIs). Certain HEIs do provide access to these students through pathway, foundation or extended degree programmes, usually incorporating a minimum level of mathematics competence. Additional intervention strategies have been recognised by a private HEI, but not formally investigated. The purpose of this study is to determine the role of motivation strategies in the academic orientation of ex-Mathematical Literacy learners in order to refine a private institution's current foundational intervention. A quantitative design was adopted, exploring the motivation factors of the *Motivation and Strategies for Learning Questionnaire* (MSLQ). Participants were a purposive sample of 419 Foundation Programme students; of which 106 were ex-Mathematical Literacy learners. The latter group displays significant lower levels of motivation than their mathematics counterparts, in certain MSLQ items. The findings have practical significance and implications for designers and facilitators of foundation programmes.

Keywords: Mathematical Literacy; University foundation programme; Student motivation; Mathematics achievement; Motivation and Strategies for Learning Questionnaire (MSLQ)

1. INTRODUCTION AND PURPOSE

Learners choosing Mathematical Literacy at matriculation level are not expected to consider further studies in disciplines requiring mathematics (South African Department of Education [SA DoE], 2008). Business Science and Computer and Information Science are two such disciplines. Four per cent of any matriculating cohort (Jansen, 2012) achieves the necessary results to enter undergraduate studies in these disciplines and only half of these are likely to graduate (Council for Higher Education [CHE], 2012). The South African Government ([SA Gov], 2010, p. 1) adopted a performance outcome to redress this situation by aiming to develop a "skilled and capable workforce to support an inclusive growth path."

To attain this, the South African Higher Education and Training department aims to "[i]ncrease access to programmes leading to intermediate and high level learning" (South African Higher Education and Training [SA HET], 2012, p. 4). Higher Education South Africa (HESA) (2009, p. 7) recognises the commitment of HEIs to increasing access, but states that these steps "have to be accompanied by strategies aimed at ensuring success". Strategies to date have incorporated student support systems, interventions and pathway programmes, including extended degree- and foundation programmes.

Few strategies to increase access to undergraduate studies and ensure success have expanded study opportunities for ex-Mathematical Literacy learners at public HEIs; the extended degree in Commerce at the University of Johannesburg[2] is one. Monash South Africa (MSA) offers Mathematical Literacy matriculants achieving at least 50% the opportunity to complete a Foundation Programme intervention year with the aim of articulating to undergraduate studies in Business

2 Students achieving at least 70% for Mathematical Literacy may apply to enrol in a four-year extended degree, other requirements notwithstanding (University of Johannesburg, 2014).

Science or Computer and Information Science[3]. Opportunities like these may necessitate additional academic support for ex-Mathematical Literacy learners, but the need for and nature of non-academic support mechanisms also needed to be explored.

No formal studies in South Africa have been found, which involve ex-Mathematical Literacy learners enrolled in foundation programmes, aiming to articulate to undergraduate studies in Business Science and Computer and Information Science. To create an effective intervention strategy that optimally addresses the needs of ex-Mathematical Literacy learners, both academic and non-academic support components should be identified and studied. One non-academic component that has been identified by other studies (Allie & Scott, 2009; Bye, Pushkar & Conway, 2007; Dunn, Lo, Mulvenon & Sutcliffe, 2011; Lubben, Davidowitz, Buffler, Zerpa, Hachey, Van Barneveld & Simon, 2011) is motivation (described in Section 2 below). The research question for this paper is thus: How does the motivation of ex-Mathematical Literacy learners compare with the motivation of ex-mathematics[4] learners, enrolled for the MSA Foundation Programme in 2014? The purpose of this study is two-fold. The first purpose is to investigate and compare the motivation of ex-Mathematical Literacy learners with that of ex-mathematics learners in the Monash South Africa Foundation Programme (MSAFP). The second, broader purpose is to use this information to determine whether it is appropriate to incorporate motivational strategies into the mathematics intervention strategy, which forms part of the abovementioned Foundation Programme unit.

2. LITERATURE REVIEW

2.1. Theoretical framework

Before the development of the Motivation and Strategies for Learning Questionnaire (MSLQ), many "study skills inventories were criticized for having no theoretical basis" (Artino, 2005, p. 2). Pintrich, Smith, Garcia & McKeachie (1993, p. 801) developed the MSLQ, based on a social-cognitive view of motivation to be a "self-report instrument designed to assess college students' motivational orientations." The purpose of the MSLQ is to create a general model to understand the motivation (and learning strategies) of university students (Artino, 2005). The model postulates a direct link between motivation and self-regulated learning. Students who display self-regulation are described by Zimmerman (1989, p. 329) as "metacognitively, motivationally, and behaviorally active participants in their own learning process".

Pintrich (2003) proposes a motivational science framework to integrate and unify findings in studies about motivation research, with three core themes. Firstly, research about motivation can be approached from a scientific perspective, supported by empirical evidence. Secondly a multidisciplinary approach is necessary to understand elements of human behaviour such as motivation. Lastly, researchers should strive to meet two goals, the scientific understanding of motivation and the practical application of the results.

Pintrich's socio-cognitive view of motivation thus serves as the theoretical framework for this research. It assumes that motivation is course specific and that learning approaches may vary according to the student's perception of a course. This assumption allows course-related motivation, rather than motivation in general to be studied, measured and reported on, with the understanding that different levels of motivation could be reported by the same participant in different courses (Duncan & McKeachie, 2005). In keeping with the theoretical framework of the MSLQ, no norms have been developed for this instrument (Artino, 2005).

3 Other requirements include an Academic Progress Score (APS) of at least 23 and a pass for the English subject (Monash South Africa, 2014).

4 Mathematics in this context refers to National Senior Certificate Core Mathematics, widely known as mathematics.

2.2. Motivation in the context of this study

Motivation has been studied as a component of psychology as far back as Descartes, who postulates the construct instinct psychology, which then developed along two positions: molecular (a study of the parts) and molar (a study of the whole) psychology (Cassel, 1952). More recent motivation studies have popularised intrinsic and extrinsic motivation types. The difference between motivation, which is innate and which is externally driven is established in classic motivation theories, such as Maslow's hierarchy of needs (Maslow, 1943), McGregor's theory X and theory Y (McGregor, 1960), and Herzberg's Motivation-Hygiene theory (Herzberg, Mausner & Snyderman, 1959).

The word motivation is derived from the Latin movere, which means 'to move' (Schunk, Pintrich & Meece, 2014). Deci and Ryan (2000, p. 227) explain that "contemporary theories of motivation assume that people initiate and persist at behaviours to the extent that they believe the behaviours will lead to desired goals or outcomes." Cherry (2014, para. 1) concurs that motivation is the "process that initiates, guides and maintains goal-oriented behaviours. Motivation is what causes us to act," … "It involves the biological, emotional, social and cognitive forces that activate behaviour".

Several studies investigating goal orientation and goal-oriented behaviour were detected (compare Coutinho & Neuman (2008); Deci & Ryan (2000); Meece, Anderman & Anderman (2006); Payne, Youngcourt & Beaubien (2007) and Watkins, McInerney, Akande & Lee (2003)). Goal orientation is described by Vandewalle (1997, p. 995) as "an individual disposition toward developing or demonstrating ability in achievement situations". Pintrich (2003) expands on the work of Deci and Ryan (2000) to note that this disposition may originate intrinsically or extrinsically. More studies agree that self-efficacy is positively correlated with goal-oriented behaviour (Coutinho & Neuman, 2008; Meece, Anderman & Anderman, 2006; Payne, Youngcourt & Beaubien, 2007).

Pintrich, Smith, Garcia & McKeachie (1991) developed an educational research mechanism (the MSLQ), which considers various components of motivation, including information around goal-oriented behaviour and self-efficacy. This questionnaire has been widely used in empirical research and also to determine potential opportunities for intervention (Artino, 2005). It has been extensively used across culture and language divides and has undergone validity and reliability testing in three languages and has been shown to have sound, albeit moderate predictive validity (Artino, 2005).

Seven overarching questions are the basis for the motivation category of the MSLQ. These questions (Pintrich, 2003) explore ideas such as: What do students want? How do students get what they want? Do students know what they want or what motivates them? What motivates students in classrooms? How does motivation lead to cognition or cognition to motivation? How does motivation change and develop? What is the role of context and culture? The 31 resulting statements in the motivation category of the MSLQ are grouped into six components, presented in table 1.

Table 1: Components of the motivation category of the MSLQ

Motivation category	Value components	Intrinsic Goal Orientation
		Extrinsic Goal Orientation
		Task Value
	Expectancy components	Control of Learning Beliefs
		Self-efficacy for Learning and Performance
	Affective component	Test Anxiety

Intrinsic goal orientation relates to Maslow's self-actualisation and concerns the "student's perception of the reason why she [or he] is engaging in a learning task" (Pintrich et al., 1991, p. 12). Extrinsic goal orientation refers to external factors, such as reward or competition, which compel action toward a goal; the course is perceived as a means to an end, rather than an end in itself. Task value considers the expected importance, interest and usefulness of the course. These components determine the value that the student places on the course and informs the level of involvement the student will invest in her/his learning.

The expectancy component investigates the student's opinions regarding the results that they believe their actions will achieve. Students who are confident that their learning efforts result in positive outcomes, who feel in control of their academic achievement and able to perform to the expectations they set, will rate the two categories in the expectancy component highly. Test anxiety is inversely related to the expectancy component and thus learning and performance. Two elements comprise this component. Worry is a cognitive element that interrupts the ability to perform correctly, while anxiety is an emotional element with physiological implications.

Studies that use questionnaires such as the MSLQ have become popular and central to research in learning and teaching contexts (Pintrich, 2003). Tuan, Chin and Shieh (2012) concur that attitude and motivation are two of the most important factors to predict student achievement and use the MSLQ as a basis for comparison in the study of motivation in science scholars. Lin and Lui (2010) and Mousoulides and Philippou (2005) have modified the MSLQ to research links between motivation and mathematics. Bong, Cho, Ahn and Kim (2012) and Van der Walt, Maree and Ellis (2008) utilise the MSLQ, in addition to other assessment tools, to predict student motivation in mathematics and study the implications of this for education. Payne and Israel (2010) have used the MSLQ as a performance prediction tool for the development of interventions for mathematics students in South Africa prior to the adoption of the Outcomes Based Education (OBE) approach.

3. RESEARCH DESIGN, DATA COLLECTION AND PARTICIPANTS

3.1. Research approach

The investigation adopted a quantitative approach, based on the assumption that the variables of interest (the motivation strategies of first year Foundation Programme students, enrolled at a private HEI) can be enumerated and measured. This approach is therefore post positivist (Heppner & Heppner, 2004, p. 143), which presumes that an external reality exists independent from this research, and that this reality cannot fully be known. From this perspective, the aim of the empirical inquiry is to investigate how the motivation components of ex-Mathematical Literacy learners, who have enrolled for a Foundation Programme at a private HEI, compare to the corresponding components of ex-mathematics learners in the same programme. The findings might generate guidelines that can be used to optimise student support in the aforementioned Foundation Programme. The post positivist approach does not aim to generate theories, models or frameworks that reflect absolute truths about the reality of the participants. The empirical outcomes should rather be judged with respect to their usefulness (substantively and practically).

3.2. Data collection instrument and administration

The MSLQ was used for data collection in this study. It is a "self-report instrument designed to assess … motivational orientations and the[ir] use of different learning strategies, … based on a general cognitive view of motivation and learning" (Pintrich et al., 1993, p. 3). The MSLQ consists of 81 statements, to which participants should respond according to a seven-point Likert scale from **1** (not at all true of me) to **7** (very true of me) with **4** being neutral. The first 31 statements explore the value, expectancy and affective components of motivation. Data collection was administered during the mathematics class in the second week of the first semester (in March).

3.3. Participants

The population for this study encompassed 482 students enrolled in the Business, Information Technology and Health streams in the Foundation Programme of MSA, selected as a purposive, convenience sample. Forty-five students chose not to take part in the study and two students who completed the questionnaire left the MSAFP during the semester.

Eventually 437 students (90.7% of the population) completed the questionnaire. The data of 18 of these students could not be utilised for various reasons, which finally provided 419 students' data (86.9% of the population) for analysis. The latter group comprised 106 (25.3%) ex-Mathematical

Literacy-, 183 (43.7%) ex-Mathematics Core- and 130 (31.0%) 'other' learners, who were not exposed to either of the former mathematics course options in their final school year. The demographic breakdown of the three groups in respect of gender and final school year mathematics choice is outlined in Table 2 below.

Table 2: Participant breakdown in respect of gender and mathematics choice

	Ex-Math Literacy	Ex-Math Core	'Other' Math	Total
Female	46	88	55	189 (*45.1%*)
Male	60	95	75	230 (*54.9%*)
Total	**106** (*25.3%*)	**183** (*43.7%*)	**130** (*31.0%*)	**419** (*100.0%*)

Analyses and comparisons in this paper only involve the ex-Mathematical Literacy- and the ex-Mathematics Core learner groups.

3.4. Ethics, validity and reliability

The Research Ethics Committees of both the University of Johannesburg (the paper forms part of the first author's Master's studies) and MSA (home institution of the participants) granted clearance for the study. Permission to use the MSLQ was obtained from W.J. McKeachie, one of the original designers of the questionnaire (Personal communication, September 23, 2013) and intellectual property rights were recognised. Their rights and interests were explained to the participants and also protected by confidentiality and anonymity measures. Completed questionnaires were also securely stored.

The designers of the questionnaire (Pintrich et al., 1993, p. 4-5), on numerous occasions and by using diverse samples, calculated the correlation of each of the MSLQ scales with final student grades. They concluded that the instrument demonstrates significant *predictive validity*. Results from their confirmatory factor analyses (Pintrich et al., 1993, p. 79-87) indicate that instrument also shows sound *factor validity*. For this study, *content* and *face validity* were confirmed when the MSLQ was sound boarded with three knowledgeable colleagues and then piloted with five students, who have previously completed the MSA Foundation Programme.

The internal consistency (*reliability*) of the data by means of Cronbach's alpha coefficients was calculated for each motivation component in the study. The findings, outlined in Table 3 below, indicate that in respect of five of the six components (*control of learning beliefs* excluded), and also for the cumulative motivation scale, alpha values of between 0.63 and 0.89 were obtained. This resembles a moderate to high internal consistency and level of data reliability for three components with alpha values greater than 0.7. The Cronbach's alpha coefficients are between 0.6 and 0.7 in the case of both intrinsic and extrinsic goal orientation, which is lower that the usually acceptable 0.7.

Table 3. Cronbach's Alphas for each MSLQ motivation component

MSLQ component	Number of items	Alpha* (α)
Intrinsic goal orientation	4	0.630
Extrinsic goal orientation	4	0.643
Task value	6	0.809
Control of learning beliefs	4	0.502
Self-efficacy for learning and performance	8	0.886
Test anxiety	5	0.744
Motivation scale	**31**	**0.848**

*N = 419

4. EMPIRICAL FINDINGS

4.1. Finding an appropriate statistical test

Sampling was conducted in a non-probability (purposive) manner. The Shapiro-Wilk W test (*p* =.000) generated a significant finding ($p < .01$) on all six motivation components of the MSLQ. This means that a normal distribution of the data cannot be assumed. However, with moderately large data sets ($n > 200$), as is the case in this investigation ($n = 419$), and based on a careful analysis of the distribution's stem-and-leaf and PP plots as well as 'common sense', the researchers rationalised (supported by the Cross Validated website of StackExchange) that a parametric test, like Student's t test would be sufficiently robust to handle this perceived 'non-normality'.

An independent samples t-test was firstly conducted to test for the significance of differences between the mean scores of ex-Mathematical Literacy- and ex-mathematics learners on all six motivation components of the MSLQ. The non-parametric Mann-Whitney U test was subsequently used to analyse differences between the median values and ranked scores on the same six motivation components of these two groups. The Mann-Whitney test results corresponded to and confirmed the initial t-test findings.

4.2. Significant differences between the motivation strategies of the two groups

Tables 4 and 5 below reveal the results of the independent-samples t-test in respect of differences between the mean scores of ex-Mathematical Literacy and ex-mathematics learners on all six motivation components of the MSLQ, including their total motivation score. The t-test indicated significant differences between scores of the two groups in respect of four of the components and the motivation total, with the details as follows:

- **Intrinsic goal orientation**: Scores of ex-mathematics learners (M = 19.4, SD = 4.35) are significantly higher than the scores of the ex-Mathematical Literacy learners (M = 18.0, SD = 4.39), $t(287) = -2.56$, $p < .05$, $d = .31$. Cohen's effect size (.31) is in the small to medium interval (Thalheimer & Cook, 2002, p. 3), which implies that this internal goal orientation difference has a minor to moderate practical significance.
- **Task value:** Scores of ex-mathematics learners (M = 32.44, SD = 6.21) are significantly higher than the scores of the ex-Mathematical Literacy learners (M = 29.66, SD = 6.4), $t(287) = -3.63$, $p < .01$, $d = .44$. Task value differences have a minor to moderate practical significance.
- **Self-efficacy for learning and performance**: Scores of ex-mathematics learners (M = 43.19, SD = 7.49) are significantly higher than the scores of the ex-Mathematical Literacy learners (M = 37.57, SD = 8.28), $t(287) = -5.92$, $p < .01$, $d = .71$. Self-efficacy for learning and performance differences have a moderate to major practical significance.
- **Test anxiety**: Scores of ex-Mathematical Literacy learners (M = 23.78, SD = 6.81) are significantly higher than the scores of the ex-Mathematics learners (M = 21.62, SD = 6.92), $t(287) = 2.58$, $p < .05$, $d = .32$. This test anxiety differences have a minor to moderate practical significance.
- **Total motivation**: Scores of ex-mathematics learners (M = 162.27, SD = 21.24) are significantly higher than the scores of the ex-Mathematical Literacy learners (M = 154.37, SD = 20.63), $t(287) = -3.08$, $p < .01$, $d = .38$. This total motivation difference between the groups has a minor to moderate practical significance.

Table 4: Group statistics

Motivation components	Group	N	Mean	Std. Deviation	Std. Error Mean
Intrinsic goal orientation	1	106	18.02	4.386	.426
	2	183	19.38	4.350	.322
Extrinsic goal orientation	1	106	23.74	3.895	.378
	2	183	23.88	3.781	.279
Task value	1	106	29.66	6.398	.621
	2	183	32.44	6.214	.459
Control of learning beliefs	1	106	21.60	3.796	.369
	2	183	21.75	3.593	.266
Self-efficacy for learning and performance	1	106	37.57	8.275	.804
	2	183	43.19	7.485	.553
Test anxiety	1	106	23.78	6.813	.662
	2	183	21.62	6.918	.511
Total motivation	1	106	154.37	20.633	2.004
	2	183	162.27	21.235	1.570

Group 1 = ex-Mathematics Literacy learners **Group 2** = ex-Mathematics learners

Table 5: Independent samples t-test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
IGO total	EVA	.002	.965	-2.561	287	.011	-1.364	.533	-2.412	-.315
	EVNA			-2.555	217.902	.011	-1.364	.534	-2.416	-.312
EGO total	EVA	.153	.696	-.308	287	.758	-.144	.467	-1.062	.774
	EVNA			-.306	214.107	.760	-.144	.470	-1.071	.783
TVAL total	EVA	.580	.447	-3.629	287	.000	-2.782	.767	-4.291	-1.273
	EVNA			-3.600	214.198	.000	-2.782	.773	-4.305	-1.259
CLB total	EVA	.099	.753	-.336	287	.737	-.150	.448	-1.032	.731
	EVNA			-.331	209.671	.741	-.150	.454	-1.046	.746
SELP total	EVA	1.056	.305	-5.921	287	.000	-5.625	.950	-7.495	-3.755
	EVNA			-5.765	201.936	.000	-5.625	.976	-7.549	-3.701
TANX total	EVA	.367	.545	2.579	287	.010	2.166	.840	.513	3.818
	EVNA			2.589	222.139	.010	2.166	.836	.517	3.814
Motivation total	EVA	.001	.975	-3.080	287	.002	-7.900	2.565	-12.949	-2.851
	EVNA			-3.103	224.597	.002	-7.900	2.546	-12.916	-2.883

IGO = Intrinsic goal orientation
EGO = Extrinsic goal orientation
TVAL = Task value
CLB = Control of learning beliefs
SELP = Self-efficacy for learning and performance
TANX = Test Anxiety
EVA = Equal variances assumed
EVNA = Equal variances not assumed

4.3. Empirical synthesis

Goal orientation relates to the reasons why students are engaging in learning. **Intrinsic goal orientation** "…concerns the degree to which the student perceives herself [or himself] to be participating in a task for reasons such as challenge, curiosity, mastery" (Pintrich et al., 1991, p. 8). The ex-mathematics learners displayed a significantly higher intrinsic goal orientation, than their ex-Mathematical Literacy counterparts. It can be interpreted that ex-mathematics learners, to a greater extent engage in academic tasks in order to be challenged, to have their curiosity stimulated or in striving for mastery. On the other hand, ex-Mathematical Literacy learners, to a significantly larger degree engage in an academic task as a means to an end – so as to get it 'done and dusted' on their way to something more personally satisfying and meaningful.

Extrinsic goal orientation didn't produce significant differences between the scores of the two groups of learners. This motivation component considers the importance of factors such as receiving praise from others and being in competition with others. A finer interrogation of this component's items reveals that ex-Mathematical Literacy learners seem to be less interested in the content area of mathematics than ex-mathematics learners.

While goal orientation considers the reasons why students have chosen to participate in the course, **task value** investigates students' impressions of the interest, importance and usefulness of the course (Pintrich et al., 1991). The significantly higher task value of ex-mathematics learners denotes that these learners regard mathematics as more interesting, important and useful than the ex-Mathematical Literacy group.

Control of learning beliefs is the only component where every item of the component shows no significant difference between the two groups under discussion. Cronbach's Alpha was not able to report that the data gathered for this component was reliable and thus useful. Control of learning beliefs refers to the belief of students that "their efforts to learn will result in positive outcomes" (Pintrich, 2001, p. 12). An interpretation that both ex-Mathematical Literacy and ex-mathematics learners' beliefs that personal effort is positively rewarded can thus not be excluded or accepted.

Bong et al. (2012, p. 337) describe **self-efficacy for learning and performance** as "an individual's subjective convictions in his or her ability to organise and execute actions that are required to achieve a desired outcome in a given context". The findings indicate that ex-mathematics learners are significantly more likely to trust their ability to complete mathematics tasks as they might have more confidence in their abilities than ex-Mathematical Literacy learners.

According to Pintrich et al. (2001, p. 18) test anxiety is comprised of a cognitive component (worry) and an emotional component (anxiety). Both adversely affect expectancy and academic performance. The significantly higher test anxiety result for ex-Mathematical Literacy learners suggest that these learners may experience higher levels of worry and anxiety about test taking in mathematics than ex-mathematics learners.

There is a significant difference between the two groups in respect of their total motivation. Ex-Mathematical Literacy learners displayed a lower level of motivation towards mathematics than ex-mathematics learners. Artino (2005, p. 3) states that within the MSLQ framework, "students' motivation is directly linked to their ability to self-regulate their learning activities". It thus seems as if ex-Mathematical Literacy learners embarking on studies in a foundation programme are not as capable of taking charge of their learning in mathematics as the ex-mathematics learners.

5. IMPLICATIONS OF THE FINDINGS

Based on these findings, ex-Mathematical Literacy learners may not grasp the value of mathematics, or the purpose of a mathematics course for their studies, or they may merely view the subject as a means to an end. Alternatively, they may not find the work interesting, useful or important at this point in their studies. One implication of this is that ex-Mathematical Literacy learners may not place a high value on a foundation programme mathematics course, leading to lower expectancy measures. It is possible that these ex-Mathematical Literacy learners neither expect to be particularly successful in mathematics, nor believe in their ability to master the subject. They are thus likely to worry more and exhibit aspects of anxiety when taking tests.

A suitable strategy might begin with reinforcing ex-Mathematical Literacy learners' control of learning beliefs. Teacher reinforcement that continued hard work is rewarded with positive outcomes may be incorporated more frequently into student conversations. External goal orientation is a further component to address, as ex-Mathematical Literacy learners appear to be as motivated as other students in this component. Offering rewards and/or creating healthy competition that allows ex-Mathematical Literacy learners to be successful may develop their extrinsic goal orientation. This may encourage these students to work conscientiously at the subject and in turn reinforce or build other motivation components.

From an intrinsic goal orientation perspective, ex-Mathematical Literacy learners could be assisted to understand why mathematics is important as an end in itself. Mathematical applications that relate to Business Sciences and Information and Technology Sciences can support this goal. Students need to develop their confidence in working with mathematics in order to foster a passion for inquiry related to the subject so that it is viewed as an end in itself. A passionate, patient teacher, which present work that appears to be useful to all students will assist students to gradually develop their intrinsic goal orientation.

Strategies that assist students to begin to answer questions independently and successfully might increase students' belief in their ability to master the subject. Such strategies may include providing selected questions that can be successfully attempted during class, assisting students to identify sections of work that they can do to build their confidence and the development of their examination preparation techniques. All these strategies may assist with the development of self-efficacy for learning.

Within the test anxiety component, two MSLQ questions were specifically identified as having significant differences in the means of ex-Mathematical Literacy learners and ex-mathematics learners. These questions are: *When I take a test, I think about how poorly I am doing compared with other students* and *I have an uneasy, upset feeling when I take an exam*. Stress and anxiety reducing techniques could be incorporated into the intervention to assist ex-Mathematical Literacy learners to learn how to cope with the anxiety of test taking and the worry of forgetting work. Practice and repetition of mathematical procedures and providing practice questions that these students are able to attempt, might also decrease their anxiety levels.

6. CONCLUSION

The focus of this paper is to identify and understand differences in the motivation of ex-Mathematical Literacy learners and ex-mathematics learners enrolled in a foundation programme at a private university. The MSLQ, a tool used in hundreds of studies world-wide (Artino, 2005) was chosen as an appropriate data collection instrument. The research revealed that ex-Mathematical Literacy learners display a lower level of motivation towards mathematics than ex-mathematics learners. The current mathematics intervention should ideally be adapted to include a motivation and self-regulation section specifically geared at the learning of mathematics.

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PROFESSIONAL DEVELOPMENT OF MATHEMATICS EDUCATORS FOR OPEN AND DISTANCE LEARNING THROUGH EFFECTIVE COLLABORATION

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Abstract–Open and Distance Education has become a viable alternative to Conventional Education in Nigeria. More so, Open and Distance Learning (ODL) Institutions depend on collaboration with conventional Institutions in order to thrive and succeed. Therefore, Mathematics Educators need better tools to address the challenges of education. This paper unmasks the extent to which collaboration between ODL and conventional Institutions contribute to effective teaching and meaningful learning in Nigeria. Data were collected from the academic staff of National Open University of Nigeria (NOUN) using structured questionnaire. Mean, standard deviation and chi square were used for data analysis. The findings revealed that ODL can bring sustainable development when well supported with effective collaboration between ODL and Conventional Institutions. This can be strengthened and sustained through professional development of Mathematics Educators. This professional development should include training for effective teaching and meaningful learning, the use of modern technologies and development of course materials.

Keywords: Opening and Distance Learning, professional development, Mathematics Educators, conventional, Collaboration.

1 .INTRODUCTION

Today's workforce requires abilities of critical thinking, problem solving, and be also ICT compliant. Thus, institutions are faced with ever-increasing demands in their attempts to ensure that learners are equipped to enter the workforce and navigate a complex world. For an individual to possess higher order skills and critical thinking, he/she should have a good knowledge of Mathematics, since Mathematics, Science and Technology move hand in hand. As Baiyelo (2007) observed that Mathematics is widely regarded as the language of science and technology and Abiodun (1997) stated that, while science is the bedrock that provides the springboard for the growth of technology, Mathematics is the gate and key to the sciences. Ukeje (1997) further revealed that Mathematics has contributed enormously to the modern culture of Science and Technology. Hence, without mathematics there is no science, without science there is no modern technology and without modern technology, there is no modern society.

Furthermore, other researchers supported that Mathematics is considered as the bedrock of all scientific and technological breakthrough and advancement of all activities of human developments as well as the only language and cultural common to all studies (Harbor–Peter, 2000; Uzo, 2002). Mathematics is an expanding and evolving body of knowledge as well as a way of perceiving, formulating and solving problems in many disciplines. The subject is a constant interplay between the walls of thought and applications. Therefore, there is need for professional development of Mathematics Educators for effective teaching and meaningful learning in both Open and Distance Learning (ODL), and conventional institutions, especially at higher level of education.

Higher Education is considered as the pinnacle of the educational pyramid (Odili, 2011), as education in itself is the most important instrument of change in any society (FME, 2004) and any fundamental change in the intellectual and social outlook of any society has to be preceded by an educational revolution in Nigeria came in form of open and Distance education. Thus, ODL has been integrated and recognized as a viable alternative to the conventional (face-to-face) system of tertiary education.

According to UNESCO (2002), Open and Distance Learning (ODL) represents approaches that focus on opening access to Educational and training provision, freeing learners from the constraints of time and place, and offering flexible learning opportunities to individuals and group of learners. Peratton & Hulsman(2003) and Creed (2001) defined Distance Learning as an educational process in which a significance proportion of the teaching is conducted by someone far removed in space and/or time from the learner. Open learning in turn, is an organized educational activity, based on the use of teaching materials, in which the constraints on study are minimized in terms of access, entry or time and space, method of study, or any contribution of these. Hence, the concept of Open and Distance Learning (ODL) suggest an educational approach designed to reach learners in their homes, offices, shops, amongst others, providing the learning resources for them to quality without attending formal classes in person, or create opportunities for lifelong learning, no matter where or when they want to study (Ojo, Rotimi & Kayode, 2006).

The National Policy on Education (FME, 2004) recognized the place of ODL in achieving lifelong education. Some institutions are uni-mode while others are dual mode Institutions. The uni-mode institutions are delivered either through the conventional methods or distance learning methods of instructions. The dual mode institutions combine conventional and distance learning methods of instructions.

ODL system of Education is seen as a Panacea to the problem of socially induced constraints on the acquisition of education that may lead to the ability to attend higher institutions of learning, acquire certificate, and become a qualified skilled worker by being able to study for the course of study chosen by individual. Thus, Nations of the world, in recognition of this, sought to provide quality education for majority of their citizens in an equitable and accessible manner. This is contingent on the realization of the leaders that a nexus exist between education and nation development processes (Jegede, 2000). This reality has led many countries, developed and developing alike, to make huge investments in the education of their people. This effort is gearing towards fulfilling the nations commitment in provide education to all as declared by the World Forum on Education For All (EFA) 2015 goals. FME, (2002) clearly stated the goals as:

> … ensuring that the learning needs of all young people and adults are met through equitable access to appropriate learning and life skills programmes; and improving all aspects of quality of Education, and ensuring excellence for all so that recognized and measurable learning outcomes are achieved especially in literacy, numeracy and essential life skills. By giving this opportunity to maximize the use of high-level academic personnel who would be able to teach larger numbers of students especially after sustainable distance learning materials are developed and distributed.

Thus, effective adoption of ODL calls for professional development of Mathematics educators who are part of the servicing staff of the Institutions in Nigeria - a professional development that prepares Mathematics Educators to integrate 21st century skills in ODL environment for effective and meaningful learning.

In response to the strong social demand for access to tertiary education in Nigeria, the National Open University of Nigeria (NOUN) was established and now has 53 study centres. NOUN is a responsive model for higher education which will hopefully reduce the challenges of gaining access to tertiary education as well as to create a vehicle for delivery of continuing professional development. As a result of shortage of manpower (severe shortage of qualified academic staff, and difficulties of recruiting and retaining academic staff) in Nigeria Universities, the Open Universities of Nigeria has to crave and thrive by depending highly on collaboration with the conventional Institutions for academic staff as instructional and tutorial facilitators (Okonkwo, 2005).

In ODL system of Education, Mathematics Lecturers are to conduct regular tutorial meetings and facilitate instructions in Mathematics and Mathematics based courses at a distance and at the various study centres. They are to assist with professional workshop, course development and course designs. Besides, they are responsible for tutor marked assignment, supervision of research projects and thesis as well as assisting on the conduct and marking of examination.

In addition, Knowledge Management Technologists are required to support the electronics and computer mediated learning environment created as a result of the ODL (NOUN, 2004; Okonkwo, 2005). However, Mathematics Educators are faced with the challenges brought about by the emergent globalize system of education in the 21st century. In line with this trend of events, UNESCO (2008) observed that one of the solutions to the challenges to educational development is the use of ICT. Mathematics, Science and Technology Educators can make use of benefits of technologies for effective teaching and meaningful learning. This study therefore, looked at professional development of Mathematics Educators in line with identified needs, challenges and benefits in collaboration between ODL and Conventional system of Education. Effective collaboration between Mathematics Educators and ODL Institutions is imperative in meeting the challenges for sustainable development in the system.

1.1 Objective

The objectives of the study include:

i. To identify the extent to which the collaboration between ODL and Conventional Institution contributes to best practices in areas of needs in Nigeria's ODL Institutions;
ii. To identify the extent to which the challenges hinder best practices in the collaboration between ODL and Conventional Institutions in Nigeria;
iii. To identify the extent to which result from collaboration between ODL and Conventional Institutions beneficial to Nigerian's ODL Institutions; and
iv. To determine the extent use of technology in ODL Institutions enhance sustainable development in Nigeria system of Education.

1.2 Research Questions

The study answered the following research questions:

i. To what extent does collaboration between ODL and Conventional Institutions contribute to best practices in areas of needs in Nigeria's ODL Institutions?
ii. To what extent do challenges hinder best practices in the collaboration between ODL and Conventional Institutions in Nigeria?
iii. To what extent does result from collaboration between ODL and Conventional Institutions beneficial to Nigeria's ODL Institution?
iv. To what extent does use of technology in ODL Institutions enhance sustainable development in Nigeria system of Education?

1.3 Hypotheses

The following hypotheses were tested:

H_O1: Collaboration between ODL and Conventional Institutions has no significance contribution to best practices in areas of needs in Nigeria's ODL Institutions.

H_O2: Collaboration between ODL and Conventional Institutions has no Significance challenges that hinder best practices in Nigeria's ODL Institutions.

H_O3: Result from collaboration between ODL and Conventional Institutions has no significance benefits to Nigeria's ODL Institutions.

H_O4: Use of technology in ODL does not enhance sustainable development in Nigeria system of Education.

1.4 Significance of the Study

This study would provide insight on empirical evidence on the collaboration effort of Mathematics Teachers in teaching and learning Mathematics at the ODL Institutions and improve upon. It would help Mathematics teachers to discover the effect of their interest, participation in professional development programme, production and supply of adequate resource materials, their workload and attitudes towards effective teaching and meaningful learning in Mathematics.

The findings of this study would lead to the improvement of the qualities of Mathematics Teachers, as their professional interest would be taken into consideration during their engagement in the service of ODL programme. Above all, the study would add to the pool of knowledge in the area of effective teaching and meaningful learning in Mathematics as well as a serving as the springboard for further researches in Mathematics education in Nigeria and beyond.

2. METHODOLOGY

2.1 Research Design

The study adopted a survey design in order to determine the professional development of Mathematics Educators towards Collaboration between ODL and conventional institutions as it affects areas of needs, challenges, benefits and technology.

2.2 Participants

The population for this study is the staff of the 53 study centres of NOUN in the six Geo-political zones of Nigeria – North-West, North-East, North-Central, South-West, South-East and South-South zone.

Sample drawn from the population consist of academic staff of NOUN, using both male and female academic staff serving in NOUN with minimum qualifications of master Degree in Mathematics and Mathematics related subjects. They have varied teaching experiences in tertiary institutions from 2 years and above. Sixty academic staff (10 from each Geo-political zone) consisting of course coordinators and programme leaders were randomly selected because they are directly involved in the collaborative processes.

2.3 Research Instruments

The data for this study were collected by using structured questionnaire developed by Olaitan and Nwoke (1988) where 5-point Likert scale was adopted in structuring the questionnaire items. Five responses; Strongly Agree (SA); Agree (A); undecided (U); Disagree (D) and strongly Disagree (SD) were obtained and the response were assigned weights of 5; 4; 3; 2 and 1 for favourable statements. The study used 40 questionnaire items and 10 each for the 4 research questions and hypothesis.

2.4 Administration of Instruments

The instruments were administered by the researcher and 3 research assistants. Sixty copies questionnaire were administered and were all retrieved.

2.5 Data Analysis

The data were analyzed by computing the mean, variance and standard deviation for each item in answering research questions and chi square (X^2) was used in answering the research hypotheses at 5% level significance. To take a decision whether an identified factor is indicated by the respondents should be accepted as significance and contribute to best practices in collaborative areas of needs, challenges, benefits of technology, the researcher choose a mean score of 3.50 and above while an item that scored less than 3.50 was not accepted. However, the variance (V) and standard Deviation (SD) were also computed to show how individual scores from the mean scores were dispersed.

3. FINDINGS AND DISCUSSION

The results of the findings are presented in tables and the 4 tables reflected on the 4 research questions and hypotheses. The tables show the mean, variance, standard deviation as well as the observed frequencies (f_o) and Expected (f_e) in which decision regarding the research questions and hypotheses are presented.

3.1 Research Questions

Table 1. The Extent to Which the Collaboration between ODL and Conventional Institutions Contributes to Best Practices in Areas of Needs in Nigeria.

S/N	ITEM	5	4	3	2	1	X	V	SD	Decision
1.	Provision of skilled manpower for item writing tailored to enrich question bank	17	35	7	0	1	4.12	0.54	0.73	Accept
2.	Provision of right personnel for conduct of examination	9	34	11	6	0	3.77	0.66	0.81	Accept
3.	Subject specialists for marking candidates' examination answer scripts	19	32	5	4	0	4.99	0.67	0.82	Accept
4.	Proper orientation of personnel's involved in examination related activities	15	26	7	8	4	3.67	1.39	1.18	Accept
5.	Skilled manpower for tutorial and academic counseling of distance Learners	16	30	3	5	6	3.75	1.32	1.15	Accept
6.	Adequate financial resources to take care of the services provided	16	25	7	8	4	3.68	1.42	1.19	Reject
7.	Skilled manpower for effective supervision of students' projects and practical	16	25	7	7	5	3.70	0.66	0.81	Accept
8.	Development of enriched course materials by experienced academics in conventional institutions	20	37	2	1	0	4.27	0.58	0.76	Accept
9.	Pooling of expertise leading to course content integrity in line with NUC standard	28	21	6	4	1	4.18	0.78	0.89	Accept
10.	Capacity building for staff of conventional institutions to expertise in various areas of distance learning	16	31	5	5	3	3.87	1.12	1.06	Accept
	Total	172	296	60	48	24				

Expected Frequencies 17.2, 29.6, 6.0, 4.8, 2.4

X^2: Cal (66.16), df = 36, Crit. (40.11)

From the responses of the respondents in the table 1, all the 10 items of the questionnaire were accepted to be significant. It is an indication that effective collaboration between ODL and Conventional Institutions lead to best practices in areas of needs in Nigeria's ODL Institutions. The responses to the items also show that qualitative and skilled personnel reveal the importance Mathematics Educators in these areas of needs for effective professional development.

Table 2. The Extent to Which the Challenges Hinder Best Practices in the Collaboration between ODL and Conventional Institutions in Nigeria.

S/N	ITEMS	5	4	3	2	1	X	V	SD	Decision
1.	Provides of facilities by conventional institutions may not be readily available	12	26	5	10	7	3.43	1.68	1.30	Accept
2.	Available facilities may be inadequate in number	24	30	1	3	2	4.18	0.88	0.94	Accept
3.	Available facilities lack ODL needs like ICT support for efficiency of operations	15	26	2	14	3	3.60	1.51	1.21	Accept
4.	Some higher conventional staff may have different orientation and are difficult to manage	20	29	5	6	0	4.05	0.68	0.83	Accept
5.	Remuneration of course writers is not worth the effort due to scarcity of fund	28	23	4	3	2	4.28	0.60	0.78	Accept
6.	Course writers are unwilling to cede write course materials to ODL institutions	20	31	1	5	3	4.00	1.13	1.06	Accept
7.	Course writers prefer to write textbooks, publish and earn royalty on them	26	28	3	3	0	4.28	0.60	0.78	Accept
8.	Capacity building of hired part time personnel for effective ODL delivery is not adequate.	5	28	0	9	8	3.22	1.27	1.13	Reject
9.	Bough-in materials may raise curriculum and cultural issues	12	30	7	5	6	3.60	1.40	1.18	Accept
10.	The cost of adaptation and translation of bought – in course materials is significant	10	31	6	7	6	3.53	1.42	1.19	Accept
	Total	172	264	5	76	3				

Expected Frequencies 17.2, 26.4, 5.1, 7.6, 3.7

X^2: Cal (96.11), df = 36, Crit. (40.11)

Table 2 shows that there are various challenges that hinder best practices in collaboration between ODL and conventional institutions in Nigeria. Except that capacity building of hired personnel for effective ODL Programme is found to be inadequate. These challenges arose as a result of improper implementations of principles guiding the operation of ODL programmes. There should be strict compliance of guiding principles as presented by the National University Commission (NUC) in Nigeria. Proper professional development should be made for Mathematics teachers and other personnel in order to forestall the challenges faced by the ODL Institutions. This can be done through regular training and retaining as well as organizing of workshops, seminars, conference and public enlightenment on issues that relates to ODL system of education. These activities will go a long way in updating the staff knowledge and eliminating the challenges that hinders effective collaboration. The management of ODL Institutions should plan strategies that will change the attitude of professionals and bring about acceptable conditions for collaboration in area of manpower need, such as course materials development, effective teaching and meaningful learning.

Table 3:The Extent to Which Result from Collaboration between ODL and Conventional Institutions Beneficial to Nigeria's ODL Institutions.

S/N	ITEM	5	4	3	2	1	X	V	SD	Decision
1.	Provides increase access to learning opportunities as well as geographical access	29	20	0	6	5	4.03	1.63	1.28	Accept
2.	Provide increase opportunities for updating, retraining and personnel enrichment	26	27	3	2	2	4.22	0.87	0.93	Accept
3.	Supports the quantity and quality of existing educational structures	19	21	1	12	7	3.55	1.98	1.41	Accept
4.	Provision of tutoring and academic counseling of ODL learners	17	29	11	2	1	3.98	0.75	1.87	Accept
5.	Balancing educational inequalities between age groups and between genders	18	30	4	6	2	3.93	1.06	1.03	Accept
6.	Enhances item development, conduct of exams and marking of answer scripts	20	31	1	5	3	4.00	1.13	1.06	Accept
7.	Enhances readiness of course materials as at when needed	14	28	6	8	4	3.67	1.36	1.16	Accept
8.	Production of quality course material because of the expert input from the conventional system	11	32	5	7	5	3.62	1.33	1.15	Accept
9.	It is effective to hire manpower on part time basis, reduces overhead cost	10	29	9	11	1	3.60	1.04	1.02	Accept
10.	Helps to popularize ODL activities and boost quality assurance	30	23	0	5	2	4.23	1.08	1.04	Accept
	Total	194	270	40	64	32				

Expected Frequencies 19.4, 27, 4, 6.4, 3.2

X^2: Cal. (82.36), df = 36, Crit (40.11)

In table 3, respondents have indicated the benefits derived from effective collaboration between ODL and Conventional Institutions in Nigeria. The findings have also revealed that Mathematics teachers have important roles to play in order to ensure positive attitudes towards the programmes and sustain the benefits. This can be done through professional development of the Professionals. Thus, Mathematics Teachers preparation should take note of these benefits and plan strategies that would enhance their realization in the classroom for effective teaching and meaningful learning in ODL Institutions.

Table 4. **The Extent to Which Use of Technology in ODL Institutions Enhance Sustainable Development in Nigeria System of Education.**

S/N	ITEM	5	4	3	2	1	X	V	SD	Decision
1.	Enhances outreach of ODL provisions to distance learners and individualization of instruction	25	21	6	8	0	3.85	1.09	1.04	Accept
2.	Leads to easier access to information & wider range of opportunities for learning	30	18	6	4	2	4.17	1.14	1.07	Accept
3.	Helps to overcome geographical distance & lack of educational infrastructure	21	23	7	5	4	3.87	1.37	1.17	Accept
4.	Helps to overcome personal, cultural and social barriers to learning	20	28	6	6	0	4.03	0.83	0.91	Accept
5.	Facilitates the collaboration with international, regional and sub-regional networks	26	27	3	4	0	4.25	0.69	0.83	Accept
6.	Enhances partnership with information, communication and industrial sectors.	22	25	7	5	1	4.13	0.98	0.99	Accept
7.	Enhances the generations of public interest in the use of ODL mode of schooling	10	35	6	4	5	3.68	1.18	1.09	Accept
8.	Allows for new delivery system such as use of simulation techniques	17	25	8	6	4	3.75	1.36	1.16	Accept
9.	Provides increased opportunities for updating re-training and personal enrichment	11	29	8	9	3	3.77	1.24	1.11	Accept
10.	Delivers educational campaigns and other information to large audiences	26	25	3	4	2	4.15	1.03	1.01	Accept
	Total	208	256	60	55	21				

Expected frequencies 20.8 25.6 6 5.5 2.1

X^2: Cal(52.23), df = 36, Crit(40.11)

In table 4, the respondents have indicated that use of technology enhances best practices in areas of needs and benefits of ODL in Nigeria system of education are enormous. It also confirmed that the challenges of education for sustainable development in the country would reduce to the barest minimum and in particular, remedy those challenges that hinder best practices in ODL Institutions.

3.2 Hypotheses

The essence of the research hypotheses is to further confirmed the findings in the research questions. The hypotheses were tested at 27 degree of freedom and 5% level significance.

H_O1: In table 1, the calculated value of is 66.16 while the critical value is 49.77. Hence, Cal(66.16) > Crit(49.77), reject the H_O in favour of H_a. This implies that collaboration between ODL and Conventional Institutions has significance contribution to best practices in areas of need in Nigeria's ODL Institutions.

H_O2: The result in table 2 shows that calculated value is 96.11 while the critical value is 49.77. Thus, Cal(96.11) > Crit(49.77), which reject H_O in favour of H_a. This implies that collaboration between ODL and Conventional Institutions has significance challenges that hinder best practices in Nigeria's ODL Institutions.

H_O3: In table 3, the calculated is 82.36 while critical value is 49.77. Hence, Cal(82.36) > Crit(49.77), which reject the HO in favour of Ha. This also implies that result from collaboration between ODL and Conventional Institutions has significance benefits to Nigeria's ODL Institutions.

H_O4: The result in table 4 shows that calculated value is 52.23 while the critical value is 49.77. Thus, Cal(52.23) > Crit(49.77), which reject the H_O in favour H_a. This implies that use of technology enhances sustainable development in Nigeria system of education.

The results of the tested hypotheses correspond with the results of research questions that collaboration between ODL and Conventional Institutions contribute to best practices in areas of needs, challenges, benefits and technology in Nigeria's ODL Institutions. This result is also in line with the contribution of NOUN (2004) and Okonkwo (2005), and realization of Education For All (EFA) initiative in Nigeria.

This sustainable development in education can not be achieve without an extended outreach and qualitative improvements in individualization of instructions, access to information and better use of modern techniques through professional development of Mathematics Teachers who offer some of these services. Since Mathematics is the language of science and technology (Baiyelo, 2007), and the gate and key to the Sciences (Abiodun, 1997), Mathematics Educators are to be trained and retrained in the pedagogy, to possess efficient and adequate ICT skills needed in the globalization of education.

4. CONCLUSION

The carrying capacity of Conventional Institutions is not enough and cannot ensure that the learning needs of all Nigerian citizens are met. Therefore, adoption of ODL calls for professional development of Mathematics Educators who are part of high-level academic personnel needed for ODL delivery in Nigeria, and in response to strong social demand for access to tertiary education. More so, professional development of Mathematics Educators toward effective collaboration between ODL and Conventional Institutions is a move in the right direction for realization of Education For All (EFA) initiative in Nigeria. Therefore, it is obvious that Open and Distance Education has come to stay as a viable alternative to the Conventional Education System in Nigeria and rely largely on the service provided by Conventional System of Education.

The implications of the findings call for Professional development of Mathematics Educators to be able to:

- Product instructional course materials for ODL;
- Use modern technologies for effective teaching and meaningful learning in large class size at a distance;
- Develop modern pedagogy of ODL – use of simulations, audio and video conferencing, online instruction and evaluation, etc.
- Use modern technology in assessment of learning outcomes.
- Forestall the challenges faced by ODL Institutions, taking cognizance of benefits derived from ODL and plan strategies that would enhance realization of the set goals of NUC and Education For All (EFA) initiative in Nigeria.

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RELATIONSHIP BETWEEN LEARNERS' MATHEMATICS-RELATED BELIEF SYSTEMS AND THEIR APPROACH TO NON-ROUTINE MATHEMATICAL PROBLEM SOLVING: A CASE STUDY OF THREE HIGH SCHOOLS IN TSHWANE NORTH DISTRICT (D3), SOUTH AFRICA

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Abstract–This study aims to determine if there is a relationship between High School learners' mathematics-related belief systems and their approach to mathematical non-routine problem-solving. Data was collected, firstly, from 425 high school learners using survey questionnaires and mathematics non-routine problem test and, lastly, from six cases selected from the 425 learners using interview schedules, open-ended and retrospective questionnaires. The basic methods used to analyze the data were factor analysis, thematic analysis and methodological triangulation. Learners' mathematics-related beliefs were classified into three categories, according to Daskalogianni and Simpson's (2001) macro-belief systems: utilitarian, systematic and exploratory. A number of learners' problem solving strategies that reflected their general behaviour in non-routine mathematical problem solving were identified, that include unsystematic guess, check and revise; systematic guess, check and revise; trial-and-error; systematic listing; looking for a pattern; making a model; and considering a simple case. A weak positive linear relationship between learners' mathematics-related belief systems and their approaches to non-routine problem solving was discovered.

Keywords: mathematics-related belief system, problem solving, non-routine problem solving, approach to mathematical non-routine problem solving

1 INTRODUCTION

Studies conducted over the past twenty years on South African learners' problem solving abilities discovered that the learners lack adequate problem solving strategies and skills (e.g., Maree, Aldous, Swanepoel, & Vander Linde, 2006; and Wessels, 2012). Similar findings were also discovered in some other countries, for example, Netherlands (Kolovou, Heuvel-Panhuizen, Bakker, & Elia, 2011), Chile, Phillipines and Indonesia (HSRC, 2006), and Malaysia (Zanzali & Nam, 1997). There seems to be a debate among mathematics education researchers on to whom learners' deficiencies or incompetence on problem solving should be attributed to. Some researchers blame the high school classroom mathematics as not preparing learners adequately to solve non-routine problems (e.g., Mabilangan, Limjap, & Belecina, 2011). Some researchers (e.g., Maree et al., 2006; and Wessels, 2012), attach the blame to mathematics educators who fail to prepare learners for non-routine problem solving because of various reasons, such as, teacher adopting a traditional teaching approach and teacher's inadequate mastery of mathematics content.

Some researchers, e.g., Lester (2013) and Kolovou et al. (2011), argue that teachers are not to blame but the whole mathematics education community should bear the blame. Kolovou et al. (2011) posit that research findings have not yet revealed much on how learners approach non-routine mathematical problems and how teachers can facilitate or support learners to solve the problems. Lester (2013) states that, as of to date, among all the research studies conducted aimed at enhancing learners' meta-cognitive abilities in problem-solving, none has identified the proficiencies teachers need to do this.

In search of a solution to learner performance in mathematics, over the past twenty years, there seems to be an interest among some researchers on the effects of beliefs to performance in mathematics (e.g., Callejo & Vila, 2009; and Daskalogianni & Simpson, 2001). Though the researchers attempted to unravel the relationship between beliefs and other constructs such as learners' performance, problem solving behaviour, mathematics learning, motivation, meta-cognition, just to mention a few, there is still a lack of clarity on how learners' beliefs are related to their mathematical problem solving. Rather, contradictory conclusions were reached. For example, Daskalogianni and Simpson (2001) assume a causal relation; Spangler (1992) views the relationship as cyclic; and Callejo and Vila (2009) and Goldin, Rosken, & Torner (2009) assume no causality, but, rather, view the relationship between them as complex.

The present study determined if there is a relationship between high school learners' mathematics-related belief systems and their approaches to non-routine mathematics problem solving. As the classroom instruction do not prepare learners to solve non-routine mathematical problems effectively (Kolovou et al., 2011), the researcher conjectures that learners' mathematics-related belief systems do guide their mathematics problem solving behaviour.

2. CONCEPTUAL FRAMEWORK

2.1. Mathematics-related belief systems

Several scholars expressed their views on the definition of belief systems (e.g. Benbow, 2004; Callejo & Vila, 2009; Op`t Eynde, De Corte, & Verschaffel, 2006; Schoenfeld, 1985). Some researchers define a belief system in terms of its components (e.g, Op`t Eynde et al., 2006; Schoenfeld, 1985); while some researchers define it as a way one's beliefs are organized (e.g, Benbow, 2004; Callejo & Villa, 2009). In this study, the researcher viewed mathematics related belief systems as perceived by both Schoenfeld (1985) and Op`t Eynde et al. (2006). As such, he viewed mathematics-related belief systems as the conscious and unconscious subjective conceptions learners hold to be true about mathematics education, about themselves as learners of mathematics and about the mathematics class context that determine their approach to mathematics and mathematical tasks.

Daskalogianni and Simpson (2001), Jin, Feng, Liu, and Dai (2010), Lazim, Abu Osman, and Wan Salihin (2003), Op`t Eynde et al. (2006), and Schoenfeld (1992) are some of the researchers who gave different categories of mathematics-related belief systems. The categories proposed by these researchers reveal a lack of consensus among them on the precise categories of beliefs. Though there are quite a number of belief systems, in this study, the researcher classified learners' beliefs according to Daskalogianni and Simpson's (2001) belief systems (systematic, exploratory and utilitarian) (see table 1). Daskalogianni and Simpson's (2001) macro-belief systems appealed to the researcher because they provided examples of beliefs that fall into each category which guided him to classify learners' beliefs more appropriately into the respective belief systems.

Table 1: Macro- and micro-belief systems.

		MACRO-BELIEFS		
		Systematic	Exploratory	Utilitarian
MICRO-BELIEFS	Nature of mathematics	Methodical, logical	Problem-solving, linking things	Tool for other subjects, applied in life
	Focus of exercises	Follow series of steps	Understand different ways of thinking	Obtain correct exam answer
	Working in mathematics	Exact answer, similar exercises	Explore things, enjoy challenge	Known algorithms, study techniques
	Didactical contract	Dependence on notes and teacher	Dependence on own abilities	Dependence on teacher

Adopted from Daskalogianni and Simpson (2001, p. 15).

Learners whose macro belief systems can be classified as 'systematic' believe that mathematics is a static subject that is made up of a rigid body of knowledge. They are at easy with exercises where they have to apply previously practiced methods or strategies. As such, they also view mathematics as a logical and methodical subject, and view mathematical exercises as tasks that have exact answers and whose solution process involves a series of steps. When working on problems, they constantly refer back to notes and depend much on the teacher.

Learners whose macro belief systems can be classified as 'exploratory' view mathematics as dynamic. They believe that new mathematical truths, concepts and approaches to problem solving are under discovery. They view mathematics as involving problem solving, and having more than one correct answer. They also enjoy the challenge of new exercises and they do look for connections or links between the concepts learnt. They depend much on their own abilities on learning and solving mathematical problems.

Learners, whose macro belief systems can be classified as 'utilitarian', view mathematics as a tool for other subjects and as a subject that can be applied to solving real life problems. They focus much on study techniques and expect to obtain correct answers in exercises or exams. They approach mathematical problem solving by applying well known algorithms and numerical techniques. Utilitarian believers tend to depend much on the teacher in learning mathematics and problem solving.

2.2. Mathematical problem solving heuristics, approaches or strategies

The researcher defines problem solving as a process of applying previously acquired knowledge to new and unfamiliar situations. Unlike a routine mathematical question which a learner knows how to resolve immediately, a non-routine mathematical question requires a learner to apply creative thinking and resourcefulness in search of an appropriate problem solving approach (Bunday, 2013; Branca, 1980). In this study, what the researcher considered as important in problem solving were the methods, procedures, strategies, and heuristics that learners used in solving the problems.

Schoenfeld (1985) defines heuristic as rules of thumb that can be used when solving problems. Elia, Van den Heuvel-Panhuizen, and Kolovou (2009) classify heuristic strategies into cognitive (e.g., working backwards, finding a pattern; using analogies; considering extreme cases; visual representation; intelligent guessing and testing; systematically accounting for all possibilities; and deductive reasoning) and meta-cognitive strategies (e.g., decomposing the problem, monitoring the solution process, evaluating, and verifying results). However we should note that although a heuristic acts as a set of guidelines that a person applies to various situations, it does not guarantee success (as an algorithm) in problem solving. In this study, learners' cognitive and meta-cognitive approach strategies to problem solving were analyzed in connection to their mathematics-related belief systems.

In this context, this study attempted to determine if there is an observable relationship between, the 10th, 11th and 12th graders' mathematics-related belief systems and their approaches to non-routine mathematical problem-solving. The study addressed the following research questions:

1. What are the grade 10, 11, and 12 learners' mathematics-related belief systems?
2. Are the grade 10, 11, and 12 learners' approaches to mathematical non-routine problem solving?
3. Is there any relationship between learners' mathematics-related belief systems and their approach to mathematical non-routine problem-solving?

3. METHODOLOGY

This study employed a mixed methods study to determine and explain the nature of relationship between high school learners' mathematics-related belief systems and their approach to non-routine mathematical problem solving. A mixed methods design was adopted in consideration of the complexity of unravelling the relationship between the two constructs (Callejo & Vila, 2009). An explanatory sequential method design was used, and it is a design in which the qualitative data collected will be used to explain, in depth, the quantitative data previously collected (Cresswell, Klassen, Plano Clark, & Smith, 2011). In addition, the researcher adopted a positivist-interpretive paradigm in conducting the research study.

The primary purpose of this study was to use a beliefs questionnaire (close-ended) and mathematics non-routine problem solving test to determine learners' belief systems and approaches to problem solving, respectively. A secondary purpose was to gather qualitative data, by use of interviews and open-ended questionnaires, which explained the learners' beliefs and approaches to problem solving. The two data sets were, then, analysed to reveal the possible relationship between belief systems and approach to problem solving.

3.1 POPULATION AND CASE SELECTION

A convenience sample of 425 grade 10, 11 and 12 learners was selected from three high schools of Tshwane North District, Gauteng province of South Africa for participation in the study. All the selected learners, firstly, completed the mathematics beliefs questionnaire and then answered the mathematics problem solving test. The researcher used SPSS to cluster learners into two groups using the Hierarchical (complete linkage) method. He, then, purposefully selected six learners, three from each cluster as a case study on the basis of their degree of representative of learners belonging to each cluster. The selected learners participated in interviews and answered an open-ended questionnaire and a retrospective questionnaire.

3.2. DATA COLLECTION INSTRUMENTS

Mathematics beliefs questionnaire (BQ)

The researcher developed a 63-items mathematics-related beliefs questionnaire which he modelled on different beliefs questionnaires developed by Op't Eynde et al. (2006) and Physick (2010). The researcher conducted principal component factor analysis to assess 'construct validity' of the beliefs questionnaire. With the aid of a scree plot, five factors were identified that represented the 63 items loaded for factor analysis (See figure 1).

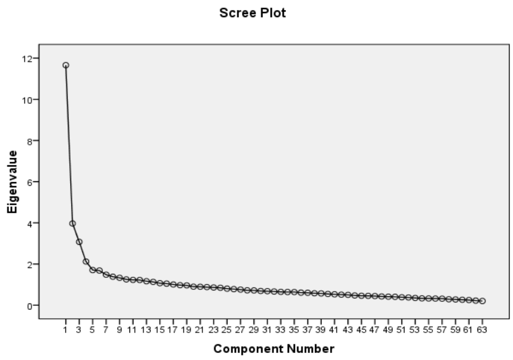

Figure 1: Scree plot showing number of components and eigenvalues of the correlation matrix

To facilitate analysis of BQ, the items were encoded in such a way that positive beliefs (that is, desirable or healthy beliefs about mathematics learning and problem solving) always gave a high value, while negative beliefs (that is, undesirable or unhealthy beliefs about mathematics learning and problem solving) gave a low value. For example, the belief: 'It is not important to understand why a mathematical procedure works as long as it gives the correct answer' was coded from 1 = "strongly agree" to 5 = "strongly disagree", and "For me the most important thing in learning maths is to understand" was coded from 5 = "strongly agree" to 1 = "strongly disagree".

To establish learners' beliefs about each scale used in this study, the researcher calculated the mean value of their responses to each scale. He considered a learner having an average score greater than 3 as holding that belief; and a mean score of 3 as holding a neutral belief. As such, a higher average belief score meant that the belief was held stronger than the other beliefs by the learner (Jin et al., 2010). The researcher used Daskalogianni and Simpson's (2001) key macro-belief systems (systematic, exploratory and utilitarian) to classify all the beliefs questionnaire items used in this study. Then, using the average score of each category in conjunction with the thematic analysis, he identified learners' predominant beliefs that largely influenced their behaviour in problem-solving.

To measure the reliability of the mathematics beliefs questionnaire, the researcher calculated the Cronbach's alpha on each factor. Factor 1 (I can do well in maths) had a very high reliability coefficient, **α** = 0,900. Similarly, factors 2 (I make sense of what I learn); 3 (Group work facilitates learning maths); and 4 (Maths is numbers, rules and techniques) had high reliability coefficients of 0,766; 0,816 and 0,696, respectively. Factor 5 (Maths is continuously evolving) had a slightly lower alpha of 0,557 as compared to the other four factors. After combining all the five factors, he concluded that the mathematics beliefs questionnaire was reliable.

To assess both convergent and discriminant validity of the beliefs questionnaire instrument, the researcher computed the correlation coefficients between the factors and represented them in form of a matrix (see table 2.1). The matrix of correlations revealed that the convergent coefficients were higher than the discriminant ones. Thus, the correlation matrix provided some evidence for both convergent and discriminant validity. By virtue of having evidence for both convergent and discriminant validity, the researcher concluded that the mathematics beliefs questionnaire was valid (Trochim, 2006).

Table 2.1: Extract of matrix of correlations between factors.

		FACTOR 1				FACTOR 2				FACTOR 3			
		Q16	Q14	Q12	Q43	Q34	Q33	Q36	Q37	Q21	Q27	Q30	Q38
FACTOR 1	Q16	**1**	**.629**	**.636**	**.437**	.333	.255	.227	.254	.173	.172	.119	.069
	Q14	**.629**	**1**	**.649**	**.447**	.312	.256	.310	.273	.066	.135	.094	.056
	Q12	**.636**	**.649**	**1**	**.482**	.339	.260	.271	.270	.101	.122	.111	.003
	Q43	**.437**	**.447**	**.482**	**1**	.250	.248	.189	.170	.156	.129	.095	.056
FACTOR 2	Q34	.333	.312	.339	.250	**1**	**.446**	**.389**	**.355**	.137	.138	.227	.024
	Q33	.255	.256	.260	.248	**.446**	**1**	**.340**	**.376**	.163	.158	.208	.049
	Q36	.227	.310	.271	.189	**.389**	**.340**	**1**	**.376**	.118	.109	.197	.044
	Q37	.254	.273	.270	.170	**.355**	**.376**	**.376**	**1**	.241	.229	.246	.196
FACTOR 3	Q21	.173	.066	.101	.156	.137	.163	.118	.241	**1**	**.370**	**.397**	**.355**
	Q27	.172	.135	.122	.129	.138	.158	.109	.229	**.370**	**1**	**.292**	**.311**
	Q30	.119	.094	.111	.095	.227	.208	.197	.246	**.397**	**.292**	**1**	**.404**
	Q38	.069	.056	.003	.056	.024	.049	.044	.196	**.355**	**.311**	**.404**	**1**

Mathematics problem solving test (PT)

The PT was made up of six multi-step, real life problems. The problems were adopted from Burton (1984); Greenes, Immerzel, Ockenga, Schulman, and Spungin (1986); Muis (2004) and Callejo and Vila (2009). The variables considered in selection of the problems were: (1) the problem should be comprehensible by the learners, (2) the problem requires no specialist mathematical knowledge, (3) facts and concepts to be applied, (4) strategies or approaches to be applied in solving the problem, and (5) the level of difficulty of the problem- demands of the questions should match the academic level of learners.

Problem 1 (P1) was an arithmetic sequence word problem. It required learners to look for pattern, list possible values or use an algorithm either derived from pattern analysis or from recognition. Problem 2 (P2) could be solved by use of logic (reasoning), or simple proportion, Problem 3 (P3) could be solved by use of an algebraic approach (forming an inequality). It expected learners to be able to manipulate inequalities, and look back to check if the answer makes sense.

Problem 4 (P4) could be solved by either logic (reasoning) or systematic trial and error. Problem 5 (P5) could be solved by an algebraic method (forming an equation) or by systematic trial and error. Problem 6 (P6) had no clear mathematics referents (i.e. had no numbers in its formulation). It could be solved by reasoning and algebraic method. Learners were also expected to be able to manipulate inequalities.

To identify the approaches applied by learners in solving problems, the researcher analyzed their written responses to the PT. Examples of approaches he sought from their written work were: random trial and error, systematic trial and error, seeking patterns, piece-wise, holistic, and non-attempts (blank answer sheet). He used the learners' approaches to problem-solving to infer their belief systems that explained their problem solving behaviour. To facilitate analysis of the learners' responses to the PT, the researcher formulated a coding scheme for each problem (Elia et al., 2009; Mabilangan et al., 2011) (see table 2.2).

Table 2.2: Extract of Coding scheme for the non-routine mathematics problem solving strategies

Category	Variable Name	Explanation
Systematic listing	SL	Making an organized list which is composed of at least three values. The steps are of the same size and trials 'move' in one direction.
Modeling	MD	Use of algebra (linear equations, simultaneous equations, linear inequalities), drawing diagrams, or sketches
Look for patterns	LP	Identifying some common characteristics that can be generalized and used to solve the problem.

Adapted from Elia, et al, (2009) and Mabilangan, et al (2011).

As suggested by Mabilangan et al. (2011), the researcher classified the problem solving strategies applied by learners into three main categories: (1) Thorough or insightful use of strategies, (2) Partial use of strategies, and (3) Limited strategies (see table 2.3). To facilitate analysis of the approaches or strategies employed by learners to problem solving, a point system was used: 5 points for insightful use of strategies, 3 points for partial use of strategies, and 1 point for limited use of strategies. 2 points were assigned to an approach in between limited and partial use of strategies. Similarly, 4 points were assigned to an approach in between partial and insightful use of strategies (Mabilangan et al., 2011). A score of 0 was assigned to a blank answer sheet. As such, the researcher used the table that classifies problem solving strategies as a marking rubric in this study.

Table 2.3: Classification of problem solving strategies

Thorough/ Insightful use of strategies	Partial use of strategies	Limited strategies
The strategies show some evidence of insightful thinking to explore the problem. **The learner's work is clear and focused.** **The strategies are appropriate and demonstrate some insightful thinking.** **The learner gives possible extensions or generalizations to the solution or the problem.**	The strategies have some focus, but clarity is limited. The learner applies a strategy which is only partially useful. The learner starts the problem appropriately, but changes to an incorrect focus. The learner recognizes the pattern or relationship, but expands it incorrectly.	The strategies lack a central focus and the details are sketchy or not present. The procedures are not recorded (i.e., only the solution is present). Strategies are random. The learner does not fully explore the problem and look for concepts, patterns or relationships. The learner fails to see alternative solutions that the problem requires.

Adopted from Mabilangan et al. (2011, p. 28).

The content of the mathematics problem solving test was validated by two public high school heads of mathematics department and three high school mathematics teachers. To measure the reliability of the test, the researcher computed Spearman-Brown coefficient measure of reliability. The researcher obtained a coefficient of 0,509 which he regarded as lower than expected (0.70 and higher) (Maree et al., 2006) probably because most learners faced difficulties on solving the non-routine problems.

Open-ended Questionnaire (OQ) and Retrospective questionnaire (RQ)
The OQ was made up of seven questions the researcher wanted to follow up from the case studies. The RQ was made up of both closed and open questions (see Lucangeli & Cabrele, 2006). The RQ gave the respondents an opportunity to reflect on how they solved each problem, explain the approaches they employed, state any obstacles or difficulties met in problem solving, and their perception on whether they had solved the problems correctly. Basically, it tested learners' meta-cognitive skills of predicting, monitoring and evaluating their problem solving process.

Interview Schedule
The interview was semi-structured and pre-sequenced. The researcher selected five basic common questions that were based on learners' responses to the beliefs questionnaire. He requested the respondents to state reasons why they chose the specific rating for each belief item he selected from the beliefs questionnaire. Any other interesting leads that emerged during the interview were also discussed. Data from semi-structured interviews and questionnaires were cross-validated through convergent validity. Converging as well as diverging responses were noted and interpreted, thereof. In this regard, Anderson (1990) argues that conclusions suggested by different data sources are far stronger than those suggested by one alone. Reliability was determined by the consistency of the responses got from the interviewees.

4 FINDINGS

Learners' mathematics-related belief systems

As mentioned above, the items of the beliefs questionnaire were classified into three sub-categories according to Daskalogianni and Simpson's (2001) three key macro-belief systems, namely systematic, exploratory and utilitarian. By calculating the mean score of each of the three belief systems (see table 3.1), the learners' strongly held belief systems were identified as follows: The researcher considered a learner having a mean score greater than 3 as holding a certain belief, and the greater the score the more strongly held the belief is (Jin et al., 2010).

Table 3.1: Selected learners' mathematics related belief systems mean scores

Learner	Mean belief score		
	Systematic	exploratory	utilitarian
A26	3.39	3.65	3.68
A31	4.11	3.87	4.21
B08	3.94	3.48	4.05
B57	4.50	4.65	4.63
C27	3.94	3.87	3.74
F43	3.83	3.87	3.95

The table shows that each learner holds all the three belief systems, since their scores are all more than 3 in all the belief systems. The researcher considered the belief systems with higher scores as the predominant set of beliefs that could possibly explain the learners' approaches to problem solving. Using table 3.1 and based on the predominant belief systems, four learners, A26, A31, B08 and F43, were classified as utilitarian believers; one learner, B57, was classified as an exploratory believer; and one learner, C27, was classified as a systematic believer.

Out of 425 learners, 32 learners were systematic believers, 255 learners were exploratory believers and 122 learners were utilitarian believers. 10 learners were classified as neutral believers because they had mean belief scores which were less than or equal to 3. One learner had two equivalent highest mean scores of systematic and exploratory belief systems. 5 learners had, each, two equivalent highest mean scores of exploratory and utilitarian belief systems. In order to understand the constituents of each belief system, the researcher analyzed learners' responses to beliefs questionnaire in conjunction with their responses to retrospective questionnaire and interviews. The researcher, also, inferred some beliefs from learners' solutions to non-routine problems.

Most of the learners (99.1%) scored points between three and five, inclusively, on beliefs questionnaire (see table 3.2). This percentage (99.1%) could be extremely high and questionable.

The mean belief score of 425 learners was 3.73 and a standard deviation of 0.504. A mean score of 3.73 in beliefs indicated, in this study, that the learners held the beliefs in question. However, when answering the beliefs questionnaire, it is possible for a learner to choose the socially acceptable beliefs and fail to reveal his/her actual beliefs in mathematics problem solving. A similar finding was discovered by HSRC (2006) who discovered that South African learners stated some socially acceptable attitudes to mathematics other than their real attitudes. A qualitative analysis of the relationship between learners' mathematics-related belief systems and their approach to non-routine mathematical problem solving took into consideration learners' beliefs that were derived and inferred from responses on interviews, open-ended questionnaire and non-routine mathematics problem solving test to counteract the weaknesses of the closed-form beliefs questionnaire whereby learners might choose only the socially acceptable beliefs and hide their actual beliefs.

Table 3.2: Beliefs mean score frequencies. N = 425.

Mean Score (Nearest whole no.)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1	.2	.2	.2
	2	3	.7	.7	.9
	3	112	26.4	26.4	27.3
	4	303	71.3	71.3	98.6
	5	6	1.4	1.4	100.0
	Total	425	100.0	100.0	

Learners' non-routine mathematical problem solving strategies

For in-depth study, the researcher focused on the solution strategies and answers of the six learners he selected since they represented each category of learner clusters as indicated above. The six selected learners solved the problems using the following strategies: Systematic Listing (SL); Modeling (MD); Trial-and-error (TE); Use a Formula (F); Systematic Guess, Check and Revise (GCR(sys)); Unsystematic Guess, Check and Revise (GCR(unsys)); Consider a simple case (SC); Logical reasoning (LG); No logical reasoning (NLG); and Look for patterns (LP). (See table 3.3). Figures 2, 3 and 4 present examples of learners' written solutions to the problems.

Table 3.3: Summary of strategies applied by learners in solving the six non-routine problems.

							Problem					
							P1	P2	P3	P4	P5	P6
Learner	A26						GCR(unsys)	SC; LG	NLG	NLG; GCR(unsys)	NLG	SC; MD
	A31						SL	LG	GCR(unsys)	NLG; GCR(unsys)	SC; GCR(unsys)	MD; SC; LG
	B08						GCR(unsys)	SC; LG	GCR(unsys)	MD; GCR(unsys)	GCR(unsys)	MD
	B57						SL;LP; MD	SC; LG	MD	MD; TE	NLG; MD	MD; SC;TE
	C27					GCR(unsys)	LG	GCR(unsys)	NLG; GCR(unsys)	MD; GCR(unsys)	MD	
	F43	GCR(unsys)	LG	SC	MD; LG	MD	MD; LG					

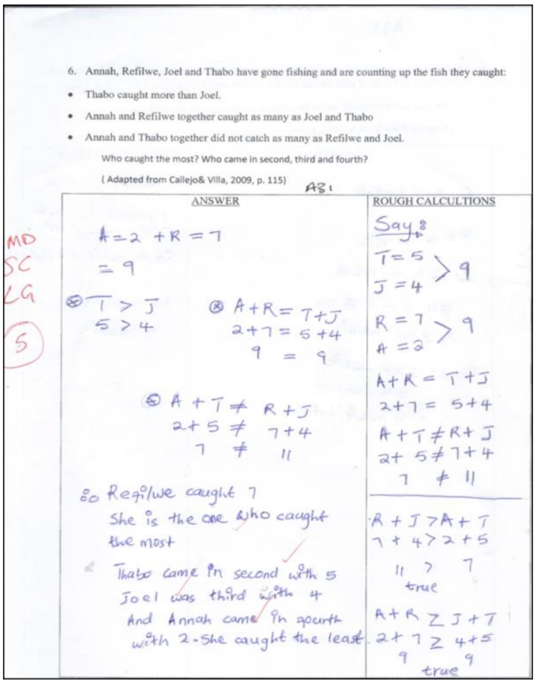

Figure 2: Learner A31's solution to P6.

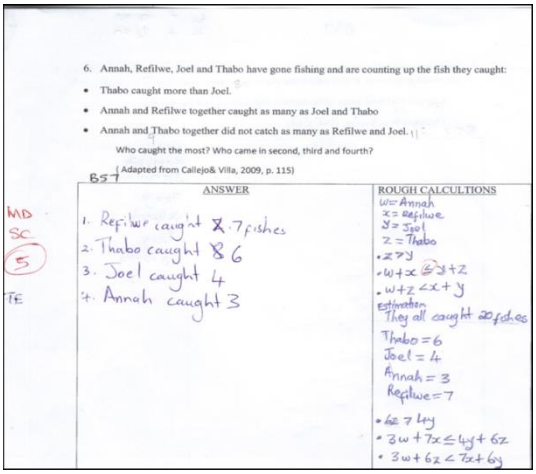

Figure 3: Learner B57's solution to P6.

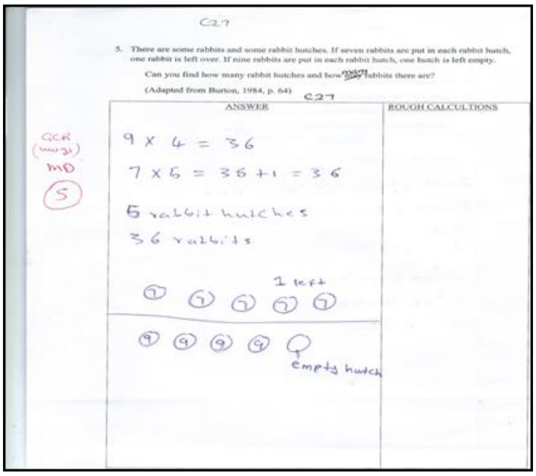

Figure 4: Learner C27's solution to P5

The majority of learners (85.6%) performed poorly and scored low points in mathematics non-routine problem solving test (see table 3.4). On average, the problem solving mean score of 425 learners was 1.62 (out of 5) and a standard deviation of 0.877. On average, the learners performed poorly in solving non-routine mathematical problems. Similarly, Maree et al. (2009) discovered that South African learners performed poorly in mathematics problem solving. The TIMSS (2003) discovered that, approximately, 30% of the South African grade 8 learners were able to solve non-routine mathematical problems. Similar results were discovered in other countries as well. For example, Mogari and Lupahla (2013) and Kolovou et al. (2011) discovered that Namibian and Dutch learners, respectively, performed poorly in mathematics non-routine problem solving even though they were classified as high performers in school mathematics.

Table 3.4: Problem solving mean score frequencies (N = 425)

Mean Score (Nearest whole no.)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	36	8.5	8.5	8.5
	1	157	36.9	36.9	45.4
	2	171	40.2	40.2	85.6
	3	53	12.5	12.5	98.1
	4	8	1.9	1.9	100.0
	Total	425	100.0	100.0	

Relationship between learners' mathematics related belief systems and their approaches to mathematics problem solving

The researcher computed Pearson's correlation coefficient as a numerical measure of the relationship between belief systems and approaches to non-routine mathematics problem solving. Pearson's correlation coefficient obtained was 0.242 which means that there is a very weak statistical linear relationship between mathematics problem-solving approach and mathematics-related belief systems. The correlation coefficient of determination, $R^2 = 0.0586$ means that only 5.86% of the change in approach to problem solving is explained by the mathematics-related belief systems and vice versa. The researcher, also, analysed the relationship between approach to problem solving and each belief system.

Pearson's correlation coefficient of utilitarian belief system versus approach to problem solving was 0.241 which means that there is a very weak positive linear relationship between approach to problem solving and utilitarian belief system. The correlation coefficient of determination, $R^2 = 0.058$ means that only 5.8% of the change in approach to problem solving is explained by the utilitarian belief system and vice versa. Pearson's correlation coefficient of exploratory belief system versus approach to problem solving was 0.175 which means that there is a very weak positive linear relationship between approach to problem solving and exploratory belief system. The correlation coefficient of determination, $R^2 = 0.031$ means that only 3.1% of the change in approach to problem solving is explained by the exploratory belief system and vice versa. Pearson's correlation coefficient of systematic belief system versus approach to problem solving was 0.270 which means that there is a very weak positive linear relationship between approach to problem solving and systematic belief system. The correlation coefficient of determination, $R^2 = 0.073$ means that only 7.3% of approach to problem solving average score is explained by the systematic belief system and vice versa. A qualitative analysis of the relationship between the belief systems and approach to problem solving was, also, done to explain the nature of their relationship.

4. CONCLUSION

Though learners faced difficulties in solving non-routine mathematical problems, they employed several strategies to resolve the problems (see table 3.3). Grades 10, 11 and 12 learners hold mathematics related beliefs that could be classified into belief systems, namely, systematic, exploratory and utilitarian. Among the three belief systems, it was discovered that every learner held one of the belief systems stronger than the others. The predominant belief system influenced the behaviour of the learners in solving non-routine mathematical problems.

It was discovered that there is a weak positive linear relationship between high school learners' mathematics-related belief systems and their approaches to non-routine mathematical problem solving. The existence of a positive relationship might mean that a positive change of a learner's mathematics-related beliefs (i.e., development of more healthy beliefs) is likely to result in a positive improvement in use and application of problem solving strategies. A weak positive relationship might, also, mean that a relatively large change in development of positive, healthy mathematics-related belief systems among learners would result in some noticeable improvement in learner performance in mathematics (as measured by effective use and application of problem solving strategies). Though the correlation coefficient of determination (R^2) was relatively low, in general, the learners' predominant mathematics-related belief systems could explain their approach to mathematics non-routine problem solving (and vice versa). This means that one can possibly predict a learner's likely approach to a certain non-routine problem by taking stock of his/her predominant mathematics-related beliefs (and vice versa).

Similar finding was discovered by Spangler (1992), Schoenfeld (1992) and Mason (2003) who discovered that there is a positive relationship between beliefs and mathematics learning and problem solving. Schoenfeld (1992) concluded that beliefs determine the approach a learner applies to a given problem. Spangler discovered that mathematics-related beliefs and learning influence each other. Hence, Spangler (1992) described the relationship between them as cyclic. Mason (2003) concluded that learners' beliefs can be used to predict their achievement in mathematics. A contradictory finding was discovered by Goldin et al. (2009) and Callejo and Vila (2009). They discovered a complex relationship between beliefs and approach to problem solving. As a result, they could not identify if beliefs influence problem solving behaviour and vice versa.

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EVALUATING THE EFFECTIVENESS OF A MENTORSHIP PROGRAMME FOR NOVICE LECTURERS OF MATHEMATICS

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Abstract–This paper considers the implementation of a mentorship programme for novice lecturers of mathematics at a higher education institution. Two experienced retired lecturers were appointed as mentors for three novice lecturers. Interviews were conducted with the mentors and mentees to establish their experiences about the mentorship programme after a six-month period. The report by the mentors was also analysed to ascertain the procedure that was followed. The mentors reported positively about the mentor-mentee relationships but mentioned that the programme was not without challenges. The major challenge reported by the mentors seemed to be the lack of cooperation at times from the mentees regarding submitting documents on time. The mentees respected the experience of the mentors but reported negatively about the class visits. They also felt that the relationship was hierarchical and did not encourage sharing of ideas. This paper argues that the quality of the interactions between mentors and mentees may influence the effectiveness of mentorship programmes. Future mentorship programmes should provide a safe space where mentors and mentees can reflect on the quality of the teaching and learning of mathematics in an honest and open manner.

Keywords: mentorship programme; mentor, mentee, mentoring, mathematics teaching, novice lecturers

1. INTRODUCTION

Mentoring programmes in the context of higher education have been found to show positive effects for mentees, as well as for mentors and universities (Leidenfrost et al., 2011). The availability of effective guidance by an experienced mentor teacher positively impacts on novice teachers' developing teaching competencies (Lindgren, 2005); plays a key role in their socialisation process (Bullough & Draper, 2004); and provides emotional and psychological support to them (Marable & Raimondi, 2007). Empirical research also reveals, however, that the potential contribution of mentoring to the pedagogic learning of the novice teacher is rarely realised (Edwards & Protheroe, 2003, p. 228; Boice, 1992, p. 107). Studies show that such guidance generally involves merely low level training interventions such as the mentor showing the "correct" way to teach and offering hints and tips (e.g. Hart-Landsberg *et al.*, 1992, p. 31).

This paper reports on a mentorship programme that was introduced at a higher education institution in January 2014. The paper is structured as follows. Firstly, the context of the study is outlined and the rationale for introducing the mentorship programme is explained. This is followed by a review of the literature on mentorship programmes. An exposition of the methodology that was applied and the findings are listed thereafter, followed by a discussion against the backdrop of the theoretical framework. The article concludes with recommendations for implementing future mentorship programmes.

1.1 The context of the study

Since 2008 Engineering Extended programmes for Civil, Electrical, Industrial, Mechanical and Mechatronics Engineering have been offered at a University of Technology. Mathematics (Extended) 1 is offered for all the different disciplines. Students placed in these programmes do not meet the minimum requirements for direct entry into diploma courses and normally have deficiencies in terms of background knowledge and skills, especially in mathematics and science. Experienced lecturers with a solid understanding regarding problematic areas normally encountered by students were used to teach these subjects. As this programme was funded by the Department of Higher

Education and Training (DHET), all staff in this programme were appointed on a 3-year contract basis. Two of the lecturers involved in this subject could not be re-appointed as they were beyond retirement age and the policy of the institution did not allow for further appointments. It was therefore decided to embark on a mentoring process with new appointees.

1.2 The rationale for introducing a mentorship programme

Part of the Faculty's strategy was to grow and develop young academics and this is the rationale for introducing the mentorship programme. The programme was to be conducted for six months and the two lecturers that retired were appointed as mentors for the three novice lecturers. The purpose was to assist the new lecturers in a smooth transition into the department and to give them a firm foundation to build from when offering Mathematics (Extended) 1 to Engineering Extended students at the university.

In light of this background this study seeks to share the experiences of the mentors and mentees on the mentoring process. The main research question to be answered was:

How did the mentors and novice lecturers experience the mentorship programme? To address this main question the following subquestion guided the inquiry: How does the quality of the interactions between mentors and mentees influence the effectiveness of a mentorship programme?

2. THEORETICAL BACKGROUND

In this section the literature on mentorship programmes is reviewed. Because the focus of this study was to investigate how mentors and mentees experienced a mentorship programme with the aim of improving future programmes, the review of the literature focuses on the goal of mentorship programmes; the interpersonal dimensions of the mentor-mentee relationship; mentoring styles; and what constitutes an effective mentorship programme.

2.1. The goal of mentorship programmes

Since the early nineties scholars have advocated for novice teachers' support (Darling-Hammond et al., 2009; Department of Education and Training, 2005). Countries differ in their conceptions of what is important for novice teachers or lecturers to learn. Wang, Odell and Schwill (2008) found that mentors in the United States, influenced by the decentralized curriculum and individualistic culture of teaching, tend to believe that learning about individual students and establishing purposes for teaching are important. In contrast, Chinese mentors believe that novices should develop a deep understanding of subject matter, curriculum, and professional ethics, as suggested by their centralized curriculum and subject-based teaching (ibid., p. 135). In addition, mentors in the United States spend less time talking with novices, and when they do interact, they focus on issues of curriculum materials, whereas Chinese mentors spend more time interacting with their novices, with a focus on pedagogical issues (ibid., p. 135).

In Southern Africa, Nyaumwe, Mtetwa and Brown (2005) investigated whether pre-service and experienced teacher partnerships open possibilities for implementing constructivist theories in pre-service teachers' practice with the supervision of mentors. It seems that the goal of their mentorship programme was to bridge the theory-practice gap and develop a synergy of constructivist teaching skills. Barnard (2013) investigated first year student mentees' experiences of transition at a University of Technology in South Africa and found that the efforts invested in selecting, training and implementing student mentors have had a highly positive impact on the academic, social and personal-emotional transition of these students.

2.2 Interpersonal dimensions of the mentor-mentee relationship

Possible types of mentor-mentee relationships were identified by Rippon and Martin (2003). A *procedural* relationship type is one that is mechanistic and unresponsive to the particular needs and abilities of the novice teacher and proved to be least effective; a *power* relationship type requires the novice teacher to conform but there is little support in the relationship; a *personal* relationship type proved to be most effective in succeeding to combine procedural elements with a genuine working partnership. Key features of the *personal mentor-mentee relationship* are the nature and type of feedback given and overall approachability of the mentor.

According to Gratch (1998) there is a high level of emotional commitment to each of the roles of mentor and mentee. Handling feedback is therefore considered an important feature for both the mentor and mentee. Rippon and Martin (2003, p. 223) stress that understanding "the importance of self-awareness and empathy" underpins the success or failure of feedback.

2.3 Mentoring styles

Harrison, Lawson and Wortley (2005) used a framework of **mentoring styles** to analyse mentoring dialogues. The first included *telling* where the mentor is the 'expert' offering tips, suggests areas for further work, and offers opinions and judgements without taking the opinions of the novice teacher into account. *Active coaching* is another mentoring style where the mentor makes planned interventions, and challenges the novice teacher's versions of events. In the *guiding* mentoring style the mentor acts as a critical friend, focusing on the students' learning rather than the mentee's teaching performance. The planning and intentions are examined and challenged by both the mentor and mentee. The mentor and mentee operate together in the *enquiry* mentoring style, investigating the causes or possible solutions to problems and testing ideas. The last mentoring style mentioned by Harrison, Lawson and Worthley (2005) is *reflecting* where the mentor allows the mentee to critically reflect and explore 'why' he/she is doing something in a particular way.

2.3 Effective mentorship programmes

Wang and Paine (2001) report on a case from a Chinese elementary school in which an experienced mathematics teacher supported a first-year mathematics teacher through collaborative inquiry and reflection about teaching. The study identified several features of mentoring practice that contributed to the novice's learning: 1) The mentor was able to develop a clear and consistent notion of good teaching that aligned with a constructivist approach to mathematics instruction, using this notion to engage the novice in reflecting about teaching practice. 2) The mentor was able to practice, model, analyse and reflect on "good" mathematics teaching and used these skills to help the novice develop her own ideas and approaches to teaching. 3) The mentor was able to define zones of the novice's proximal development (Vygotsky, 1978) in learning to teach and develop different kinds of support relevant at each stage.

2.4 The theoretical framework for this study

According to Warhurst (2003) social learning theory provides a useful way of understanding the learning of new higher education lecturers. It represents a step towards a situated understanding of the knowing and learning of lecturers. Billett (2001, p. 21) argues that social learning theory emphasises the role of "proximal guidance" such as that derived from the guide (mentor). The proximal guide (in this study the mentor) ensures that the learner (in this study the mentee) undertakes challenging, but achievable, tasks, the mentor models appropriate work behaviour, instructs, assists performance, guides practice, elicits explanations from the mentee, and provides feedback. However, the social context created between the mentors and mentees also play a role in the development of the mentee as a professional. The ways in which communication between the mentors and mentees take place, how they perceive their roles, and the ways in which opportunities for collaboration are structured—all influence the mentees' understanding and construction of knowledge. As a theoretical framework the social learning theory suited the interpretive nature of this study, which is centrally concerned with meanings mentors and mentees constructed whilst reflecting on their experiences.

3. METHODOLOGY

In this section the methodology used by the mentors are discussed first, followed by the methodology employed by the researcher of this study. The methodology used by the mentors in this mentorship programme is presented in Table 1.

Table 1: Activities employed by mentors during the mentorship programme

Class visits	The mentees were visited on average 2 – 3 times per week
Individual feedback sessions	The mentor discussed his observations with the lecturer – pointing out positive aspects and aspects that need attention
Group discussions	Five group sessions during the 6-month period were conducted
Document analyses	Moderation of tests and marked scripts

During the class visits the mentor sat at the back of the class and took notes of everything that happened during the lesson, indicating what he wanted to discuss with the lecturer during the feedback session. The mentor did not intervene or interfere during the class visits in any way whatsoever.

The mentor discussed didactical issues that he observed during the individual feedback sessions with the mentee, such as introducing new content using a deductive rather than an inductive approach; participation of students in class; time management; communication; discipline; and issues regarding the content knowledge of the mentee.

The first group discussion dealt with learning theories (Piaget, Ausabel and Bruner). During the second group discussion classroom practice and assessment were addressed. The third and fourth group discussion dealt with mathematics content to broaden the mentees' knowledge of mathematics, while the last session was used to discuss the characteristics of an effective teacher.

A discussion of the methodology employed by the researcher of this study follows.

3.1 Research design

Within the qualitative approach, the design chosen for this research study was a case study design. According to Cohen, Manion and Morrison (2005) a case study provides a unique example of real people in real situations.

3.2 Participants

The participants in this study were two experienced mathematics lecturers (both male) and three novice mathematics lecturers (two males and one female) at a higher education institution in Pretoria. The biographical details of the participants are presented in Table 2. In the interest of confidentiality the identities of the participants are protected.

Table 2: Biographical details of participants

Participant	Mentor A	Mentor B	Mentee A	Mentee B	Mentee C
Age	67	67	28	39	27
Qualifications	PhD	Med	BSc (Hons)	MSc (Ed)	BSc (Hons)
Institution where qualification(s) was obtained	University of Pretoria	University of Stellenbosch	University of Stellenbosch	Wits	University of Limpopo
Number of years teaching mathematics	40+	40+	1	4 (tutoring)	0
Home language	Afrikaans	Afrikaans	Sepedi	Xhosa	IsiZulu

Table 2 indicates that the two mentors have considerable teaching experience while the three mentees have limited to no teaching experience. Mentee A has one previous year experience at a tertiary institution. Mentee B has been tutoring Grade 12 learners since 2010, but no tertiary teaching experience. Mentee C is busy with his MSc at Unisa and this is his first year of teaching.

A discussion of the methods of data collection follows.

3.3 Data collection

Data were collected through interviews with the participants of the mentorship programme. Document analysis also formed part of the data collection in the form of the report on the mentoring presented by the mentors.

Semi-structured interviews were conducted with the two mentors, focusing on their goal for the mentorship programme; what they thought was important for the novice lecturers to learn through mentoring; how they planned and implemented the mentoring process; how they viewed their role as mentors; the interaction between them and the mentees during individual feedback sessions and discussions; the challenges and positive experiences of being mentors; whether the mentorship programme had an influence on the way the novice lecturers teach; and suggestions for improving a future mentoring programme.

Due to availability constraints an interview with Mentees B and C was conducted simultaneously while an individual interview was conducted separately with Mentee A. The interviews with the mentees focused broadly on the same issues discussed during the interview with the mentors but also probed whether the mentees believed that the mentoring process had an influence on their teaching practice.

3.4 Data analysis

The qualitative analysis of the data collected for this study is based on an interpretative philosophy that is aimed at examining meaningful and symbolic content provided by the participants during the reflective interviews. According to Nieuwenhuis (2010, p. 99) such a broad approach to data analysis "tries to establish how participants make meaning of a specific phenomenon by analysing their perceptions, attitudes, understanding, knowledge, values, feelings and experiences in an attempt to approximate their construction of the phenomenon".

The interviews were transcribed verbatim by the researcher and analysed qualitatively. The report by the mentors were used to verify whether they actually did what they intended to do during the mentoring process. Codes were assigned to meaningful segments of text and organised and combined in related themes. The research questions and interview questions guided the coding and categorisation process. Seven themes emerged from the coding of the transcripts and document analysis: the goal of the mentorship programme; perceived role as mentor and mentee; interaction between mentor and mentee; mentoring styles; positive feelings about the mentoring; negative feelings about the mentoring; suggestions for improvement of the mentorship programme.

A discussion of the results follows.

4. RESULTS AND DISCUSSION

4.1 The goal of this study's mentorship programme

According to the mentors the goal of the mentorship programme for this study was to support new colleagues in constructing a good framework for lecturing. The mentees were asked during the interviews whether the mentorship programme had any influence on their ways of teaching mathematics. Two of the mentees stated that it definitely influenced the way they teach, however they were unable to provide examples from the classroom.

> It was one of those great influences it has given me and eh … in shaping my lecturing, it was very, very important. Ja … so I mostly enjoyed interacting especially after the class … with the mentors, being shown how … when something hasn't went right, they just … so I enjoyed it …

The third mentee commented on strategies that she learnt from the mentors to help her in teaching mathematics:

> Content wise I'm fine but you know how you lecture, first year, there are strategies that are quite helpful that they (mentors) would bring in … that if you are doing a certain section, this is the right way … the one that I'm using every day, even with my high school learners is the one of the mind map, it is a powerful tool, strategies of how you teach while mentoring I found very helpful.

From these comments it seems impossible to determine whether the current study's goal of constructing a good framework for lecturing has been met. Compared to the goals of mentorship programmes reported by Wang, Odell and Schwill (2008) (see Section 2.1.1) in the United States (*learning about individual students and establishing purposes for teaching*); China (*novices should develop a deep understanding of subject matter, curriculum and professional ethics*); and Southern parts of Africa (*implementing constructivist theories*); it seems as if the goal set for the current study's mentorship programme was too broad. The goal was also set by the mentors without consultation with the mentees before the onset of the programme.

4.2 Mentor and mentee roles

From the interviews and document analysis the mentors perceived their role as working with the newly appointed mathematics lecturers in a partner relationship to develop the mentees' careers and ensure that they have sufficient support and constructive feedback to succeed in their lecturing of mathematics at a higher education institution. According to Kajs (2002) it would be appropriate to develop a job description that outlines the roles and responsibilities of a mentor as well as a list of the available organizational resources (e.g. continuing education, substitute teacher assistance) to better serve the mentoring role.

The mentees described their roles in terms of their relationship with the mentors as follows:

> … sometimes it was like a father and a son …
> I felt like a student … my experience was I was learning…

This view corresponds with Mentor A's description of his role saying he felt like lecturing when dealing with the mentees. However, Mentee B pronounced a more negative feeling about her role as mentee:

> … how do you say it … whereby you were open, you were just being fed (Interviewer: like an open vessel?). Ja, you're an empty vessel, exactly like that, and something is being … it is not like you also come with something and then you share …

From these comments it seems as if the mentor-mentee roles for this study were not discussed openly and honestly before introducing the mentorship programme. Kajs (2002) suggests that novice teachers and prospective mentors spend time discussing each other's roles and expectations in the mentoring relationship, checking for similar and differing viewpoints. This exchange of values and perspectives not only provides useful information in the matching process of novice teachers and prospective mentors, but also sets the stage for developing a significant mentorship based on personal styles and mutual interests (Hardcastle, 2001).

4.3 Interaction between mentors and mentees

The participants interacted formally as mentors and mentees during the class visits, the individual feedback sessions and during the group discussions. Informally they interacted on a continual basis because they shared the same office space. Because of this, the mentors reported that communication among mentors and mentees was easy: "With time the lecturers (mentees) became more comfortable to approach us with questions". This was confirmed by Mentee A who stated during the interview that " … any time I felt I have something I just go to them and ask …".

All three mentees reported that they felt uncomfortable with the **class visits**.

> … because I was not used to being mentored in … like somebody sitting at the back then we have to … so my challenge was … especially my voice …my voice sometimes gets down but when … when it went on because the mentors was telling me you should try to remember to talk to the person sitting in the back, not in the front
> … when they come to the classroom, that one I don't like, it is very uncomfortable, very … sometimes you know, when you … you feel like someone is here to assess me, even the students … I don't know, most of the time when there are mentors in the class they will do funny things because they see that there is this person and you will end up having to discipline them … and then, even yourself, you are not so free, free to do the … the lecturing … I know it is done for you … to assess you and then I think … eh (sigh)
> Their presence in the class, you won't be free as much as when they are not around… even the students behave in other ways, you know if you are free you… will address that issue in another way, so you tend to be Mr. Goody Two Shoes, but ja, their everyday presence …

The mentees reported mostly positively about the **individual feedback sessions**.

> … now I know that whatever I do … it has to make sense to the students
> Maybe I left out a section and they will come and correct me … so with the next class I will start with that section … but they were honest and open with the individual sessions, they will just tell you the truth …

> The individual feedback was very good, because they will come and share what they've observed during the classroom, which is good … also with the discipline of the students … and also if there are other sections, which I have left out, the individual was very helpful, and I'm aware that it cannot happen if they were not in my class …

Martin and Rippon (2011) state that handling feedback is a two way process and new teachers may face real challenges in dealing with criticism. Fletcher (2000) argues that mentoring is something that should be done *with* a trainee and not *to* them. She sees it as an active and creative process, rather than simply a mechanism to find evidence to support externally imposed standards (Fletcher, 2000). It seems that the mentors in this study handled the feedback sessions very well and hence the positive responses from the mentees.

The mentees felt that the **group discussions** were not as productive as the individual sessions.

> The group ones … that one I don't want to lie; they were a complete waste of time for me. Cause I felt with the group thing they would be talking about abstract math which is not attending to the content that we are talking about, so I really feel the group sessions could be something for maths education … because when we started they were talking about the learning theories, constructivism, which was good, but as time went on, they were more like taking something from abstract thing, which I could not relate to that, and then for at times … I felt like I'm getting through a lecture … it is abstract, like numerical analyses, which is not helpful …

When compared to the possible types of mentor-mentee relationships identified by Scotland, Rippon and Martin (2003) (discussed in Section 2.1.2 of this paper), it seems that the interpersonal dimensions of the mentor-mentee relationships of this study as reported through their interactions, are situated between the power and personal relationship types. Concerning interaction between novice teachers and mentors Kajs (2002) states that both need to have good skills in interpersonal communication to develop a meaningful mentoring relationship. These skills assist them to actively listen, clarify, and problem-solve in their communications with one another (Kajs, 2002). "Significant mentorships are not brief, formal, one-way exchanges. They take time to develop and evolve through mutual interaction" (Hardcastle, 2001, p. 202).

4.4 Mentoring styles of this study

Compared to the mentoring styles identified by Harrison, Lawson and Wortley (2005) (Section 2.1.3 of this paper) it appears as if the mentoring style of this study corresponds with the *telling*, *active coaching*, and *guiding* mentoring styles. From the analysis of the transcripts of the interviews the mentors and mentees never seemed to operate together in the *enquiry* and *reflecting* mentoring styles where there is collaboration between the mentor and mentee to investigate causes or possible solutions to problems and testing ideas and where the mentor allows the mentee to critically reflect and explore **why** he or she is doing something in a particular way.

4.5 Challenges experienced

Both the mentors and mentees reported about challenges they experienced during the mentorship programme. The main challenge that the mentors mentioned was:

> It was somewhat disappointing that our ideas were not used as we expected it would have been done. At this stage it seems that they (mentees) are going to stick to a deductive presentation of new learning material where the rule or formula or graph is given and the exercises are done by applying the rule. Although we urged the lecturers (mentees) to use an inductive approach when new concepts are introduced, by setting the stage where students can discover the concept or rule and thus create their own knowledge, but in most cases this is still not done.

This challenge expressed by the mentors relates to Buell's (2004) "cloning" model of mentoring where the mentor directs and control the mentee and try to make the mentee a carbon copy of him.

The mentors also expressed concerns about certain didactical issues they have observed during the class visits:

- An introduction at the beginning of the period where links are formed with previous work, are often missing.
- In many cases a lack of urgency to get as much as possible done in a period, was observed. Too much time was often given to complete a problem.
- The lecturers are inclined to discuss the memorandum of a test without handing back the marked scripts the same day

- In the classes of Mentee B it frequently happened that she was explaining work while students were still talking to each other, or not paying attention, or not working on their own or in groups. This was pointed out to the lecturer a number of times during feedback sessions.

The mentees found the class visits challenging, mainly because they felt their interaction with the students changed as a result of someone sitting at the back of the room and because they felt they were evaluated. Two mentees (B and C) agreed that:

> The students don't see this person as … they will tend maybe to undermine us, they will even pick up … they'll pick up that you are different, and you know the students, they will kick you when you are weak …

These experiences of the mentees of this study are consistent with the literature reviewed. Wang, Odell and Schwill (2008) argue that beginning teachers constantly struggle with classroom management problems, which assume time and attention and prevent the mentor-novice interactions from focusing on understanding students' learning and looking for new ways of teaching.

4.6 Positive experiences

The mentors reported that "We think this was a worthwhile exercise. The novice lecturers gained mathematically and educationally".

From the interviews it appears that although there were challenges, the mentees experienced the mentorship programme mostly in a positive way:

> I've grown from where I was, you know I was never a teacher before, I am coming from a background where I was a tutor, a facilitator, so I think I have grown in a way that … eh, how you do lecturing more like teaching, whereby you also invite the students … that interaction … how you deal with a classroom … discipline and all that stuff, so I think from where I started I have grown, I've grown a bit.
>
> … same to me. I'm from a background of pure mathematics, there is the education part, I only know the science part … they kind of helped me a lot on how to tackle issues, the math is not about solving a sum because I can solve a sum, but it is about learning the logic behind it, they kind of put those small things that you should do … this and this … follow steps … not about me being a lecturer, it is quite, it helped a lot, it was a positive influence.

The literature reviewed reveals that through the guidance, support and understanding of competent mentors, novice teachers experience professional growth, personal satisfaction, and organizational productivity (Kajs, 2002). In addition, a wealth of evidence, based predominantly upon the accounts of mentors themselves, suggests that mentoring beginning teachers may also have a positive impact on the professional and personal development of mentors (e.g. Hagger & McIntyre, 2006).

4.7 Suggestions for improving the mentorship programme

Suggestions for improvement of a mentorship programme were provided by the mentors and mentees. Mentee A suggested:

> I feel like it's more easier if they give us a clear direction … before we go to class they should give us information … these are the most important points that we have to tell the students …

In their report the mentors also felt that "before a new section is started, a group discussion should be held where time management, amount of content per period, and possible lecturing methods (inductive and deductive), are discussed". Mentee B proposed that more emphasis should be placed on "how you teach, how you discipline, those kinds of things". The mentors agreed that they neglected to give structured guidance with respect to lecturing and classroom management. In addition the mentors felt that more guidance should be given to the lecturer (mentee) responsible for setting a major test paper. "This should include management in time planning to meet due dates, the cognitive level of questions, and covering the domain of work". Mentee B suggested that the mentorship programme can be improved by changing the relationship between the mentors and mentees from a hierarchical to a more horizontal one:

> Generally the mentorship is good, and if ever we can come up with the learning theories, what is the best way of learning math and how to take it to the students, we can have a relationship whereby we are all in the same place, we are all learning, even then they can come to the class five times, you know you are not being evaluated, more like you will be sharing, this is what they've seen, OK, this is why I've done this, and then, that will be great.

The suggestion for improvement by this mentee is mirrored in the literature reviewed. Feiman-Nemser (2001) argues that mentors in an effective mentoring programme will provide room for co-thinking with novice lecturers about teaching and about how students think; help novice lecturers frame their self-identified teaching problems and articulate reasons for them; and model teaching that demonstrates principles of good teaching.

In the next section the results are used to verify the research questions.

4.8 Summary of verification of research questions

Table 3 provides a summary of the link between the results and the research questions.

Table 3 Summary of verification of research questions from the results

Research questions	Verification
How did mentors and mentees experience the mentorship programme?	Roles: The mentees and mentors experienced their roles differently, ranging from an intimate father-son relationship, a more formal lecturer-student relationship to an alienated relationship where the mentee felt like an empty vessel with nothing to contribute. Interaction: The mentees expressed resistance and discomfort about the class visits but felt more positively about the individual feedback sessions. They found the group discussions unproductive. The mentors seemed unaware of these feelings and reported that interaction was open and easy. Challenges: The mentors were disappointed that their suggestions for improvement were not taken seriously while the mentees' main challenge seemed to be the class visits. Positives: The mentors and mentees experienced the programme as worthwhile and reported growth as mathematics teachers.
How do the interactions between mentors and mentees influence the effectiveness of a mentorship programme?	From the interactions between the mentors and mentees it seems as if the mentor-mentee relationship in this study did not provide for collaboration and sharing of ideas, but rather appeared to be of a more hierarchical nature. Nurturance and care are hallmarks of the mentoring relationship (Kalbfleisch, 2002) and will contribute to the effectiveness of a mentoring programme.

5. RECOMMENDATIONS

From the discussion of the results and the verification of the research questions we recommend that training should be provided for mentors before the onset of a mentorship programme. Although the mentors in this study were experienced teachers of mathematics, they admitted in their report that

> To us, mentoring was new. We got some information of what mentoring is about from the literature, and blended that with the experience that we gained through the years of lecturing. We used a few articles (two) to develop a programme that we thought could work in our situation.

A further recommendation is that the mentors and mentees should meet and agree upon the goal of the mentorship programme; their roles as mentor and mentee; the process of mentoring; and how the class visits and the feedback sessions would be conducted. Future mentorship programmes should provide a safe space where mentors and mentees can reflect on the quality of the teaching and learning of mathematics in an honest and open manner, build rapport and maintain a healthy relationship in which there is trust, focus, empathy and empowerment. A strong recommendation is made here for university administrators and policy makers to extend the use of mentorship programmes to novice lecturers in all faculties.

6. CONCLUSION

Lecturers have a professional responsibility to be reflective and evaluative about their practice. More importantly, novice lecturers should be engaged in a cycle of reflection with a mentor to identify how to improve their professional activities in order to improve the quality of their students' learning. A successful mentorship programme can strengthen novice lecturers' competence and job satisfaction. However, from the results of this study it seems that the support provided to novice lecturers should be embedded in a community of practice to be of real benefit. This study provides a basis for further research in establishing the components of an effective mentoring programme.

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TEACHER CODE SWITCHING: A CALL FOR THE DEVELOPMENT OF MATHEMATICS REGISTERS IN INDIGENOUS LANGUAGES

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Abstract–The teaching of Mathematics using English as the Language of Learning and Teaching (LOLT) to students whose first language is not English has and still is posing challenges to teachers. This has resulted in teacher code switching into indigenous languages in an effort to enhance conceptual understanding and access to a Mathematics register. This paper investigated code switching practices of three IsiXhosa first language speaking Mathematics teachers focusing on consistency and precision in the use of IsiXhosa during teaching. Results indicated that the amount of teacher code switching was not consistent across teachers and categories. Teachers were found to operate consistently in the public domain or everyday mode of talking, but not so within the esoteric mode. Very little transparent code switching which supports students' understanding and thinking in mathematics, was evident in teacher language. Teachers were consistent in the use of borrowed terms.

Keywords: Code Switching, Mathematics Register, Language

1. INTRODUCTION

Mathematics teaching and the language of learning and teaching (LOLT) is a debatable issue in the South African education system. The continual search for strategies that will enhance the increased conceptual teaching and learning of Mathematics is paramount amid calls from concerned parties for immediate and long lasting solutions to the quality teaching of the subject.

This paper draws from literature and preliminary results of a study that is ongoing in three South African Eastern Cape multilingual mathematics classes. This ongoing study focuses on the code switching consistency and precision in teachers' oral language production during teaching at secondary school level. Code switching, defined by Adler (2001) as the use of more than one language in the same conversation, is now widely accepted and viewed as a legitimate resource for supporting teaching and learning in multilingual classes (Setati, 2008). This results in the following questions: How precise and consistent is the teacher's code switching with respect to the English mathematics register (language of learning and teaching, LOLT)? With code switching widely practised in classrooms and recognised as a legitimate teaching and learning resource, what are the best practises for code switching in a multilingual Mathematics classroom in South Africa? Should the development of a mathematics register in indigenous languages of South Africa be pursued?

2. THE MATHEMATICS REGISTER

Haliday (1978: 195) defines a register as "a set of meanings that are appropriate to a particular function of language, together with the words and structures which expresses theses meanings". Words and phrases in Mathematics thus, assume specific meanings appropriate to the subject. The mathematics register, therefore, refers to "the way of using symbols, specialist vocabulary, precision in expression, grammatical structures, formality and impersonality that results in ways of expression that are recognisably mathematical" (Lee: 2006, 14). The mathematics register thus employs language that may be used in everyday life, for mathematical purposes and in expressing mathematical meanings.

Key features of a mathematics register based on the works of Lemke (2003), O' Halloran (2000), and Schleppegrell (2007, 2012) can be divided into two major groups; multiple semiotic register comprising of mathematics symbolic notations, oral language, written language, and graphical and visual displays; and grammatical patterns involving technical vocabulary, dense noun phrases, being and having verbs, conjunctions with technical meanings and implicit logical relationships. Our particular study is interested in the grammatical patterns and oral language of the multiple semiotic register. Schleppegrell (2007) and Meaney, Trinick & Fairhall (2012) further divided oral language into technical terms (words with meanings only in a mathematical discourse), lexical words (specialist use of more general terms) and everyday words (mathematics terms that use everyday words for unrelated ideas, for example, expression, function, difference).

In all the cases cited above, the presence of a technical (specialised or formal) register and the everyday (non-specialised or informal) register is reiterated. A key challenge thus exists in the teaching of Mathematics where students are to be assisted in moving from every day, informal ways of construing knowledge into specialised, esoteric and academic ways that leads to real mathematical learning and understanding. A key frame of reference in our study is that "if mathematics concepts are not introduced and explained in oral language that moves from ordinary language that students already understand, to the more technical language that they need to develop for full understanding of the concepts (and for disciplinary learning of Mathematics), student learning suffers" (Schleppegrell, 2007, 156). The case is unique and complex for English second language speakers, because they are learning the ordinary English and also use their home language which in many cases is in the form of ordinary, non-specialised language. Thus bridging the gap between conversational language and official mathematics language is not a straight forward matter and requires teachers to be more innovative than simply relying on oral discussion as a vehicle for teaching and learning (Meaney et al, 2012). Questions are then raised whether it is desirable to support the development of mathematics registers in indigenous languages in order to bridge the gap between teachers' spoken language and formal classroom mathematics language.

Teachers can facilitate and enable pupils' understanding of complex and abstract mathematical content if they use the mathematics register effectively (Schleppegrell, 2007) through the deliberate move from every day to technical use, from ordinary non-specialised forms to formal, specialised and esoteric modes of talking (Dowling, 2010). What then, are the forms of support that teachers need in order for such beneficial teacher language behaviour to become a reality in South African schools? While the prevalent use of code switching in South Africa's classrooms is widely documented (Setati 2005, 2008; Probyn, 2009, Schafer, 2010) its ad hoc use in order to explain English terms and concepts was found to be a source of learners' misconceptions regarding scientific concepts (Sanders, 1993). This is because some mathematical terms chosen by the teacher are under-differentiated in indigenous languages in relation to their English equivalents.

3. SOME INITIATIVES IN SOUTH AFRICA

In the South African Education system, there have been numerous projects that were embarked on in an effort to address the challenges caused by language in the teaching of Mathematics. As noted by Wildsmith-Cromarty (2012; 158), "the call for applied linguists and educationists to be more 'socially responsible' has been responded to by a number of initiatives in South Africa, particularly in the area of language in education".

One of such initiatives is the development and publication of Mathematics dictionaries which are available for schools to buy and use for teaching and learning. The Department of Arts and Culture, (DAC) (2003), published a dictionary for multilingual foundation phase (FP) and intermediate phase (IP) Mathematics classrooms in the eleven official languages of South Africa. This dictionary provides a glossary of Mathematics terms for Grade R-6 with definitions or explanations. A recent edition of this dictionary, the Mathematics Multilingual Dictionary (2013; xii) explains that "the aim of this list is to make a contribution towards mother tongue education for all speech communities in South Africa and it therefore does not include complex mathematics terminologies".

The Longman Multilingual Mathematics dictionary for South African schools (2008) published in English, IsiXhosa and Afrikaans has explanations, illustrations and diagrams of concepts identified. The Cambridge University Press (2010) IsiXhosa Mathematics dictionary for Grades 4-9 has concepts written in English first, and then the IsiXhosa translation, with definitions and explanations of the concept in IsiXhosa only.

All the dictionary initiatives cited above are meant for Grade R – 9 and caters to a lesser extent for the Further Education and Training (FET) phase. The Concept Literacy Project (CLP), an initiative that originated at the University of Cape Town and eventually expanded to Rhodes University (Eastern Cape) and University of KwaZulu-Natal (KwaZulu-Natal), resulted in the development of two resource books:- ‘Understanding Concepts in Mathematics and Science’ by Young et al, Volume 1 (2005) and Volume 2 (2009). As commented by Schafer (2010), these support materials provide detailed meanings and explanations for the key Mathematics and Science concepts in two indigenous languages (Xhosa and Zulu) and in English and Afrikaans. These resource books are meant to provide home language support for the learning and teaching of Science and Mathematics at FET and GET levels. Wildsmith-Cromarty (2012) emphasised that these books are not designed to replace the key or prescribed Mathematics and Science textbooks in the classroom but rather to supplement and support teaching activities carried out predominantly in English with regular teacher code switching into indigenous languages. Volume 1 published in 2005 has 56 core Mathematics concepts that are covered in the GET (Grades 4-9) syllabus, while volume 2 published in 2009 has 68 core Mathematics concepts that extends up to FET level.

One of the findings that emanated from the use of this book as observed by Wildsmith-Cromarty (2012) revealed that the availability of translations in the African language tended to enhance the use of code switching for explanatory purposes. Schafer (2010) also observed that the use of this book increased markedly the use of IsiXhosa in asking questions, explaining concepts and expressing oneself. He concluded that the teachers’ use of the resource book led to their increased first language use and they appeared to be more confident in using IsiXhosa in mediating Mathematics concepts.

In the literature, apart from the CLP, there appears to be limited published multilingual materials available for use that provides mathematical terminology and explanations in indigenous languages meeting the needs of FET multilingual classroom teachers and students in South Africa.

4. THEORETICAL FRAMEWORK

This study is informed by aspects of socio-cultural theory as envisaged by Vygotsky, particularly the critical role of language in communication and cognitive development. Vygotsky’s theory emphasizes the social environment as a facilitator of development and learning (Tudge & Scrimsher, 2003). By embracing a socio-cultural perspective it is possible to view the language backgrounds of the teachers and pupils as a resource for teaching and learning Mathematics (Moschkovich, 2007). The socio-cultural aspects of Vygotsky’s theory illuminate the point that learning and development cannot be dissociated from their context. The social environment influences cognition through its “tools” i.e. cultural objects, language, and social institutions. According to Vygotsky (1978), people use psychological tools- signs, symbols and conventions that have been socially negotiated- to engage and understand their environments. People think and perceive things in a way made possible by the vocabulary and phraseology of their language, hence, concepts that cannot be encoded in their language will not be accessible to them, or at least will prove very difficult (Durkin, 1991). Learning then is seen as internalization which is the transformation of communicative language into inner speech and further into verbal thinking (Vygotsky, 1978).

Orton (2004) emphasizes that language used for thinking is almost certainly the first language. Thus Mathematics communicated in one language might need to be translated into another to allow thinking and then translated back in order to converse with the teacher. Vygotsky thus, perceptively observed that language forms do not replace one another but coexist in the human mind (Oakley, 2004). Vygotsky’s theory helps frame issues of learners’ first languages as used by the teachers explored in this study, as they relate to code switching in the Mathematics multilingual classroom.

5. SAMPLE AND RESEARCH PROCESS

Three grade 11 Mathematics teachers were purposefully selected from three secondary schools in the Eastern Cape Province. Each teacher was observed for five consecutive lessons in a week teaching trigonometry. The lessons were video recorded. At the end of each lesson, each teacher was interviewed following up on the lesson that the teacher has just taught.

The videos were transcribed and analysed in terms of:

a) consistency in the frequency of code switching into IsiXhosa across teachers, and
b) lesson categories developed from the works of Gumperz (1982) and Mercer (1995).

The lesson categories for b) are:

- response to student contribution (RC),
- questioning (TQ),
- teacher explanation (TE),
- classroom assessment techniques (CA),
- evaluative remarks (ER), and
- class management talk (CM).

Further, the data was analysed for consistency and precision across mathematical domains of practice as propounded by Dowling (1998). These domains are:

- Esoteric domain, which is characterised by the use of highly specialized, formal and abstract mathematical language and content;
- Descriptive domain, which uses specialized mathematical language imposed on non-mathematical content;
- Expressive domain, which deploys non-mathematical language to refer to mathematical content;
- Public domain, which is characterised by referring to forms of expressions and content expressed in entirely everyday terms.

Two overall teacher code switching practises emerged. These were referred to as borrowed code switching (BCS) and transparent code switching (TCS). Data was further analysed for consistency in these two practices.

5.1. Borrowed Code Switching Strategies (BCS)

BCS is where a teacher borrows from the English language either by retaining the English spelling or by adapting the phonology of the borrowing language (Baker, 2011) in this case IsiXhosa. Two forms of borrowing code switching were noted:

Transliteration (TLT), where nativisation of existing English language mathematical terms (Begg, 1991) was done. This involved giving an IsiXhosa spelling and pronunciation to English terms (Barton, Fairhall and Trinick, 1995); and

Loan word borrowing (LWB), where teachers borrowed from the English language, retaining the spelling, meaning and pronunciation of the word (Baker, 2011).

5.2. Transparent Code Switching Strategies (TCS)

TCS is where the meaning of the terms was not concealed but noticeable, self-evident and transparent to students (Meaney et al, 2012). Four forms of TCS as adapted from Gauton et al, (2003) emerged in this study;

- Semantic Transfer (SST)-Code switching where a new meaning, and/ or additional more technical meaning, was attached to existing words by modifying their semantic content.
- Paraphrase (PAR) - Code switching that was a short description or explanation of the word derived by putting together related words or unrelated words (Baker, 2011.

- Compounding (COM) - Code switching where a term was coined by combining existing words to form one word (Meaney at el, 2012).
- Ready Translated Equivalent (RTE)- this refers to all situations where there was no problem of non-equivalence at word and/or phrase level between source (English) and target language (IsiXhosa) because IsiXhosa already possessed ready equivalent of the English term (Gauton et al, 2003).

5.3 Validity

Validity is defined as the degree to which data collected in the research truly measures that which it was intended to measure (Creswell, 2009) or how truthful the research results are. Multiple sources of evidence were used during data collection thereby increasing the validity of the data in this study. As argued by Yin (2003, p99), "case study design proposes using multiple sources of evidence in a triangulation fusion to contribute to addressing any potential problems." Three methods of data gathering (lesson observation, document analysis and semi-structured interviews) were used in our study that. Data triangulation, that is, the analysis of qualitative data received from semi-structured interviews and quantitative data from lesson observations and document analysis, was also done. The process of triangulation was intended to add value to the validity of this study as themes were established based on several sources of data.

6. RESULTS AND DISCUSSION

For the purposes of this paper, we will only be discussing the following:

- General frequency of teacher code switching
- Teacher code switching frequency per lesson category
- Code switching across domains of mathematical practice
- Emerging code switching practices

6.1. General Frequency of Teacher Code Switching

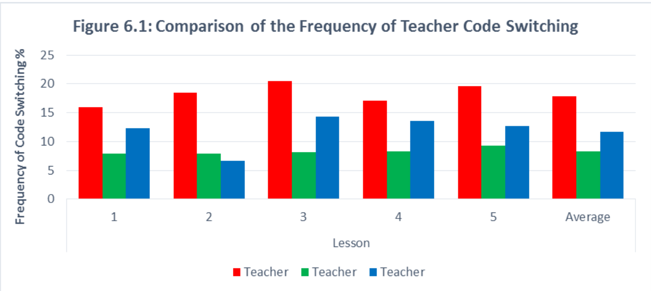


Figure 6.1: Comparison of the Frequency of Teacher Code Switching

As can be seen in Figure 6.1, teacher A code switched into IsiXhosa more than the other two teachers and was fairly consistent in this throughout the five lessons. On average teacher A conducted 18% of the classroom talking in IsiXhosa. Teacher B only did 9% of his classroom talk in IsiXhosa. Teacher B, whose amount of code switching gradually increased across the five lessons, code switched half as much as teacher A. Teacher C however, spent on average 12% of his talking in IsiXhosa and was inconsistent in the amount of code switching across lessons.

Across all teachers, the amount of code switching was found to be inconsistent. The three teachers exhibited different quantities of code switched terminology across lessons. All the teachers indicated during interviews that they did not plan in any form for code switching. It occurs spontaneously during teaching, they said. Teacher B said "In our daily conversations, we code switch without any planning and hence even in class it is the same"

6.2. Teacher Code Switching Frequency per Lesson Category

As indicated in Figure 6.2, in the teaching of Trigonometry, all teachers used IsiXhosa predominantly to ask questions-TQ- (A-31%, B- 40%, C-37%) and for the purpose of explaining concepts-TE- (A-45%, B-39%, C-42%). It is apparent that the consistency of the frequency of code switching into IsiXhosa across the teachers for TQ and TE respectively varies.

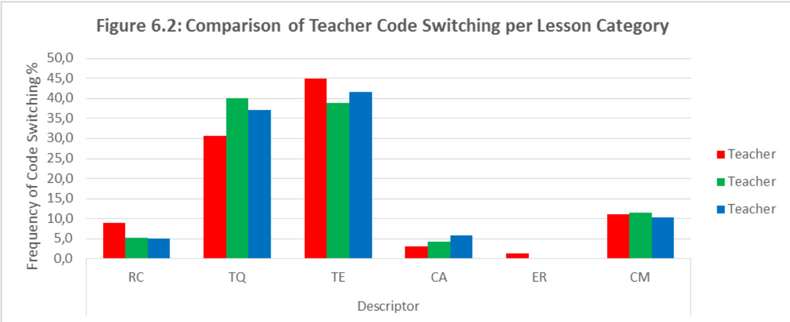


Figure 6.2: Comparison of Teacher Code Switching per Lesson Category

Interestingly, we observed that learners would make their contributions in IsiXhosa most of the time and teachers would respond and follow-up in English. During the interviews, teacher B indicated that he encourages students to respond in English and use it correctly. Teacher A said, "All our textbooks are in English, the school's language for teaching is English and all our exams and tests that we give are in English. So it [responding in English] is to help the student" Evaluative remarks (ER) by the teachers were mostly done in English except in the case of Teacher C.

6.3 Code Switching Across Domains of Mathematical Practice

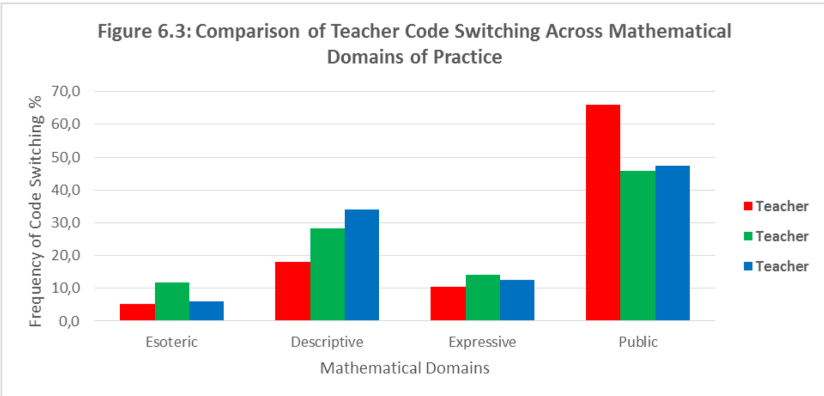


Figure 6.3: Comparison of Teacher Code Switching Across Mathematical Domains of Practice

Figure 6.3 illustrates the observation that all the participating teachers operated mostly in the public domain (A-66%, B-46%, C-47%). Very few of their IsiXhosa terms (A-5%, B-12%, C-6%) were in the esoteric domain.

Considering that most of the classroom code switching was done during questioning (TQ) and explaining (TE), and that all the three teachers operated mainly in the public domain, implies that teachers predominantly taught in the everyday domain. This, according to Dowling (1998, 2000), it can be argued that not much formal Mathematics is taught.

6.4. Document Collection and Analysis

Document collection and analysis revealed that only teacher A had access to some mathematical material in IsiXhosa even though she did not refer to it in her preparation for teaching. During the interviews, teacher A said she had the book by Young et at (2005) and (2009) but had never used it.

Teacher A stated that the terms used in the book were too deep for the students and unfamiliar. When teacher A was asked where she got her mathematical vocabulary in IsiXhosa, she said "It just comes when I am speaking, just like when we speak outside the classroom. I use common sense because we have some of these words in my language though not big ones like perpendicular or trigonometry". Teacher A did not have lesson notes nor plans and used the textbook to select examples for classwork.

Teacher B had lesson notes in the form of a compilation of questions for classwork and homework, written in English. On being asked where and how he got his Xhosa vocabulary, the teacher said that "I rely on my own knowledge and understanding of Xhosa because it's my mother tongue. I do not have any textbooks or dictionaries for Mathematics in IsiXhosa."

Teacher C brought classwork on photocopies and PowerPoint slides. Teacher C had charts in his mathematics classroom on factorisation, functions, number systems and calculus. When asked where he got his vocabulary, he said "one has to be creative. I use my knowledge of Xhosa as it is my home language and I try to merge it with Mathematics. Some terms especially in this topic (trigonometry) are not there in my language."

6.5. Data Analysis for Code Switching Strategies

6.5.1 Teacher A

Table 6.5.1

		LESSON					Total	
		1	2	3	4	5		
BCS	TLT	0.8	0.0	1.3	1.3	1.2	4.5	69.8
	LWB	19.2	3.5	17.7	13.4	11.5	65.3	
TCS	SST	1.9	0.3	2.2	0.5	0.6	5.5	30.2
	PAR	1.2	0.0	0.3	0.0	0.1	1.5	
	COM	0.3	0.0	1.8	0.4	0.4	2.8	
	RTE	7.4	1.4	3.8	4.5	3.2	20.4	
TOTAL		30.7	5.1	27.0	20.1	17.0	100.0	

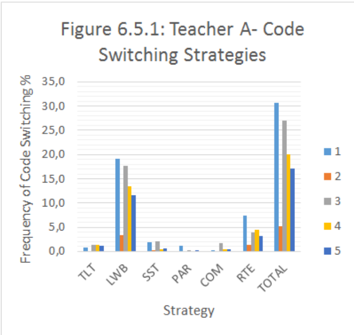


Figure 6.5.1: Teacher A- Code Switching Strategies

Table 6.5.1 shows that in all the five lessons, 65% of the mathematical terms in IsiXhosa used by teacher A in Trigonometry were obtained by loan word borrowing. The use of IsiXhosa mathematical terms varied across lessons 1 to 5 (30.7; 5.1; 27.0; 20.1; 17.0 respectively).

In summary, 69.8% of teacher A's code switched mathematical terms were borrowed. 30.2% were code switched transparently.

6.5.2. Teacher B

Table 6.5.2

		LESSON					Total	
		1	2	3	4	5		
BCS	TLT	1.24	0.93	1.55	2.17	2.79	8.67	75.9
	LWB	21.1	13.3	9.91	10.2	12.7	67.2	
TCS	SST	2.17	0	0	0	1.55	3.72	24.1
	PAR	0.62	0	0	0	0	0.62	
	COM	0.62	0	0	0	0.31	0.93	
	RTE	5.88	3.72	3.72	2.79	2.79	18.9	
Total		31.6	18	15.2	15.2	20.1	100	

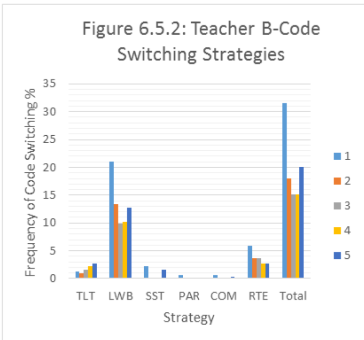


Figure 6.5.2: Teacher B-Code Switching Strategies

The use of mathematical terms by teacher B was fairly consistent across lessons as shown in Table 6.5.2. The LWB strategy (67.2%) occurred for most of the time. BCS accounted for 75% of the identified mathematical terms of teacher B, used during the teaching of trigonometry. 25% of the mathematical terms were through TCS. Teacher B consistently operated in the BCS strategy.

6.5.3 Teacher C

Table 6.5.3

		LESSON					Total	
		1	2	3	4	5		
BCS	TLT	4.8	1.3	1.1	0.4	3.1	10.8	78.7
	LWB	22.9	7.7	9.5	8.4	19.6	67.9	
TCS	SST	1.8	1.3	1.1	0.9	0.0	5.1	21.3
	PAR	0.0	0.0	0.2	0.0	0.2	0.4	
	COM	0.9	0.0	0.9	0.4	0.2	2.4	
	RTE	5.5	2.0	2.2	1.3	2.4	13.4	
Total		35.8	12.3	14.9	11.4	25.5	100.0	

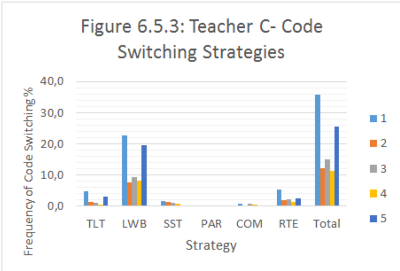
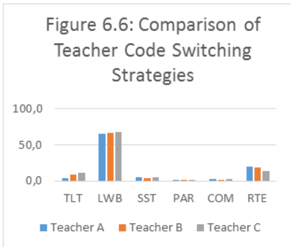


Table 6.5.3 shows that 79% of Teacher C's use of mathematical terms was through borrowing while only 21% was through TCS (see Table 6.5.3). For the transparent code switching strategy, RTE was employed 13.4% in the five lessons.

6.6. Comparison of Teacher Code Switching Strategies

Table 6.6

			Teacher A	Teacher B	Teacher C	Total
Strategy	BCS	TLT	4.5	8.7	10.8	78.7
		LWB	65.3	67.2	67.9	
	TCS	SST	5.5	3.7	5.1	21.3
		PAR	1.5	0.6	0.4	
		COM	2.8	0.9	2.4	
		RTE	20.4	18.9	13.4	



As is apparent from Table 6.6, teachers consistently used the LWB (A-65.3; B-67.2; C-67.9) strategy throughout the five lessons. The greater part of the mathematical talk in IsiXhosa was done through borrowing where teachers would attach prefixes to already existing English mathematical terms. All the teachers consistently used the borrowing strategy (A-69.8%; B-75.9%; C-88.7%) throughout the teaching of trigonometry, more than using the transparent code switching strategy (A-20.2%; B-24.1%; 11.3%). Teacher C borrowed 89% of mathematical terms from English and transparently code switched only 11% of the time.

Commonly noted borrowed terms were of the form ***u-Sin, Kwi-triangle, i-perpendicular, i-height, ngu-Tan*** and others. Teachers would also use a prefix on symbols and notation. Examples include ***u-AB, ngo-AD*** (meaning side AB), ***u-C*** (meaning angle C), ***la-x*** (x standing for a side), ***sino-ABC*** **(we have), *ku-E.***

For all the teachers, most of their terms in the esoteric domain where code switched using the LWB and TLT. For example LWB- ***i-height***, ***Uyintoni u-angle C ku-AD?*** (What is angle C in relation to AD?) ***siyayibona ngantoni i-hypotenuse kanene?*** (How do you identify the hypotenuse?)

TLT: ***ufune i-ratio kengoku e-involved ne-hypotenuse*** (find the ratio that involves the hypotenuse); ***u-x wethu sim-provile uba u-x…*** (We have proved that x…); ***ubu solva la-C*** (you were solving for C)

As illustrated in table 6.6, the presence of the RTE strategy in each of the teachers' mathematical terms (A-20.4%; B-18.9%; C-13.4%), was of interest to this study. The mathematical isiXhosa words that teachers used in day to day life and are mathematical, were categorised in this strategy.

The classroom use of RTE strategies suggests that there are mathematical words that exist in IsiXhosa. And because the teacher is using such terms in the classroom, means they are of the students' IsiXhosa dialect or they are familiar to these students. Interestingly, these RTE terms were commonly used by all the three teachers without reference to published mathematical sources in IsiXhosa. What may be required is to have these captured, collated and formalised. Examples of such terms used by the teachers included ***fumana*** (find), ***bala*** (calculate), ***kuqala*** (first), ***zoba*** (draw), ***Krwela umgca*** (draw a straight line), ***dibanisa*** (add), ***cala*** (side), ***lingana*** (equal to). These, according to teacher A, are used in daily life by the students and the teacher. These same terms/phrases have a technical or mathematical meaning. On checking the meaning of these terms, it was noted that they retain their mathematical meaning of their English equivalents.

Teacher C used connectives in IsiXhosa considerably more than others. These include; if (***noba***), or (***okanye***), of (***ka-***), that, if, so (***uba***), if (***xa***), that (***ubanangaba),*** but (***qha***) among others. These had ready translated equivalence in IsiXhosa and hence were also categorised under RTE.

As Table 6.6 depicts, RTE, a transparent switching, was done at a very minimum level (A- 20.4%, B-18.9%, C-13.4% of the total mathematical terms). Very little transparent code switching, which according to Meaney et al (2012), supports students' understanding and thinking in Mathematics, was evident in the observed teachers' language practices. Teaching strategies that will enhance the conceptual understanding of Mathematics and those that will aid thinking are key to achieving improvement in the teaching of the subject. The preliminary results suggest that, because most of the observed code switching practices are not transparent, the intended outcome of quality learning is compromised. Prevalent borrowed code switching, which apart from the added prefixes, are words in English does not provide learners with clues, hints or access to Mathematics concepts.

7. BEST PRACTICES FOR CODE SWITCHING

As code-switching is very prevalent in our schools and recognised as a legitimate teaching and learning resource, there is a pressing need to identify and document best practice. Although there is a scarcity of code switching materials in Mathematics, it is important that available code-switching support materials are utilised effectively. There is a huge need for the production of more and even better multilingual teaching resources in Mathematics. The complex and challenging nature of teaching Mathematics in multilingual classrooms makes the identification, production and use of materials for best instructional practices for code switching an urgent matter.

Considering that school mathematics texts are written in formal language, and code switching happens mainly in informal languages, there is an urgent need to reduce this gap. We argue that in order to introduce the formal Mathematical talk in indigenous languages, resulting in orienting students' oral language towards esoteric mathematical practices (Dowling, 1998), requires the development and use of mathematics registers in indigenous languages, in this case IsiXhosa. Mathematics teachers in multilingual classrooms need to be made aware of, and encouraged to use available multilingual mathematics resources to aid their teaching and learning of Mathematics.

Teachers in this study pointed out that they were trained to teach in English only because it is the LOLT. Essien (2013), a teacher trainer points out that teachers are trained in English and it is assumed that these same teachers will recontextualise what they have learnt in English into a different linguistic context at the end of their qualification. School teacher training institutions will need to be adequately resourced for this task. Essien (2010) noted that there are no structured courses that attend specifically to mathematics pre-service teachers of students who are not yet proficient in the language of instruction. The implementation of multilingualism in the classroom is left entirely for the teacher to decide as to the how, when and where to draw the mathematical vocabulary in indigenous language. Khisty (1995) cautions that knowing the mathematics register in one language is not an obvious indication of knowing it another language. Deliberate steps will need to be taken to orient teachers to knowing mathematics register in another language that is to be used in the classroom. Wildsmith-Cromarty (2008) recommends that teacher training needs to be conducted in a bilingual institutional context to enable teachers to use indigenous languages for instructional purposes.

The issue of availability of resources in indigenous languages resonates with the idea of teacher preparedness for code switching. Best practices will thus imply proper prior planning for code switching in the classroom as opposed to impromptu, inconsistent and ad hoc code switching which is a current phenomenon in mathematics secondary school classrooms. Mgqwashu (2004) found that Tanzanian High School teachers using KiSwahili were not using KiSwahili technical terms, but non-technical register, and this did not give students access to the concepts and vocabulary needed for understanding the subject. Proper planning for code switching, where teachers refer to available multilingual resource for guidance, is regarded in this study, as important. We argue that this willlead to code switching that is beneficial to students. Such switching is as a result of the use of transparent terms in indigenous languages (Meaney et al, 2012) leading to code switching that is transparent.

A balance needs to be established between code switching and indigenous language terms that are familiar to students. Schafer (2010) reports that teachers who participated in the Concept Literacy Project and their students expressed concern over the 'deep' Xhosa also referred to as rural, old, traditional or formal, that was not familiar to both teachers and students. This paper argues for transparent code switching, where terms familiar to students are precisely and consistently used to give students access to mathematical concepts.

8. CONCLUSION

Teachers who participated in this study did not use any mathematical materials prepared in IsiXhosa. They relied on their own individual understanding and translations. Yet in those few instances they managed to code switch precisely and consistently with formal definitions of English Mathematics terms. With necessary support, through relevant and adequate teaching materials, teaching Mathematics for conceptual understanding can be enhanced. Development of teaching materials in IsiXhosa that will aid the teaching of Mathematics at GET and FET phases is crucial. This paper also concludes that initiatives on developing teaching materials in indigenous languages that have occurred and yielded results should be revisited, improved and made readily available and more accessible to teachers.

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TEACHERS AND LEARNERS' PERCEPTIONS ABOUT TEACHER-OUTSOURCING AS A COMPLIMENTARY STRATEGY IN GRADE 12 MATHEMATICS CLASSROOMS

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Abstract–The study reported in this paper sought to explore outsourcing as a strategy to influence the 12th grade learners' academic performances in the under-performing schools. The study followed a descriptive framework as it is qualitative in nature. Data collection strategies included semi-structured interviews and focused groups, as well as classroom observations throughout the outsourcing process. Ten teachers were purposefully selected from ten secondary schools. An average sample of 8 learners per school participated in the semi-structured interviews and later was engaged about their perceptions regarding outsourcing as a strategy via the focused group discussions. The findings indicated that outsourcing as strategy used appeared to have benefits towards improving learners' academic achievements on topics that were taught. Furthermore, both the teachers and learners in the host schools identified outsourcing as having a value in influencing their practice positively.

Keywords: Outsourcing, mathematics achievement, mathematics teaching; learning.

INTRODUCTION

South African high school learners have been underperforming in mathematics for many years now (Department of Basic Education [DBE], 2011). The schools that do not exceed the standard pass rate of 50% are classified as under-performing (Department of Education, 2001). Research has demonstrated that the poor academic achievement in Mathematics appeared to be connected to factors such as: teachers' subject matter knowledge; classroom assessment for learners; learners' socio-economic status; overcrowded classrooms; lack of resources; low motivation and attitude (Mbungua, Kibet, Muthaa, & Nkonke, 2012;). Geldenhuys (2000) argued that learners' poor academic achievement may be caused by absenteeism as well as mathematics anxiety. Some other factors that affect poor performance in mathematics are teacher workload, school discipline and time management (Musasia, Nakhunu, & Wekesa, 2012). However, it was observed that most of the schools in one of the district in Limpopo Province performed poorly whereas some produced poor results in Mathematics. The cause(s) of poor academic performance in those schools were unknown and the district office intervened by inviting teachers who produced good results to the underperforming schools to conduct lessons with the aim of sharing best practices. Such an intervention was termed *outsourcing*.

It is for the rationale discussed above that this study sought to explore *outsourcing* as a strategy to influence academic performances in the underperforming schools. According to Smith and Smith (2012), *outsourcing* is any task or operation that can be performed by an expert from institution in which the teachers in the institution lack expertise to carry out those duties effectively. Hima (2006) defined outsourcing as a business process term for hiring an external expert to provide services for the institution to do a specific task or tasks in which the institution does not have an expert to do on its own. Moreover, Pescheck and Schneider (2001) confirmed that *outsourcing* is when an organisation gets help from outside to perform specific task that cannot be performed in-house.

The intervention used in the study's design was in a form of sourcing (or inviting) performing schools' teachers to assist the teachers in the under-performing schools by sharing and demonstrating their best practices. In other words, experts (performing teachers) were invited in the institution that lacked the expertise in (effective teaching and learning of mathematics) of executing a particular task (Pescheck & Schneider, 2001). In this regards, teachers from other schools were invited by the district office to teach mathematical concepts that seemed difficult to the host teachers to teach.

These processes of *outsourcing* had prompted our curiosity to evaluate and explore it by establishing how effective this model of intervention is. The effectiveness of *outsourcing* was measured by Fischer's (2000) model for evaluating the process. In the evaluation process, we have interviewed teachers, the host and guests' teachers about the process of outsourcing. The guest teachers' lessons on the specific aspects of mathematics were observed. Focus groups were used to draw information from learners about outsourcing and how effective (or not) it was. This article starts by providing an overview of related literature, presents Fischer's model within the contexts of *outsourcing*, then it discusses methodological issues, and then finally presents conclusions and recommendations.

THEORETICAL ISSUES

As noted earlier, the research reported in this article is framed by Fischer's (2000) fields of competence to evaluate outsourcing, its impact on learners' learning of mathematics. Fischer's fields of competence of expert teachers' outlines basic knowledge and skills, operations and reflections .It provides an understanding of what constitute(s) an expert teacher in the field of mathematics. The expertise of teachers is discussed in accordance with the three attributes of the expert teacher. Invarson, Beavies, Bishop, Peek & Elsworth (2004) is of a view that expert teachers are those who teach mathematics effectively and have coherent beliefs and understanding of mathematical concepts. Such expertise of the guest teachers made it possible for the host schools to learn how to teach concepts that appeared to be difficult to teach.

Outsourcing is defined as a process in which one delegate the expertise of others to execute tasks that are challenging to others to execute (Pescheck & Schneider, 2001). Other scholars defined it as a process of hiring external employees/teachers to perform a specific task for an institution in which the institution does not have the expertise to perform on their own (Smith & Smith, 2012; Hima, 2006). Lazarus and McCullough (2005) describe outsourcing as a way to improve service, and reduce costs. They argued that little is known about whether outsourcing impact schools in rural areas differently to those in non-rural areas. Outsourcing consists of two teachers, the guest teacher who renders the service in the host school and the host teacher who is assisted in the difficult concepts. Outsourcing is characterised a process whereby the host teachers invite the guest teachers to teach topics that are perceived as difficult to teach in their schools. The guest teachers' skills and expertise are outsourced in order to improve learners' academic performances in the host schools.

For the purposes of the study discussed in this article, Fischer's (2000) description of what constitute(s) a 'good teacher' in the teaching and learning of mathematics was adopted. In actual fact, Fischer identified the following fields of competence that teachers of each subject should acquire in order to teach their contents: *basic knowledge* (notions, concepts, and forms of representations); *operative knowledge and skills* (solving problems, proofs in general, generating new know knowledge); and *reflections* (possibilities, limits and meaning of concepts). The expert teachers in particular should be competent in the first two fields of competence to teach the mathematics content effectively. Fischer also considers the fields of basic knowledge and reflection as being particularly important for the generally educated laypersons (referring to novice teachers). Basic knowledge ''is a prerequisite for communicating with experts, reflection is necessary for judging their expertise'' (p.5).

The expert teachers are regarded as the ones who are effective and competence in teaching mathematics (Invarson et al, 2004). Such teachers should be creative and innovative and follow a learner–centred approach in their teaching (Miranda & Adler, 2010). They should also display adequate experience of mathematics teaching that meet learners' needs. Teachers' experiences in effective teaching of mathematics are important to improve learners' academic performances (Mogari et al., 2009). A solid body of research has demonstrated teachers' experience influences learners' academic performances in school Mathematics (Betts, Zau & Rice, 2003; Center for Public

Education, 2005; Greenwald et al., 1996; Rivkin, Hanushek & Kain, 2005). Moreover, expert teachers display a good background of subject content knowledge (SCK) and pedagogical content knowledge (PCK) in teaching and learning of mathematics (Shulman, 1986).

The teaching and learning of school mathematics basically requires teachers to have good command of subject content knowledge (Sepeng, 2014). Teacher subject content knowledge (SCK) is regarded as mathematical knowledge for teaching (Shulman, 1986; Hill et al., 2008; Hill, Rowan, & Ball, 2005). According to Hill (2010), teacher mathematical knowledge is related to classroom teaching and is bound to influence learners' academic achievement. Teachers with poor mathematical knowledge are less likely to present materials clearly and provide error-free content to the learners (Ball, 1990a; Borko et al., 1992; Cohen, 1990; Heaton, 1992; Putnam, Heaton, Prawat & Remilhard, 1992; Stein, Baxter, & Leinhardt, 1990). In the study discussed in this article, teachers who participated in host schools needed to have acquired the skills and knowledge of an 'expert' or a 'good' teacher within the framework of SCK in order to improve learners' performance in mathematics. The guest teachers' services in this process complemented the normal classroom practice in mathematics for the betterment of learners' achievement. These teachers can interpret and respond to learners' problems in mathematical concepts and produce more conceptually grounded lessons (Lloyd & Wilson, 1998).

Teachers' SCK and PCK may be an ingredient for and integrated parts of effective mathematics instruction (Shulman, 1986). In other words, in order to construct mathematical concept in learners' mind, SCK and PCK are needed. The manner in which teachers relate their subject matter to their pedagogical knowledge and how subject knowledge is a part of a process of pedagogical reasoning are seen as integrant of PCK. PCK is knowledge of how to learn content of mathematics or approaches used in the teaching of a mathematical topic (Shulman, 1986; Wilson, Shulman, & Richert, 1987; Speer & Wagner, 2009). It requires teachers to have knowledge of learners' understanding of mathematical thinking, such as how learners process, store, retain and recall information learnt (Shulman, 1987; Romberg, 1988). The host teachers attended the lessons presented by expert teachers in order to improve both their PCK and SCK.

RESEARCH METHODOLOGY

The study reported in this article followed a descriptive framework. The qualitative data were collected via classroom observations, interviews and focus groups. The data analyses were descriptive in nature (Johnson & Christensen, 2004). The interview questions at both learner and teacher levels assisted us to understand how they perceived the notion of *outsourcing* in relation to mathematics academic performances. The observation schedule (adapted from Luneta, 2006) was used in order to make sense of pedagogies that are employed by the guest (or expert) teachers in the teaching and learning of mathematics during outsourcing process. In addition, the focus groups in the 10 schools assisted us to have a reliable data on the effectiveness (or lack thereof) of *outsourcing* as an intervention model at learner level.

The study was conducted in ten resource constrained secondary schools in one of five cluster circuits in Polokwane. The questionnaires were distributed by us to the 10 participating teachers before and after the *outsourcing* intervention. The classroom observations were conducted in five consecutive days to each guest teacher. On average, eight learners were randomly selected to participate in the focus group discussions from each participating schools.

DATA ANALYSIS

Data collected from teachers and learners were analysed separately as the study included both teachers' and learners' perspectives about the intervention. The analysis of data was based on teachers' observation lessons in the five schools and the conducted interviews. The learners perspectives were analysed which was collected through focus group interviews. The teachers' classroom observations were analysed within the contexts of theories used in this study.

RESULTS AND DISCUSSIONS

This section provides selected data for purposes of this article and is presented at both teacher and learner levels within the contexts of *outsourcing* as a strategy to improve academic performances in teaching and learning mathematics. The data are presented separately according to the instruments used in the study reported in this article.

Classroom observations

Data obtained from classroom observations revealed that most of the teachers had introduced their lessons by engaging learners with questions in order to link learners' current knowledge (or prior-knowledge) with new knowledge on concepts to be taught before they could start with their topic of discussion (Fischer, 2000). These introductions were sometimes in line with what learners knew to enable them to start with the concepts that had to be taught. The concepts taught by the guest teachers were clearly presented for learners to understand. The concepts involved were financial mathematics, height and distances in trigonometry, data handling and probability. Guest teachers and learners in host schools interacted through a questioning and answering method, to actively involve learners in the lessons. The lessons involved discussions between teachers and learners and learners and learners through questioning and answers. It was therefore not a traditional type of one-way traffic. The four teachers A, C, D, E, H, I and J did not ask questions to get correct answers but involved those who seemed to be passive during the lesson. Teacher B sometimes asked learners to get correct answers because she pointed those who put up their hands. Learners who did not raise their hands were sometimes not given chance to answer questions in Teacher B's class.

Group discussion was used as another approach to teach the stated concepts in the host schools. Learners were given problems to solve in groups and then followed by whole class discussion. The guest teachers attended them by walking around visiting each individual group to clarify misconceptions learners had. After every group discussion, learners were given an opportunity to write the answers on the chalkboard. The teachers A, B, E, F, H, I and J gave learners to engage amongst themselves before they could give them feedback. Only teachers C and D had mostly just gave learners feedback without engaging the whole class for peers to rectify their peers.

From the teachers' interview perspective, eight of the teachers confirmed that the concepts taught by the guest teachers were difficult for learners to cope with. The other two teachers highlighted the point of teaching approaches they used to teach those concepts and confirmed that they are not so good in those concepts. Seven teachers suggested that maybe they organise workshops for them to develop them in those difficult concepts. The host teachers were satisfied the way their cluster circuit organised these guest teachers to assist in teaching the stated concepts. Mostly, they showed their satisfaction with the intervention as contributed to their work and helped their learners. Some of the host teachers asserted that the instructional approaches used by the guest teachers were effective as it enhanced their teaching skills in teaching the difficult concepts. Guest teachers used different teaching approaches and strategies such as group discussions which catered for all slow learners.

Learners' Perspectives

In this study, 260 learners from ten host schools participated in interviews, 100 participated in-person interviews and 160 in focus groups. Interview sessions were conducted on two different occasions before and after the implementation of the intervention as indicated earlier on. Learners in the ten schools appreciated the intervention as it played a significant role in their mathematics achievement. Most of them confirmed that the instructional approaches used by the guest teachers were effective and different from the ones used by the host teachers. And also, teachers proved themselves to have a good background of SCK according to learners' perspectives, they presented their lessons well. Hill et al. (2008) say that there is a relation between the teachers' subject content knowledge and pedagogical skill and the work done in the classroom and the outcomes achieved by the learners. The guest teachers had mostly taught topics that were difficult to learners and host teachers as has been requested (Hill, 2010).

The learners in the focus groups also showed their satisfaction with outsourcing process, they concurred that topics were made much easier for them to understand. Most of them also confirmed that the guest teachers gave them chance to ask questions and most of them are clarified. Unlike, with some of their teachers that they were not giving learners chance to ask questions, in short, some of the host teachers are impatient to learners. This indicated that guest teachers used approaches that differed from the ones used by their own teachers. Some of the learners cited examples regarding height and distance, where they initially had difficulties in understanding the concepts, but after it was taught by the guest teachers, they understood it. Some other mathematical concepts were made easier to learn by the guest teachers according to the learners perspectives. For an example, the concepts of financial mathematics were problematic where some of the learners struggled to differentiate between the annuities, scrap values, bond repayments and sinking funds. They claimed that such concepts were not taught well enough for them to understand. However, they demonstrated the opposite after the concepts were taught by the guest teachers during the intervention.

As noted earlier and indicated in the extract below, the intervention appeared to be effective. Most of the learners in host schools were convinced that they had a better understanding of the concepts that were taught by the guest teachers in their schools. The following extract is used as an example to illustrate learners' perceptions about the intervention:

Extract 1

Researcher: Is this outsourcing beneficial to you?
L10S3S2: Yes Sir, re ithutile se sengwe ka mathitjere a (*We have learned a lot from these teachers*).
Researcher: Why do you say this?
L10S3S2: They made concepts easier for us, such as probability, the topic was not taught well before this intervention by our teacher.

According to learner 10 in school 3 (L10S3S2), the guest teacher made the data handling topic look much easier for their understanding. Probability was one of the topics which were viewed as difficult by the participating. As a result of the intervention, most of the learners indicated that guest teachers' approaches to teaching this topics put emphasis on conceptual understanding and less on procedural knowledge (Sepeng, 2014). The learners also learned more from the teachers as some of them in the focus groups indicated that the guest teachers were mostly ready to respond to their problems. Some of the learners revealed that their teachers are not patient with them especially when they ask for clarity during mathematics lessons. This had shown that the guest teachers in host school displayed good content knowledge of the subject and managed to blend it with its pedagogy during teaching and learning of the stated concepts (Invarson et al., 2004; Shulman, 1986; Wilson, Shulman, & Richert, 1987 and Speer & Wagner, 2009). Therefore it appeared that the strategies used by the guest teachers influenced better understand the concepts that were viewed as difficult before the intervention. This was supported by leaners' focus groups, interviews and classroom observations. It is therefore suggested that the host schools develop their teachers by giving them opportunities to attend teacher professional development programs in mathematics.

Teachers' perspectives

Host teachers identified the challenging mathematical concepts in grade 12 which were taught by the guest teachers. They learned and gained more knowledge about the approaches and strategies used in the teaching of the identified concepts (TSCK and TPCK). The extract below is used as an example to demonstrate the host teachers' perceptions and views about the outsourcing process (R-researcher and T1-teacher):

Extract 2

Researcher: How does outsourcing help you and your learners?
Teacher 1: It helps us a lot as other teachers teach concepts that are challenging to us. Our learners will have an opportunity to be taught differently by a new teacher.
Researcher: What do you mean by being taught differently?
Teacher 1: I mean they have to be taught using different approaches from other teachers.

The teacher was confident that the guest teachers would assist in improving their grade 12 mathematics results. Some of the teachers said that the instructional approaches used by the guest teachers were effective as they enhanced the host teachers' teaching skills of those concepts and other mathematical concepts. The teachers A, D, E, F, H I and J cited one concept, height and distances in grade 12 trigonometry. The learners in their schools struggled to solve problems in this topic and the guest teachers made it easy for learners for them and their learners. One of them said that the teacher had used the corner of a tent to explain the angles and triangles on the ropes and a corner pole of the tent. She further said that the learners enjoyed the lesson as they indicated that they experienced difficulties in identifying different triangles from a three dimensional figures. Miranda and Adler (2010) indicate that teachers should be creative and innovative in teaching mathematical concepts. The guest teachers did their best to assist the host schools according to the host teachers. They also concurred that even their learners improved academically, this was proven them when the learners were given class tests on those topics. Most of the host teachers complimented the guest teachers about the support they gave to their learners and they also gained some skills in teaching concepts that were difficult. It was only two schools that their learners struggled with probability even when taught by the guest teachers. This revealed that the learners in the two schools still struggled to solve probability problems and needed assistance. The responses from all the host teachers therefore support that guest teachers' content knowledge and pedagogical skills complemented the teaching and learning of mathematics in the host schools (Hill, 2010; Hill et al., 2008).

Comparative Grade 12 Results Analysis

The final Grade 12 mathematics examination results from 2008 to 2012 are presented in table below.

Table: 2008 -2012 Grade 12 final mathematics results in %

Schools	2008	2009	2010	2011	2012	2013
A	32.3	40.1	36.5	59.2	63.8	68.6
B	25.3	33.7	37.1	62.4	61.4	69.8
C	29.0	36.2	25.2	56.8	59.1	63.5
D	30.1	34.9	28.6	54.3	60.7	71.1
E	31.2	38.1	34.4	59.2	66.2	68.8
F	33.4	35.6	40.4	56.0	59.3	61.7
G	35.0	38.1	43.2	59.4	63.0	66.2
H	37.7	39.0	40.9	60.2	61.9	67.3
I	30.6	41.5	43.3	56.3	62.6	59.3
J	31.1	36.7	45.5	57.1	60.8	62.9

From the table, the 2011 and 2012 final examination results were also compared and contrasted with the 2008-2010 ones. The results were much better in the final examinations of 2011 and 2012 as compared with 2008-2010 examination results in mathematics. The results above showed that the schools were not performing well. These poor results had changed after the interventions were made by the circuit to introduce the outsourcing model. The final examination results for 2011 and 2012 were much more improved by more than 20% as compared to the 2008-2010. The results in the ten schools were grouped in interval 50% - 55% and 60% and above as per school. All the schools in 2011 had obtained 55% and above except D which obtained 54.3% but improved its performance by 6.4% in 2012 and obtained the mean percentage of 60.7%. Those schools that obtained between

55.0% - 59.9 were seven; A, C, E, F, G, I and J; and those obtained between 60.0% - 69.9% were only two, B and H. the academic achievement in 2011 were in contrary to the 2012 once, the final results in all the schools were above 55.0% and none of them obtained less than 55.0%. The schools which obtained between 55.0% – 59.9% were only two, C and F and those which obtained between 60.0% - 69.9% were eight and none of them went beyond 69.9%. The results concurred with the satisfaction of teachers and learners about the intervention strategies used in their schools. The results therefore revealed that most of the learners improved academically in grade 12 mathematics. The 2008 and 2010 examination results were used as a referral point to confirm the poor performance of learners in mathematics. The two examination results were also used to measure the impact of outsourcing in the five schools.

CONCLUSION

The outsourced teachers showed good background knowledge and skills of mathematics, operations and reflections, as learners and teachers perspectives had proven (Fischer, 2000). The guest teachers displayed the attributes of Fischer's (2000) model that played a role in outsourcing process. These teachers also have good subject content knowledge and pedagogical content knowledge which are in line with learners' academic achievement (Shulman, 1986; Wilson, Shulman, & Richert, 1987 and Speer & Wagner, 2009). The teachers who were used as guest teachers in the host schools showed most attributes of the Fischer's model and also good SCK and PCK. The guest teachers used approaches that met learners' needs as shown in the learners' interviews and focus groups. The host teachers had also appreciated the implemented intervention in their schools and were satisfied with the way in which the guest teachers taught their learners. They also learned teaching approaches, how to effectively engage with learners, and were informed about resources that can be used to teach mathematical concepts from their guest teacher. This therefore had shown that outsourcing process had played an important role in complementing normal teaching and learning of grade 12 mathematics. It had complemented the normal teaching of mathematics in the five schools as the learners had performed much better in 2011 and 2012 final year examinations. All the schools obtained the expected standard pass rate of more than 50% in mathematics for these two years of the study. The responses of learners in the interviews implicated that this type of intervention used complemented the teaching and learning in mathematics. Teachers and learners of the host schools appreciated the efforts of the circuit and the guest teachers for the support they gave in improving their grade 12 mathematics results.

Learners should also be informed that this intervention is implemented for their own benefit, not for comparing teachers. They should know that teachers use different approaches in teaching mathematical concepts. The 2011 and 2012 final year results had revealed that this outsourcing had complemented the normal teaching and learning of mathematics. This happened because of the guest teachers who were sourced as the host schools could not properly teach other mathematical topics. It was also due to the lack of necessary resources in the host schools. They outsourced the job, by inviting competent teachers from other schools to teach the difficult topics. Learners will also learn more from their teachers as they will have good background knowledge and skills of mathematics which will promote their content and pedagogy in the classroom. The host teachers should be encouraged to have mathematics teacher professional development initiatives in their schools. The research has to be done on the host teachers teaching mathematics in their schools to understand how they teach and learners learn mathematics. The results of the visiting teachers' teaching methods and approaches will enable the teachers in the host schools to identify the challenges they have in teaching mathematics in their schools. This will make them to change and use different approaches in teaching mathematics, and therefore enhance learners' learning of mathematics.

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THE PREDICTIVE VALIDITY OF JUNIOR SECONDARY SCHOOL MATHEMATICS SCORES: A COMPARATIVE STUDY OF SENIOR SECONDARY SCHOOL MATHEMATICS SCORES IN DELTA AND EDO STATES

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Abstract–This paper presents the results of a comparative study of the extent to which scores obtained by students at the Junior Secondary Certificate Examination (JSCE) in Mathematics predict the scores obtained in the same subject at the Senior Secondary Certificate Examination (SSCE) in the same subject. The study adopted an ex-post facto design, using 400 students who participated in JSCE in 2010 and SSCE in 2013, and randomly selected from twenty (20) secondary schools – 10 from Delta and 10 from Edo State. The JSCE scores and SSCE scores were extracted from school record files. Regression analysis was used to estimate the parameters of the specified equations. The results established that there is a significant relationship between scores obtained by students in Mathematics at the JSCE and the scores they obtain in the same subject at the SSCE. The results also indicated that location of the State has a significant effect on the scores obtained by students in SSCE Mathematics, as established by shift and slope dummy procedures and the Chow test, while the Theil's inequality coefficient showed that the forecasting power of the JSCE Mathematics on performance of SSCE Mathematics is slightly higher for Delta State compared to Edo State. The results suggest that Mathematics at the JSS should be taken seriously by students to enhance better performance in the subject at SSCE.

Keywords: predictive validity, JSCE, SSCE, mathematics.

INTRODUCTION

The Federal Republic of Nigeria (FRN, 2004) through the National Policy on Education (NPE) adopted six-year duration for secondary education given in two stages – Junior Secondary School (JSS) and Senior Secondary School (SSS) respectively. Students are expected to spend three years each at the JSS and the SSS. These two levels of secondary school education have different external bodies conducting their examinations. The Junior Secondary Certificate Examination (JSCE) is conducted by each state of the Federation, including Federal Capital Territory (FCT) Abuja through their respective Ministries of Education (MoEs) for the final year students of public and private-owned junior secondary schools. These different MoEs develop, administer, mark and award grades and award certificate to students under their jurisdiction. On the other hand, it is the responsibility of the National Examinations Council (NECO) to conduct the JSCE for all the Federal Government Colleges (Unity Schools) in the States including FCT and some interested private secondary schools, while the West African Examinations Council (WAEC) and NECO independently conduct the Senior Secondary Certificate Examination (SSCE) in Nigeria.

In line with the recommendations of the Nigerian Educational Research and Development Council (NERDC, 2008), what the students learn at the JSS level will lay the foundation for the students SSS education and it should be systematically connected to it. This continuity in the educational process is the essence of the educational system in Nigeria. It is therefore assumed that a student who is admitted into the Senior Secondary School Class 1 (SSS1) possesses the basic skills to cope with the challenges of schooling at that level. The above stated position however may not necessarily reflect what is happening at the secondary school level; for example it has been observed that some students who were promoted to SSSI because they obtained acceptable grades at the JSCE later failed at the SSCE (WAEC, 2008; Adeyemi, 2008), thus questioning the validity of the JSCE as a benchmark for predicting performance at the SSCE level.

According to Ukwuije (2009), the validity of a test is the most important attribute of a test and concerns with what the test measures and how well it does so, while the predictive validity is the extent to which test scores relate to a benchmark or criterion score (Osadebe, 2003). In line with the view of Orubu (2012), studies on predictive validity provide a framework for establishing the degree of credibility that can be placed on any prior examination.

In this study, the subject in focus is Mathematics. Oyedeji (1999) identifies mathematics as a specialized language in which knowledge of the physical world is recorded. Nurudeen (2007) viewed that Mathematics is an instrument to ease or facilitate the thinking capabilities of an individual in the learning of other subjects. A strong background in Mathematics is critical for many career and job opportunities in today increasingly technological society. Hence studies that will improve performance in it at this point are justified. Current government policy in Nigeria also specifies at least a pass in mathematics at the JSCE level (lower level) as a prerequisite for admission into SSSI. In the proposition of NERD (2008), with a pass at the JSCE, one should be able to determine students that would likely do well at the SSCE, but it is a common knowledge (and as already noted) that performance in SSCE Mathematics has always been relatively poor, when compared to other subjects, such as Biology, Government, Commerce, History, Literature in English, to mention but a few.

The results from prior studies on the effect of scores in lower level examinations predicting higher level examinations are mixed. Adeyemi (2008), in predicting students' performance at the SSCE level from their performance at the JSCE in Ondo State Nigeria, revealed that JSCE scores were good predictors of scores obtained by students at the SSCE. Osadebe (2003) investigated the predictive validity of JSCE scores in Mathematics and English for scores obtained at the SSCE in Delta State Nigeria. The results obtained showed positive and significant relationship between JSCE and SSCE students' scores in Mathematics and English. In a similar study by Onuka, Raji and Onabamiro (2010), they established that, there was a significant relationship between the overall performance in both examinations, as measured by scores obtained at the JSCE and SSCE, in Epe Local Government Area of Lagos State Nigeria. The results in a study by Falaye & Afolabi (2005), for Osun State, however indicated generally contrasting evidence, that Osun State JSCE, is a poor predictor of students' performance in the SSCE, except for their finding that JSCE English Language and Mathematics tend to have relatively greater capacity to predict performance in SSCE English language and Mathematics than the other subjects.

A few works have considered the factor of location, by investigating the proposition that variation in schools located could exhibit different performance ratings, which may be explained by heterogeneity effects such as the quality of the test, managerial skills, environmental factors and others. On school location, Adepoju & Akinwumi (2002) revealed by their study on location of secondary school students as a factor in determining academic performance of students in SSCE in Oyo State Nigeria, that there was a significant relationship between location of secondary schools and academic performance of students. However, in a related study by Onah &Ugwu (2002), they established that there was no significant relationship between school location and students' performance at Ebonyi State Nigeria.

This study is a contribution to the empirical literature on the role of scores obtained at a lower level examination in predicting scores obtained at higher level examination. Specifically, the research problem investigated hinges on the extent to which scores obtained in Mathematics at the JSCE can predict scores obtained in Mathematics at the SSCE, using data for Dlelta and Edo States. This comparative study for both States is justified, based on the historical relationship between the two States. Both Delta and Edo States in Nigeria, made up the old Midwest Region, created in 1963. In 1976, the Midwest Region was renamed Bendel State – subsisting until 1991 – when Delta and Edo States were created out of the defunct Bendel State.

Arising from the fore-going, the following three (3) hypotheses were raised to sharpen the focus of the study:

1. There is no significant relationship between scores obtained by students in mathematics at the JSCE and the scores they obtain in the same subject at the SSCE.
2. The location of the State has no significant effect on the scores obtained by students in SSCE Mathematics.
3. There is no significant difference in the forecasting power of scores obtained in Mathematics at the JSCE in respect to scores obtained in Mathematics at the SSCE, across Delta and Edo States.

The theoretical framework under-pinning this study is the one provided by Ausubel's (1970) theory of learning, which stresses the value of prior (lower) knowledge and the sequence of instruction in students' learning. This implies that meaningful learning takes place when there is appropriate link between prior knowledge and new knowledge. In other words, the learning of a new concept or skill depends upon the mastery of prerequisite concepts. This implies that previous knowledge determines higher knowledge. Therefore, one would expect the students' performance in the SSCE (higher level examination) to be determined by the performance in JSCE (lower level examination).

METHOD

The ex-post facto design is used in this study. This design is most appropriate because the event under investigation has already taken place. All the secondary schools in Delta State and Edo State who presented students for JSCE in 2010 and SSCE in 2013 were the population for the study. Twenty secondary schools were randomly selected for the study; ten from Delta State and ten from Edo State. Two hundred students were sampled from Delta State schools and two hundred were sampled from Edo State schools. The total number of four hundred students with intact record was used for the study. The instrument that was used to collect data from documented results from the principal is and Inventory. Since student's results for JSCE and SSCE are normally presented in qualitative format using A (Distinction), C (Credit), P (Pass) and F (Fail) for the JSCE and A1, B2, B3 corresponding to (Distinction, very Good and Good) C4, C5, C6 (corresponding to Credit), P7, P8 (corresponding to pass) and F9 (corresponding to Fail) for the SSCE, these format do not allow for a numerical range that will enable comparison of performance, hence for the purpose of scoring, JSCE grades of A, C, P and F were awarded 4,3,2 and 1 and the SSCE grade s of A1, B2, B3, C4, C5, C6, P7, P8 and F9 were awarded scores of 9,8,7,6,5,4,3,2,1 respectively. Thus an aggregate score that was amenable for data analysis were obtained for each student.

Data analysis involved the use of multiple Regression Analysis (MRA), using both F and T-Statistics to test for the statistical significance of the established parameters at 0.05 level of significance, the method of dummy variable was used to accommodate state location (Delta and Edo state). The basic regression equations that was estimated are

MATHSSCE = b_0 +b_1MATHJSCE + u_1 ------------- EQP_1, EQD_1 and EQE_1

MATHSSCE = b_0 + b_2STATE + u_1 -------------------- EQP_2 and EQP_3

The Chow F-statistic was computed to establish the differences in b_0 and b_1 between the two states. Theil's inequality coefficient was also calculated to verify the forecasting power of JSCE in Delta and Edo states. The dependent variable is the SSCE scores in mathematics while the independent variables are the JSCE scores in mathematics and JSCE scores in mathematics conducted by two states MoEs (Delta and Edo State). On different JSCE conducted by different MoEs, one may argue that since JSCE is meant to serve as a benchmark for admission into the SSS in any state, it is expected that the standards set with JSCE score in mathematics for any state with uniform scheme of work should be an adequate predictor of performance of students in SSCE mathematics across the country. With variation in human and material resources in the evaluation department of the state's MoEs, one should also expect the predictive validity of these JSCE scores in relation to SSCE scores to vary. How this variation is applicable to Delta State and Edo State can only be answered by an analysis of the data relating to JSCE and SSCE scores in Mathematics in Delta State and Edo State.

RESULTS

The results of data analysis are presented in table 1, according to the research hypotheses. The basic reference equations for testing hypothesis 1 are EQP_1, EQD_1 and EQE_1. For the pooled data, the sign of the coefficient attached to MATHSJSCE measured at 1.437 is positive and statistically significant at 1 percent level of significance. In terms of overall fit, the F statistic (R^2) estimated at 0.149 and the adjusted value ($\bar{R}^2$) measured at 0.147, indicating that about 15 percent of the systematic variation in the scores obtained in Mathematics at the SSCE is explained by the scores obtained in Mathematics at the JSCE. The overall F-statistics measured at 69.68 is statistically significant and showed that the regression equation has no specific error and has an acceptable fit. When the data were treated separately, the coefficient attached the MATHS JSCE in Delta and Edo States were 0.598 and 1.724. They were also statistically significant at 1 percent level of significance. With these results, the null hypothesis was rejected in favour of the alternative that there is a significant relationship between scores obtained by students in mathematics at the JSCE and the scores they obtain in the same subject at the SSCE.

Table 1. Summary of Regression Results; Dependent Variables =SSCE scores in Mathematics.

Independent Variables/Statistics	Results for Pooled Data			Results for Delta State	Results for Edo State
	EQP1	EQP2	EQP3	EQD1	EQE1
Constant	-0.245 (-0.62)	0.378 (0.92)	0.125 (0.32)	1.195 (2.30)**	-0.511 (-0.90)
MATHSJSCE	1.437 (8.35)*	1.340 (7.92)*	1.466 (8.79)*	0.598 (2.57)*	1.724 (7.24)*
STATE		-0.808 (-4.69)*			
MATHSTATE			-0.396 (-5.29)*		
R^2	0.149	0.194	0.205	0.032	0.209
Adj. R^2	0.147	0.190	0.201	0.027	0.205
F statistic	69.68*	47.70*	51.21*	6.60*	52.37*
RSS	1221.17	1156.94	1140.69	373.544	754.376
DW statistic	0.662	0.685	0.686	0.787	0.658
N	400	400	400	200	200

Source: Regression computations, using STATISTIX Version 8. Notes: The figures in parentheses under the coefficients are the corresponding t-values. The maintained null hypothesis is that the coefficient attached to each estimated coefficient is not significantly different from zero. A two-tailed test was performed. The critical t-values are: For α = 0.01, the 9bounds are $t_1 = -t_{0.005} = -2.576$, $t_2 = +t_{0.005} = +2.576$. For α = 0.05; the bounds are $t_1 = -t_{0.025} = -1.960$, $t_2 = +t_{0.025} = +1.960$. In all cases, one asterisk indicates statistical significance at α = 0.01 (1 percent), while two asterisks (**) indicate statistical significance at α = 0.05 (5 percent).

The second null hypothesis was that the location of the schools by the state of origin has no significant effect on the scores obtained by students in SSCE Mathematics. The reference equations for testing this hypothesis are EQP_2 and EQP_3 in table 1. The EQP_2 test for shift effects, while EQP_3 tests for slope or differential effect. The coefficient attached to STATE (Delta 1, Edo 0) is – 0.808, it is negative and statistically significant at 1 percent level, indicating that students in Edo State do better in Mathematics at the SSCE compared to students in Delta State. The intercept of the equation EQP_2 is 0.378. The differential effect of Delta State therefore lowered the intercept of the equation to – 1.570. The coefficient of the slope dummy variable MATHSTATE was used to establish if the performance of students in Mathematics at the JSCE exerted more effect on their performance in Mathematics at the SSCE in Delta State than in Edo State. The coefficient of MATHSJSCE as shown in figure 1 was estimated at – 0.396 and found to be statistically significant at 1 percent level of significance. Given these results, the null hypothesis that there is no significant relationship is rejected in favour of the alternative. To further confirm this result, the Chow test which is a measure of equality between coefficients obtained from different samples was estimated. The equations EQD1 and EQE1 are estimated separately for Delta and Edo States; under the null hypothesis that the coefficients estimated (that is,b_0 and b_1) do not differ significantly from each other across the two States, the Chow F-statistic (F*) is given by the formula,

$$F^* = \frac{[RSSp - (RSSd + RSSe)]/K}{(RSSd + RSSe)/(Nd + Ne - 2K)}$$

Where,

RSS_P = residual sum of squares for the regression pooled for both Delta and Edo States;

RSS_d = residual sum of squares for the regression using only data for Delta State

RSS_e = residual sum of squares for the regression using only data for Edo State

K = number of parameters estimated

N_d = sample size for Delta State's data

N_e = sample size for Edo State's data

The degrees of freedom are: v_1 = K, $v_2 = n_e + n_e - 2K$.

RSS_P = 1221.17

RSS_d = 373.544

RSS_e = 754.376

n_d = 200

n_e = 200

v_1 = 2

v_2 = 396

$F_{CHOW} = 16.37 > F_{0.05 =} 3.63$

Since the calculated Chow break point statistic (16.37) is greater than the critical value (3.63), it can be concluded that the coefficient attached to MATHJSCE is different between Delta and Edo States. In other words, it can be accepted that the data are drawn from two different samples. With these results the null hypothesis was rejected in favour of the alternative. The result indicates that location of the State has a significant effect on the scores obtained by students in SSCE Mathematics.

In order to establish if the estimated model has a better forecasting power for either Delta or Edo State, Theil's inequality coefficient (U) is computed for equations EQD1 (for Delta State) and EQE1 (for Edo State) respectively. The formula for calculating U is given by,

U = $\sqrt{[\sum(P_i - A_i)^2 / n]/[\sum A_i^2 / n]}$, $0 \le U \le \infty$

Where;

P_i = forecast or predicted value for the i^{th} observation of the dependent variable

A_i = actual or realized value for the i^{th} observation of the dependent variable

n= number of observations

As shown above, $0 \le U \le \infty$. Generally, the smaller the value of U, the better is the forecasting power of the estimated model. Perfect forecasts are obtained when U= 0. When U = 1, then the equation does not forecast better than a 'naïve' zero change prediction. On the other hand, when U > 1 it is preferable to accept the zero change extrapolation. In the case of Delta State, the following results were obtained:-

U = $\sqrt{[\sum(P_i - A_i)^2 / n]/[\sum A_i^2 / n]}$ = $\sqrt{0.2276}$ = 0.477

In the case of Edo State,

U = $\sqrt{[\sum(P_i - A_i)^2 / n]/[\sum A_i^2 / n]}$ = $\sqrt{0.2966}$ = 0.545

From the results above, it can be concluded that the forecasting power of the regression equation is slightly better for Delta State, compared to Edo State. In other words, scores obtained by students in Mathematics at the JSCE tend to predict their ultimate performance in the same subject at the SSCE marginally better in Delta State, relative to the case of students in Edo State.

FINDINGS AND DISCUSSION OF RESULTS

The finding established that scores in Mathematics at the JSCE do predict their scores in Mathematics at the SSCE level. This is in consonant with the position of NERDC (2008) and the Government policy which specified at least a pass in Mathematics at the JSCE as a compulsory requirement before a student can be promoted to SSS one. This finding is in agreement with the findings of Adeyemi (2008), Osadebe (2003), Onuka Raji and Onabamiro (2010) but negates the result of Falaye and Afolabi (2005) that Osun State JSCE is a poor predictor of students performance in SSCE.

Another finding of this study is that the location of the student's state has a significant effect on scores obtained at the SSCE Mathematics. This corroborated the finding of Akinwumi (2004) that location of secondary school students determine academic performance but contrary to the finding of Onah and Ugwu who found that there was no significant relationship between school location and student's performance.

The third finding of the Study is that the forecasting power of the JSCE Mathematics on performance of SSCE Mathematics is slightly better for Delta State compared to Edo State in Nigeria. This is in agreement with an earlier statement that since the JSCE is conducted by different MoEs in the thirty six States including FCT, with variation in human and material resources in the evaluation department, one should expect the prediction to differ across states to differ.

Based on the findings, it is recommended that:

1. Everything possible effort should be made by government, parents, teachers, students and the larger society to promote meaningful learning of Mathematics at the JSS as this would help the students perform better in Mathematics at the SSCE.
2. Since the JSCE in Mathematics in Delta has higher forecasting power, it could be better if all the State's MoEs could come together to conduct a national JSCE as the case of SSCE conducted by NECO in Nigeria. If this is done it would harness the diversified human and material resources and increase general performance at SSCE level in Nigeria.

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UNDER PREPAREDNESS OF FIRST YEAR UNIVERSITY MATHEMATICS STUDENTS

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Abstract–First year entering university students bring with them low levels of mathematical understanding and abilities. There is insurmountable evidence that points to the fact that the new mathematics curriculum is failing our students in many ways. This lack of limited repertoire of basic mathematical skills stems from a dysfunctional schooling system brought about by the exclusion of crucial topics such as geometry, trigonometry and logarithms. This has serious rippling effect for students wishing to pursue studies in the exact sciences, where problem solving, analytic and abstract thinking is the order of the day. The aim of this study is to determine to what extent the students' lack of basic mathematical skills is hampering their progression to higher study both at high school and beyond.

Keywords: curriculum reform, dysfunctional schooling, analytical skills, cognitive development and under-preparedness

1. INTRODUCTION

Research conducted by the South African Institute of Physics (SAIP) and the Council for Higher Education (CHE) (Nkosi, 2013) in some 20 South African universities revealed with great unanimity that the "school mathematics is failing varsity entrants". In particular the report points towards the under-preparedness that has engulfed the schooling sector over the past 5 years stemming from the curriculum reform that has taken place, leaving students with a lack of adequate mathematical and necessary problem solving skills in the gateway subject required for university entrance. Under-preparedness manifests itself in many ways; from "what students know and can do" (Scott, 2013) to the lack of deep conceptual and theoretical knowledge, to the "lack of fundamental ability" or a lack of "cognitive deficit" that is a prerequisite for students to bridge the gap between the exit of the secondary school sector and tertiary education. On the other hand, Higher Education curriculum which is variant for international acclaim, assumes that the baseline knowledge to be in place so that lecturers may proceed to the next level of understanding. Over the years there has been a decline in the "average-level of student preparedness" (Scott, 2013) for tertiary entrance and this has serious repercussions for South Africa as a whole where a technology driven economy is the order of the day for the 21st century competencies.

Data so far may indicate that the current situation may be worsening. There is growing evidence that suggests that the curriculum reform by the introduction of the new secondary curriculum and the National Senior Certificate (NSC) which was introduced in 2008, have led to lower levels of performance of first year entering students in university subjects such as mathematics, science, engineering and technology related subjects (Scott, 2006; Scott, 2011; Fisher, 2011). The "challenge level" of the matric examination paper together with the omission of key topics in the secondary syllabus which are pivotal for higher order studies and very predictable nature of the examination indicate a decline in the worthiness of the gateway subjects such as mathematics and physical science.

The problems that students face at the exit of their senior secondary phase all point towards a "deep-seated failings throughout the school system" (Fisher, 2011). This is indicative of the little progress that is made towards the development of cognitive level among South African youth. Local and international assessments reveal that South Africans students are performing consistently poorly in numeracy, reading, literacy, mathematics and science. Some of the assessments that testify to these assertions are from the following bodies:

1.1 South African Democratic Teachers' Union (SADTU)

According to an independent research conducted by SADTU, the new curriculum reform has had two casualties, namely the teacher and the student. On one hand, the "students' level of competency has dropped" and on the other hand the teachers have struggled to come to terms with the offerings of the new curriculum (Nkosi, 2013). If the teacher is struggling then there is a serious problem with the state of education in South Africa since they are supposed to be the embodiment of knowledge and a caveat for systemic change is necessary.

1.2 Annual National Assessments (ANAS)

The ANAS which assesses numeracy and literacy reveal low levels of achievement in the "fundamental building blocks of learning" (ANAS, 2011). In ANAS's assessment in 2012, the grade 9 learners obtained a mere 13% in the mathematics assessment tests confirming the low level achievement. The grade 6 learners have performed equally badly with achievements of 30% and 27% for the years 2011 and 2012, respectively (ANAS, 2012). To remedy the situation at any level workbooks have been issued by DOE to standardise the level of learning and teaching in schools.

1.3 Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ)

Research undertaken by SACMEQ in 2011 revealed that only 46% of grade 6 mathematics teachers were able to get an average grade 6 multiple choice question correct (Spaull, 2013) South African mathematics teachers fared badly to comparator teachers in Africa. The grade 6 learners themselves also performed badly. According to SACMEQ 83% of South African grade 6 and 8 learners did not reach the competence of their level. In particular 52% of grade 6 learners achieved mathematics scores at the level of a grade 3 learner or lower (GDE, 2010). An international report on the African consortium revealed that "only 32% of grade 6 mathematics teachers in South Africa had desirable subject knowledge". Teachers definitely need to have a thorough mastery of mathematics many grades beyond their present grade of teaching in order to have the confidence in the subjects they teach, otherwise schools will become "academically bankrupt" with levels of learning and teaching in mathematics reduced to a minimum (Spaull, 2013).

1.4 Third International Mathematics and Science Study-Repeat (TIMSS-R)

Results from TIMSS showed that 27% of South African teachers did not have any formal training in the mathematics (Howie, 2006). This is very disturbing as many teacher colleges have been shut down for no apparent reason. Further from the international assessment of TIMSS for mathematics and science, South Africa was ranked 137 out of 150 countries for numeracy and literacy (SABC news 2011). This is disappointing as comparator countries with less resource have performed better (TIMSS, 2003). In 2003 TIMSS study revealed a pass rate of 33% for grade 8 learners in mathematics (GDE, 2010). The study is of the opinion that the South African learners were the worst performers compared to other countries.

1.5 Department of Education-Mathematics results

A survey of the NSC mathematics examinations results from 2011 to 2013 is shown in the table below (DBE, 2013):

	10-19.9%	19.9-29.9%	30-39.9%	40-49.95	50-59.95	60-69.9%	70-79.9%	80-89.9	90-100%
2011	9.5	23.1	20	11.6	7.6	5.1	3.4	1.9	0.6
2012	8.3	18.8	18.9	13.0	9.2	6.4	4.1	2.2	0.7
2013	7.1	16.2	18.6	14.3	10.5	7.4	4.8	2.6	0.8

For a student to be accepted in the exact sciences, a pass of 60% in mathematics is a minimum requirement. This means that 11% (2011), 13% (2012) and 15.6% (2013) of the total cohort of students would be eligible for university admission. A pass of 30% in mathematics is undesirable. If the pass rate had to be raised to 50%, the real pass rate in mathematics would be 23.1%, 22.1 and 26.1% for the 3 years respectively. Many diploma courses require a pass of 50% or more. Many schools are "gaming" the system by allowing many students to do Mathematics Literacy to produce good pass rates so that the school may look good in the region. The number of students that are doing Mathematics Literacy is increasing at a more or less steady rate: 280 836 (2010), 275380 (2011), 290713 (2012) and 324097 (2013). The mathematics enrolment rates show a steady decline: 263034 (2010), 224635 (2011), 225874 (2012) and 241509 (2013). These numbers are too low for enrolment in Science and Technology subjects, where the average has been less than 30% from 2000 to 2010 (Bunting, 2010). The department has set this target as 30% for 2010 and above.

1.6 Enrolment and pass rates at University

Of the students that wrote the NSE examination in 2012, 136 000 of them obtained Bachelor passes, while 120 000 of these students enrolled for extended programmes (CHE, 2013). This means that their grades were not good for main stream courses and they are offered a second chance to improve their grades, with an extended duration of a degree or diploma programme. On the other hand, a staggering 153 000 students obtained diploma passes, meaning that these students will not be able to register for a degree course and will have to repeat some of their courses to improve their grades. For a 3 year degree qualification, only 16% of the registered cohort of students was able to finish in regulated time, and for a diploma the graduation rate is 33% (CHET). The attrition rate after first year of study is 56% and 46% for the degree and diploma studies, respectively. Based on the empirical data collected and analysed roughly 20% of all students that applied for tertiary studies were accepted in 2010 (SARU, 2012).

The response of universities to a failing school system is two-fold, namely a deviation of traditional-type of lecturing and by the introduction of foundation (bridging) or extended programmes. The purpose of these programmes is to improve the content knowledge that was assumed to be in place. Due to the large influx of incoming students with a wide diversity of cultures, it is imperative to know their content knowledge that they bring with them which is the primary purpose of this study.

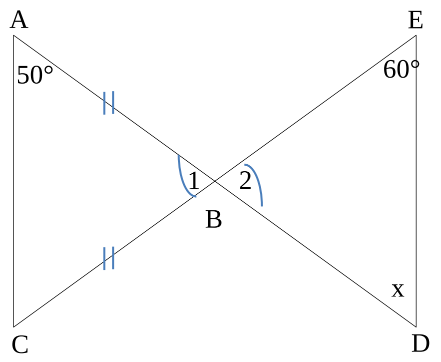
2. METHODOLOGY

A questionnaire in the form of a quiz which covered topics in mathematics from grade 8 to 12 was done in consultation with a senior member of the secondary teaching fraternity and was subsequently given to senior members of the Mathematics department of the University of Johannesburg for comments and feedback. The topics covered ranged from the senior primary phase to the senior secondary phase of high school. To test the students' mathematical skills and abilities, a broad scope of topics such as elementary geometry, word problems, calculus, algebraic equations and inequalities were assessed. It was expected that the questions set in the questionnaire was firstly, in line with the syllabus coverage and secondly, that the questions set was of a level of manageability of the student. Concomitant with the quiz, the students grade 12 Mathematics, Science and English marks were captured to ascertain if there was any correlation in performance and if they were capable of tertiary study.

3. SURVEY, DATA COLLECTION AND RESULTS ANALYSIS

During First Year Students' orientation week at University of Johannesburg (UJ) in January 2014, students were asked to complete the following quiz without any prior notice or preparation. It was of approximately 30 minute duration and consisted of 6 baseline questions which were validated by Senior Members of the Mathematics Department at UJ. They were asked to do the workings along the side of the questions, but were only required to tick off one of the options provided. Some of the answers options were: "Never seen this question before", "I cannot work it out". These options were given if the students were uncomfortable with the options provided. The use of the calculator was optional. The purpose of word problems was to test problem solving skills. A one page quiz was administered to first year entering university students (n = 203) in the fields of Engineering, Optometry, Chemical Engineering, Food Technology and Biotechnology. A summary of the quiz type and syllabus coverage is given in Table 1 below.

Table 1

QUESTION	SYLLABUS IDENTIFICATION
1. 	Basic geometric questions from the 8 mathematics syllabus
2. Half of a certain number plus one third of the same number is 14 less than twice the number. Find the number.	Word problem on the algebraic section of the grade 9 syllabus.
3. Solve for x: $\frac{1}{x} - \frac{1}{m} = \frac{t}{n}$	A question on basic algebraic manipulations of the grade 10 syllabus
4. Find the sum of all integers satisfying $x^2 - x < 20$	An inequality question from the grade 11 syllabus
5. A bell-ringer rings a church bell once every hour at 1 o'clock, twice at 2 o'clock, 3 times at 3 o'clock and so on, going up to 12 times at 12 o'clock. How many times does he/she ring the bell over a period of 24 hours?	Word problem testing the section sequences and series of the grade 12 syllabus
6. Given $y = \frac{x^3-x}{x-1}$. Find $\frac{dy}{dx}$	A calculus question of the grade 12 syllabus

Cumulative results from the performance of the students in the various fields of study is given in Table 2 below

Table 2

QUESTION NUMBER	GRADE	CORRECT OPTION
1	8	37%
2	9	55%
3	10	65%
4	11	52%
5	12	52%
6	12	33%

Most students performed badly in the grade 8 geometry question and this highlights the plight that geometry was taken out of the core mathematics syllabus and offered as an optional subject as Mathematics Paper 3, and in essence done by roughly 5% of the entire cohort of students. Although the students have just passed their grade 12 examinations, it appears their geometrical foundations are very shallow and this will have serious impact on their analytical and visualisation skills. Their performances in the grade 9 question was very average and this concurs with the national findings of the Annual National Assessment mathematics test for which the students only obtained an average of 14% in the 2013 assessments and 13% in the 2012 assessments. Also to be mentioned that only 3% of the students had obtained more than 50% for the Mathematics examination. A number of factors could be associated with this lack of basic skills and knowledge, and this could be teacher competency and whether teachers have the necessary skills and resources to teach the students under their care. Thus the inherent gaps that are associated with this lack of content knowledge in the transitional grade 9 year are carried over from year to year until they enrol for tertiary studies. The calculus question in grade 12 which was done a few months prior to this quiz leaves much to be desired. Most students choose a similar wrong option which reveals a lack of deep understanding and poor teaching of the concept. Calculus forms the basis of understanding of all tertiary mathematical and related studies, leaving these students grossly ill prepared for higher studies. Students performed reasonably well in the grade 10 algebraic question. The grade 11 question on inequality was also poorly answered. All this suggests that students are not studying with a deep sense of understanding. Teachers maybe rushing these sections in school to complete the syllabus thereby meeting the deadline of writing a common departmental paper. Roughly 45% of the student of the entire cohort of students abandon their studies between grades 10 and 12, which is a crisis in education of monumental proportion.

On the other hand if the performance of the students in the quiz is narrowed down only to those that obtained 80% or higher in their grade 12 mathematics examination, the results are quite alarming for the status of mathematics in South Africa. Of the cohort of 203 students that attempted this test, 19 of them revealed that they had obtained 80% and over in their matric mathematics paper. A summary of their performance is given in Table 2 below.

Table 2

QUESTION NUMBER	GRADE	CORRECT OPTION
1	8	68%
2	9	53%
3	10	79%
4	11	79%
5	12	53%
6	12	58%

If the students did not have any clue as to how to do a question or if they were not confident about answering a question, fearing of getting it wrong, they simply answered “I cannot work it out” or “Never seen such a problem before”. The word problems seems to be the most problematic for students to answer. The results of which are shown in table 3.

Table 3

QUESTION	I cannot work it out	Never seen such a problem before
1	1.5%	1%
2	11%	5%
3	9%	2.5%
4	7%	3.5%
5	11%	3%
6	2%	1%

These results points to the fact that the students are struggling with word problems in general. These students will struggle with tertiary work where a high level of analytical thinking and abstract work will be the order of the day. It is inconceivable that only 68% of these students got an elementary grade 8 geometry question correct. More shockingly, the section on sequences and series in grade 11 in the form of a word problem as well as a simple word problem in grade 9 reveals a poor level of cognitive development in their mathematical understanding. Therefore the reasonably good grade 12 results implicate that there might be a possibility that the students are 'spotting' examination type questions in their preparation or their marks could be moderated to produce a desired grade 12 pass rate. According to the moderator's report from the markers of the Senior Certificate in 2013, "students struggle with Mathematics in Grades 11 and 12 because they cannot do the basic mathematics of grades 8, 9 and 10" (DOE, 2013). This was in reference to questions on inequality. Comments on the calculus section point to shallow teaching of the section in school. A further comment made by them on geometry, for those that wrote the Mathematics Paper 3, students are making many errors in the paper due to a "poor understanding of the basics and foundational competencies taught in the earlier grades". Thus the understanding of concepts in the curriculum is due to a lack of deep conceptual understanding and the ability to answer questions that require a higher order of thinking.

4. CONCLUSION

Students have had the most difficulty with the section of calculus which is pivotal to the understanding of tertiary mathematics. Hence the presumption of conceptual understanding that is supposed to be in place should not be taken for granted and a baseline test needs to be in place before any form of lecturing is done (Jennings, 2009). Students appear to have forgotten the fundamental concepts in mathematics in the different phases of their study and have been promoted to higher grades without a sound and solid foundation of their previous grades, bearing in mind that they need between 30-40% to progress to the next grade. The idea of using the National Benchmark Test (NBT) as a criterion for admission to universities is much debated in South Africa, as there appears to be no correlation between the NSC matric results and the NBT tests. However, students might have performed better if they were given sufficient warning and more time for the tests. It might be interesting to see how the students would perform if the same test was given to the students after a semester of study as a follow-up test.

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A PILOT STUDY OF THE USE OF AN ANALYTICAL FRAMEWORK FOR A REPRESENTATION OF THE NATURE OF SCIENCE (NOS) IN A GRADE 8 NATURAL SCIENCES TEXTBOOK

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Abstract–This study is a pilot on the use of an analytical framework developed by Abd-El-Khalick, Waters and Le to investigate the extent to which the Nature of Science (NOS) is represented in science textbooks. Science is best defined by its characteristics, otherwise known as the tenets of the NOS. Ten key aspects of the NOS that are related to the basic tenets of science derived by Lederman (2007) formed the analytical framework used in this study. In addressing inter-rater reliability in the analysis, the pilot utilised three coders. All scores were captured in a textbook scoring sheet. Next, the coders compared and contrasted their scores. Any differences in the scoring were resolved through extended discussions by further reference to the textbook materials. The findings revealed that 40% of the analysed units were coded according to the basic NOS tenet 'Scientific theories'. The tenet 'Empirical nature of science' was reflected in 27% of the units. The other tenets of the NOS were poorly depicted in the textbook.

Keywords: Nature of Science, textbook analysis, inter-rater reliability

1.1 INTRODUCTION

This paper reports on the use of an analytical framework developed by Abd-El-Khalick, et al. (2008) for the qualitative and quantitative analysis of the representation of the NOS in science textbooks.

The framework follows a deductive category application model based on the tenets of the NOS as defined by Lederman (2007) and expounded upon by Abd-El-Khalick et al. (2008). In a deductive category application procedure pre-formulated categories are brought into connection with the text. In this case the categories were comprised of the tenets of the NOS.

This paper presents a pilot study on one CAPS compliant science textbook through the use of a detailed scoring rubric to record the extent to which the NOS is represented in the units of analysis comprising complete paragraphs, activities, worked examples, figures with captions, tables with captions, charts with captions, and marginal comments of the sampled chapters.

In using the framework we initially experienced some overlap across the tenets. Clarity was obtained through extensive discussion and the realisation that some tenets are defined relative to others. Initially discrepancies were evident in assigning scores to the NOS tenets, but this was again resolved through discussion. Overall, it can be concluded that the NOS framework that was piloted is a viable and reliable instrument that can be used in the analysis of South African textbooks.

1.2 BACKGROUND TO RESEARCH

The concept of the NOS is one that is naively understood by teachers in South Africa as researched by Bantwini, Kurup, Linneman, Lynch & Webb (2003) possibly stemming from the fact that the NOS can neither be defined by a single term nor statement. Instead the NOS is a combination of at least seven aspects derived from Lederman (1998) and known as the tenets of science. These tenets derived from Lederman are: Empirical; Inferential; Creative; Theory-driven; Tentative; Myth of The Scientific Method; Scientific theories; Scientific laws; Social dimension of science; and Social and cultural embeddedness of science. These tenants are further discussed in Table 1 under the next section on the conceptual framework of the study.

These tenets have formed the basis for curriculum documents all over the world (Lederman, 2007). In South Africa the NOS is represented in Curriculum and Assessment Policy Statements (CAPS) for science subjects, and textbooks should be written to reflect the NOS on which the curriculum documents are based (Bester, Clacherty, Cowan, Doubell, Lombard, Nkosi, Paarman, Padayachee, Sadie, Schreuder, Slamang, Ungerer, 2013). In order to identify any dependency between textbooks and the curriculum, it is necessary to analyse the textbooks for the extent to which they represent the NOS.

Content analysis of textbooks is common international research but the frameworks used or analytical tools differ. Far less common is research focusing specifically on the extent to which the NOS is depicted in Natural Sciences textbooks. Findings by other scholars in this field are documented here.

Padayachee (2012) studied the representation of the NOS in Life Sciences and Biology textbooks in South Africa and targeted four broad aspects of NOS constructs: science as a body of knowledge; science as a way of investigating; science as a way of thinking; and the interaction between science, technology and society. This research used a framework developed by Chiappetta, Sethna and Fillman (2004). The findings of the study revealed that Life Sciences textbooks represented all four NOS aspects in contrast to Biology textbooks which had no representation at all for the interaction between science, technology and society. The framework used by Padayachee is different to the one used for this pilot study. The framework used for this pilot study – as used by Abd-El-Khalick on textbooks in the United States of America – has never been used on textbooks in South Africa. This framework will be explained further in the conceptual framework

Abd-El-Khalick`s research on the representation for the NOS in textbooks in the United States of America was a long term study spanning four decades and involving five series of chemistry books that commanded a significant market share. Of the fourteen books analysed, the study focused on chapters or sections of the chemistry textbooks that covered "scientific method, scientific processes, how science works and topics related to atomic structure, kinetic molecular theory and gas laws" (Abd-El Khalick et al., 2008). These sections were selected due to their obvious relevance to the NOS. It was found that the chemistry textbooks performed poorly in their representation of the NOS and this did not improve over the decades but surprisingly decreased in some instances. This occurred despite a greater emphasis having been placed on the centrality of the NOS in education reform documents (Abd-El Khalick et al., 2008).

1.3 CONCEPTUAL FRAMEWORK

Key concepts forming the basis of this research will be defined in this conceptual framework and their relevance to the study explained so as to provide a clear understanding of the background to the NOS. The definition of the NOS has been dynamically formulated over a period of time by various scholars. The complexity of defining the NOS emanated in it being incorrectly or insufficiently addressed in science textbooks as will be discussed further. In this section concepts that have contributed to the NOS are clarified. These concepts form the basis of the analytical framework (see Table 1).

Table 1: Explication of the NOS aspects in the analytical framework

NOS aspect	Dimensions emphasised in textbook analysis
Empirical	Scientific claims are derived from, and/or consistent with, observations of natural phenomena. Scientists, however, do not have 'direct' access to most natural phenomena: Their observations are almost always filtered through the human perceptual apparatus, mediated by the assumptions underlying the functioning of 'scientific' instruments, and/or interpreted from within elaborate theoretical frameworks.
Inferential	There is a crucial distinction between observations and inferences. Observations are descriptive statements about natural phenomena that are accessible to the senses (or extensions of the senses) and about which observers can reach consensus with relative ease (e.g., objects released above ground level tend to fall to the ground). Inferences, on the other hand, are statements about phenomena that are not directly accessible to the senses (e.g., objects tend to fall to the ground because of 'gravity'). Scientific constructs, such as gravity, are inferential in the sense that they can only be accessed and/or measured through their manifestations or effects.
Creative	Science is not an entirely rational or systematic activity. Generating scientific knowledge involves human creativity in the sense of scientists inventing explanations and theoretical entities. The creative NOS, coupled with its inferential nature, entail that scientific entities (atoms, force fields, species, etc.) are functional theoretical models rather than faithful copies of 'reality'.
Theory-driven	Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, and expectations influence

	their work. These background factors affect scientists' choice of problems to investigate and methods of investigations, observations (both in terms of what is and is not observed), and interpretation of these observations. This (sometimes collective) individuality or mind-set accounts for the role of theory in generating scientific knowledge. Contrary to common belief, science never starts with neutral observations. Like investigations, observations are always motivated and guided by, and acquire meaning in light of questions and problems derived from, certain theoretical perspectives.
Tentative	Scientific knowledge is reliable and durable, but never absolute or certain. All categories of knowledge ('facts', theories, laws, etc.) are subject to change. Scientific claims change as new evidence, made possible through conceptual and technological advances, is brought to bear; as extant evidence is reinterpreted in light of new or revised theoretical ideas; or due to changes in the cultural and social spheres or shifts in the directions of established research programs.
Myth of 'The Scientific Method'	This myth is often manifested in the belief that there is a recipe-like stepwise procedure that typifies all scientific practice. This notion is erroneous: There is no single 'Scientific Method' that would guarantee the development of infallible knowledge. Scientists do observe, compare, measure, test, speculate, hypothesise, debate, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of (practical, conceptual, or logical) activities that will unerringly lead them to valid claims, let alone 'certain' knowledge.
Scientific theories	Scientific theories are well-established, highly substantiated, internally consistent systems of explanations, which (a) account for large sets of seemingly unrelated observations in several fields of investigation, (b) generate research questions and problems, and (c) guide future investigations. Theories are often based on assumptions or axioms and posit the existence of non-observable entities. Thus, direct testing is untenable. Only indirect evidence supports and validates theories: Scientists derive specific testable predictions from theories and check them against observations. An agreement between predictions and observations increases confidence in the tested theory.
Scientific laws	In general, laws are descriptive statements of relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. Contrary to common belief, theories and laws are not hierarchically related (the naïve view that theories become laws when 'enough' supporting evidence is garnered, or that laws have a higher status than theories). Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws.
Social dimension of science	Scientific knowledge is socially negotiated. This should not be confused with relativistic notions of science. This dimension specifically refers to the constitutive values associated with established venues for communication and criticism within the scientific enterprise, which serve to enhance the objectivity of collectively scrutinised scientific knowledge through decreasing the impact of individual scientists' idiosyncrasies and subjectivities. The double-blind peer-review process used by scientific journals is one aspect of the enactment of the NOS dimensions under this aspect.
Social and cultural embeddedness of science	Science is a human enterprise embedded and practiced in the context of a larger cultural milieu. Thus, science affects and is affected by various cultural elements and spheres, including social fabric, worldview, power structures, philosophy, religion, and political and economic factors. Such effects are manifested, among other things, through public funding for scientific research and, in some cases, in the very nature of 'acceptable' explanations of natural phenomena (e.g., differing stories of hominid evolution have resulted from the advent of feminist perspectives brought about by increased access, participation, and leadership of females in the biosocial sciences).

(Source: Abd-El-Khalick, 2013).

The next section provides an elaboration of the methodology explaining how the pilot study was carried out quantitatively using the analytical tool as refined by Abd-El-Khalick (2013). The findings of the study will be given and discussed accordingly.

1.4 METHODOLOGY

The pilot study adopted a structural document analysis approach. In this approach the content of a textbook is analysed and connected to pre-formed categories in what is known as a deductive category application. Four chapters of a Grade 8 Natural Sciences book approved by the Department of Basic Education were selected for analysis of their representation of the NOS.

1.4.1 Content analysis

According to Krippendorff (1980:17) "content analysis has been defined as a systematic replicable technique for compressing many words of text (or other meaningful matter) into fewer categories based on explicit rules of coding". In this pilot a deductive category application procedure was applied in which pre-formulated categories, in this case the tenets of the NOS, were brought into connection with the text. Each passage of text was qualitatively assigned to one of the categories.

The framework by Abd-El-Khalick (2013) explicitly provides definitions and examples that are typical of Natural Sciences textbooks, and coding rules for each deductive category. Also provided are rules for distinguishing between categories and assigning scores for the extent to which a category is represented. Figure 1 below represents the step model of deductive category application used in this study.

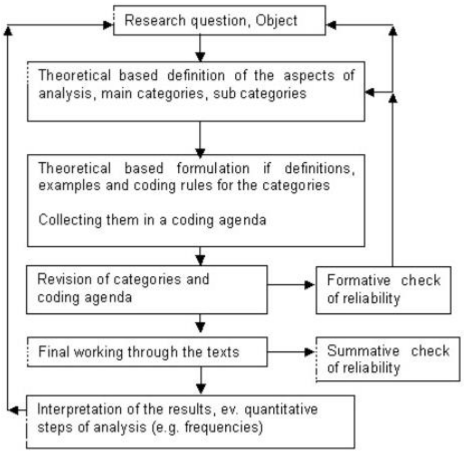

Figure 1: The step model of deductive category application used in this study

Reliability and validity are closely related since valid results "compel one to accept scientific results as evidence" (Krippendorff, 1980, 73) and are therefore reliable. To ensure reliability and validity in this study more than one coder was used for the content analysis as it tends to lend itself to subjectivity. The coders were trained on how to use the framework and had an advanced grasp of the NOS.

1.4.2 Connectedness of target NOS aspects

The analytical framework for analysis based on the NOS tenets explicated in Table 1 contains guidelines by Abd-El-Khalick (2013) to ensure its accurate use. Important to note is the fact that certain tenets of NOS cannot be viewed in isolation but in relation to other tenets. For instance, the 'Empirical NOS' cannot obtain a full score if it remains silent on 'Inferential NOS' and 'Theory-driven NOS'. Secondly, if a textbook proposes the existence of the 'Myth of the scientific method' then this affects the score of the 'Creative NOS'. Abd-El-Khalick (2013) further explains the crucial importance of differentiating between scientific laws and scientific theories as some textbooks erroneously suggest that theories change into law. Of equal importance is the distinction between observations and inferences.

1.4.3 Units of analysis

The pilot textbook is currently out of circulation and has been replaced by the revised CAPS compliant edition. During its period in circulation from 2006 to 2013, the pilot textbook commanded a considerable market share and was widely used by Grade 8 learners nationally.

Four out of thirteen chapters of the textbook were selected for the analysis, three of which were representative of the following content strands of Natural Sciences: Life and living; Energy and change; Earth and beyond. The fourth chapter analysed was the introductory chapter 'Tools and skills for Natural Sciences', which was purposefully selected due to its probable relevance to the NOS. The units of analysis included complete paragraphs, activities, worked examples, figures with captions, tables with captions, charts with captions and marginal comments.

1.4.4 Scoring rubric

The rubric developed by Abd-El-Khalick (2013) assigns a score to a unit of analysis ranging from +3 to -3 depending on the extent to which that unit represents a target NOS aspect. The rubric draws a distinction between an explicit versus an implicit representation of the target NOS aspect. Research by Abd-El-Khalick et al. (1998) on implicit versus explicit instructional approaches revealed that implicit strategies such as engaging in scientific activities do not translate into an understanding of NOS, whereas an explicit approach is more effective in ensuring comprehension of NOS. An explicit approach would entail educators differentiating between observation and inference during activities as opposed to the learners having to infer this crucial distinction from their activities.

Below is the scoring rubric used in the analysis providing the distinction between explicit and implicit representation.

Scoring Rubric

- Selected materials from a textbook are not analysed and/or scored independently:
- All such materials (e.g., chart on the 'scientific method' and associated text, narrative on the historical development of atomic structure, sections on the interaction between science and society, or bulleted text, activity boxes, and vignettes relevant to one or more NOS aspects) are carefully read and all NOS aspects addressed in these sections are identified.
- Next, all references and materials targeting the same NOS aspect are grouped together and examined holistically. In other words, the score assigned to a specific NOS aspect within a textbook is based on an examination of all materials relevant to that aspect within the examined textual materials.Scores are assigned in accordance with the following rubric.

Table 2: Scoring rubric

- **Three points = Explicit, informed, and consistent representation of the target NOS aspect**:
  i. Explicit statements that convey an informed representation,
  ii. Consistency across the selected chapters or sections in addressing the target NOS aspect, and
  iii. Consistency in addressing other directly related NOS aspects.
- **Two points = Explicit, partially informed representation of the target NOS aspect**:
  i. Explicit statements that convey an informed, but incomplete representation, and
  ii. Consistency across the selected chapters or sections in representing the target NOS aspect. An incomplete representation derives from the textbook materials remaining silent in terms of addressing other related NOS aspects that ensure a complete informed representation.
- **One point = Implicit, informed, and consistent representation of the target NOS aspect**:
  i. An informed representation of the target NOS aspect could be *inferred* from the textbook materials (e.g., relevant explanations, activities, examples, or historical episodes *lacking* structured, reflective prompts or explicit statements), and
  ii. Absence of other explicit or implicit messages, which are inconsistent with the inferred implicit representation.
- **Zero points = The target NOS aspect is not addressed**:
  i. No explicit or implicit treatment of the target NOS aspect, or
  ii. Not enough materials (statements, examples, historical vignettes, etc.) to make an informed judgment or to convey to the textbook reader a sense about the target aspect of NOS one way or the other.
- **Negative one point = Implicit misrepresentation of the target NOS aspect**: A naïve representation could be *inferred* from the textbook materials.
- **Negative two points = The textbook materials convey mixed explicit and/or implicit messages about the target NOS aspect**:
  i. Implicit, informed representations that could be inferred from some parts of the textbook materials are countered by explicit, naïve statements in other parts, or
  ii. Explicit statements that convey conflicting messages about the same NOS aspect.
- **Negative three points = Explicit, naïve representation of the target NOS aspect**: Explicit statement or statements that clearly communicate a naïve representation of the target NOS aspect.

(Source: Abd-El-Khalick: NOS textbook analysis methods/ UIUC: April 20, 2013/ Scoring rubric)

1.4.5 Reliability

In addressing inter-rater reliability in the analysis, the pilot utilised two coders, in addition to myself. Inter-rater reliability is the degree of agreement amongst raters or how much homogeneity exists between the raters' scores. The coders were selected according to their expertise as science education researchers, having at least a masters' level qualification in science education. All scores were captured in a textbook scoring sheet. Next, the coders compared their scores. Any differences in the scoring were resolved through discussions and by further reference to the textbook materials until a consensus was reached.

1.5 FINDINGS

Nine out of eleven target NOS aspects were represented by the four chapters sampled from the textbook. The textbook remained silent on 'Theory-driven' and 'Social dimensions of science'. The cumulative score for the NOS in this pilot was +7 out of a possible range of scores from -33 to +33. Individual scores for the NOS tenets range from -3 to +3 for 11 aspects giving a cumulative score of -33 to +33. The higher the cumulative score, the more explicit, informed and consistent the NOS is represented.

Table 3 below presents the scores assigned to target NOS aspects in the four sample chapters. These scores were agreed upon by the three coders through discussions and with reference to the scoring guidelines. The overall score is derived from the most dominant representation – either the most frequent or the most prominent.

Table 3: Chapter scores on the target NOS aspects

Nature of science aspect	Tools and skills for NS	Life and living	Energy and change	Earth and beyond	Overall score
Empirical	+2	+2	+2	+2	+2
Inferential	+1	0	+1	+1	+1
Creative	+1	+1	-2	+1	-2
Theory driven	0	0	0	0	0
Tentative	+1	0	0	0	+1
Myth of 'The scientific method'	-2	0	-2	0	-2
Scientific theories	+1	+1	+2	+2	+2
Scientific laws	0	0	-1	+1	+1
Social dimension of science	0	0	0	0	0
Social and cultural embeddedness	+1	0	0	+2	+2
Science vs pseudoscience	0	0	0	+2	+2

To obtain the above mentioned scores, units of analysis had to be qualitatively analysed, placed into the deductive categories of the NOS tenets then finally scored based on Abd-El-Khalick`s guidelines. Below is an exemplar table of some units analysed in the pilot, the target NOS represented and the corresponding scores:

Table 4: Chapter excerpts corresponding to target NOS aspects scores

NOS aspect	Score	Quote/ example
Empirical	+2	"Unless we use extremely powerful telescopes, we cannot see the planets that move round other stars" (Soobramoney & Vermaak, 2006:81)
Inferential	+1	"The conclusion of the investigation would be that it is the water in the rain that helps the plant to grow" (Soobramoney & Vermaak, 2006:13)
Creative	-2 +1	"You need to test your hypothesis by designing and carrying out an investigation. One possible way of testing the above hypothesis would be to use two plants of the same type. Keep the plants in the same environment. Water the one plant, but not the other" (Soobramoney & Vermaak, 2006:13) Learners are to design and make an alien " use your imagination when designing your organism and be creative" (Soobramoney & Vermaak, 2006:89)
Tentative	+1	A historic account of how the microscope has been developed by various scientists.
Myth of "The scientific method"	-2	"The scientific method is the way in which scientists go about answering questions and discovering new things" (Soobramoney & Vermaak, 2006:12).
Scientific theories	+2	A variety of consistent systems of explanations. "You are going to go outside. One of you will be blind folded. Predict the challenges you will both face in getting from point A to point B" (Soobramoney & Vermaak, 2006:77). This is an example of the predictive function of scientific theories.
Scientific laws	+1	"As the concentration of these gases continues to rise, they trap too much heat in the atmosphere and cause the temperatures on earth to rise" (Soobramoney & Vermaak, 2006:88).
Social and cultural embeddedness	+2	An account of how the San people believe the milky way came about.
Science vs pseudoscience	+2	The San believed that "the purpose of the milky way was to keep the sky from collapsing on Earth" (Soobramoney & Vermaak, 2006:79).

1.5.1 Discussion of findings

The cumulative score of +7 for the pilot is consistent with prior research findings by Abd-El-Khalick (2008) on high school chemistry textbooks indicating the general lack of attention to NOS aspects in textbooks. Similar findings emerged for South African textbooks analysed by Padayachee (2012).

In the chapter dedicated to 'Tools and skills for Natural Science', an entire subtopic is dedicated to the scientific method which explicitly confirms the 'Myth'. This error is consistent throughout the analysed chapters and could possibly be erroneously represented throughout the entire textbook. It should be noted however that although the pilot chapters confirmed the 'Myth of the scientific method', some creativity was explicitly allowed for in some units. Despite these explicit statements pertaining to creativity, the 'Creative NOS' could not get a full score because of explicit presentations of the 'Myth'.

Interesting to note is that all the sampled chapters explicitly represented the 'Empirical NOS' to the same degree but failed to get a full score of +3 due to the failure to distinguish between observations and inferences whilst remaining silent on the 'Theory-driven NOS'.

An inference of a scientific law was made in only one of the chapters and the text offered no distinction between scientific laws and theory. The lack of a representation of scientific laws could possibly be attributed to the grade level the textbook targets. The text however is consistent in its system of explanations contributing to scientific theories but unfortunately remains silent on the generative and guiding functions of theories thus failing to obtain a full score for this aspect of the NOS.

The social dimension of science is not reflected at all in the text thus suggesting to learners that scientific discoveries and claims are absolute and cannot be challenged. This implies the absence of a whole community of practice for communication, criticism and collaboration of scientific knowledge.

Natural Sciences merges four disciplines of science into four content strands. This pilot study analysed chapters from three strands, which revealed that the 'Life and living' strand represents the NOS to the least extent whilst the 'Earth and beyond' strand has more to offer in terms of representation. This could possibly be attributed to the differences in the subject matter of the disciplines – Life and living studies different forms of life or living matter whilst Earth and beyond focuses on the structure of the Earth and space.

1.6 CONCLUSION

The use of the analytical framework for analysing South African science textbooks was found to be feasible thus prompting its further use in studies of a larger magnitude. Currently it is being used in the analysis of three revised CAPS compliant textbooks. The success of the framework depends on inter-rater reliability which can be achieved through extensive training of expert coders holding a high level of science education at tertiary level and an understanding of the framework. The findings reveal that the NOS is represented to differing degrees in accordance with the strand which is being represented. However, further analysis of entire textbooks will be necessary to verify these findings.

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AN INVESTIGATION INTO STUDENT PERFORMANCE IN FIRST YEAR BIOLOGY AT THE UNIVERSITY OF JOHANNESBURG

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Abstract–The transformation in South African higher education in the past 20 years has been earmarked by mass participation (almost 80% growth). The changes in the school curriculum and increased pass rates at school level place the transition from school to university under the magnifying glass. Universities are confronted with underprepared entering students and are designing interventions and models to maintain standards and increase graduation numbers. The latest suggestion of a Flexible curriculum proposes that an additional year (i.e. four year BSc degree) is more beneficial and advantageous to many first year students as opposed to the three year BSc. degree option.

The Faculty of Science at the University of Johannesburg has been enrolling students in the BSc Life and Environmental Science programme (four year degree) which provides students with an opportunity to complete the one semester module in Biology (mainstream) over two semesters, in the four year offering. In the four year degree programme, students also start with the Biology module after completion of a generic first semester of bridging and not in the first semester when they enter university.

This research compares the success of students in the two streams (three year programme where students complete the Biology module in one semester to the four year programme where the students complete the one module of Biology over two semesters. Appropriate inferential statistics were employed in the comparison of the 2011 – 2013 cohorts (sample of 389 foundation and 457 mainstream entries). It will be shown that the interventions implemented in the four year degree can be considered as effective in developing the students' academic competency in biology relative to mainstream students.

Keywords: Flexible curriculum, Biology, Widening access, Academic success in Science programmes

1. INTRODUCTION AND PURPOSE

The transformation in South African higher education (HE) in the past 20 years has been marked by mass participation. Recent data provided by HESA (2014) and the CHE (2013) indicate, that the student enrolments have doubled post-1994. Higher education portrays higher accessibility and represents a more equitable student body with the representation by African enrolments growing from 15% in 1994 to 79% in 2010 (CHE, 2013, p.39). However, the Green Paper (DHET, 2012, p.10) raises challenges with the widening participation and lower graduation rates in Higher Education. In the field of Science Engineering and Technology (SET) the enrolment has increased by 4.4% (DHET, 2012, p.35) and the graduation rates have grown by 5.5% per year. The graduate output in the scarce skills such as SET is still insufficient to meet projections for economic development.

The CHE investigation (2013, p.43) indicates that the completion rate of BSc students is 23% and alarming when only 27% of students graduate within regulation time (three years to complete a three year degree). Many reasons can be found and parties blamed resulting in the current situation, but students have been failing first year at university long before 1994. The research question for this paper is: Does the extended Biology stream provide students with foundational provision to be successful in mainstream modules? The purpose is to provide evidence towards the increased enrolment in the extended modules.

2. LITERATURE REVIEW

2.1 Theoretical framework

This investigation will discuss four influences on the transition that first year students experience when they enter higher education. Failing first year has been discussed in academic papers, staff meetings and faculty offices for some time. Failing in science modules are almost expected and Bunting (2004, p.73-94) tracked the 2000 cohort and found that 41% dropped-out of university programmes. South Africa can no longer afford students dropping out with huge debts and no qualification to show for it. In a focus on first year science students, Jacobs (2010, p. 59-70) indicated the importance of the loss to the economy of students with scarce skills and highly subsidised programmes such as SET. Universities rely on fundamental sciences to be taught at school, by qualified teachers and that students would be able to graduate with a quality education.

2.2 Constant amendments to the school curriculum.

The South African secondary school curriculum has changed fundamentally since 1994 (Jacobs, 2010) with every new ministry bringing a new paradigm to the fragmented educational system. Politics changed in the past 20 years, school curriculums changed but poor and rural societies are still not being served with equipped schools and inspirational teaching. Prof. Jonathan Jansen (specialist educationalist) stated in the Beeld (31 December, 2003, p.8) that "… the South African school curricula, like national flags and anthems, are some of the most contested symbols of any social transition." According to the DoE (2008a, p.3), 2008 was a year of "…enormous significance for education in South Africa". The last Senior Certificate (SC) examinations were written in 2007, followed by the National Senior Certificate preceded by the National Curriculum Statement introduced in 2006 (RSA DoE, 2008b, p.3). Most recently the Curriculum and Assessment Policy Statement (CAPS) was implemented (DoE, 2011) and the first year cohort of 2015 have followed this curriculum.

The continuous changing of a national curriculum has created gaps in the knowledge and skill of learners exiting the school system (Jacobs, 2010; CHE, 2013) and teachers have needed to be trained with every new amendment. The decline in the pass rate of especially Physical and Life Science in Grade 12 emphasised the effects of these changes. In 2007, 68% of learners passed Biology (former Life Science subject) with more than 40%. The results were even worse in 2008, where only 39% of learners passed Life Science with more than 40%. An alarming trend is noted in the Physical Science results, in 2007, 69% of the learners passed Physical Science with more than 40% in comparison and only 28% in 2008 (DoE, 2007, p.27; DoE, 2008b, p.13). This is a very serious situation arising from curriculum changes Many reasons are be provided by officials to defend these pass rates.

2.3 An increase in shortage of qualified teachers

In a recent study conducted in the province of KwaZulu-Natal (South Africa) an estimated 8000 unqualified and under-qualified teachers were teaching in public schools (Bertram; Mthiyane, & Mukeredzi, 2013). According to Pandor (2004) there are 20 000 unqualified teachers in the whole of the South African Education system and a shortage of 6000 Mathematics teachers. A large number of unqualified and under-qualified in service teachers are holding back socio-economic development in the country according to Van Zyl, Els & Blignaut (2013). In 2009, there were 12,227,963 learners in 25 906 schools and with 413 067 teachers (1 teacher: 29.6 learners) (Jacobs, 2010). In these schools there were only 600 qualified Science teachers in 1997 (Naidoo & Levin, 1998, p.73) and in the past twelve years SA only delivered 5 000 teachers per year. Rademeyer (2009, p.395) calculated that SA requires to graduate 21 000 teachers annually.

2.4 Increased pass rates at school level.

Prof Johann Engelbrecht and colleagues at UP, investigated the Grade 12 performance in comparison to first year Mathematics in 2009 (Engelbrecht; Harding & Phiri, p.289). The results indicated that the 924 students had an average Grade 12 of 78% and the same group had an average of 35% for the first Mathematics test at university level. Data provided by the Department of Basic Education (DBE) showed that in 2010, 67.8% of the learners passed the examinations and this has increased to 78.2% in 2013. The graph below (figure 1) also demonstrates the increase in Mathematics and Physical Science passes.

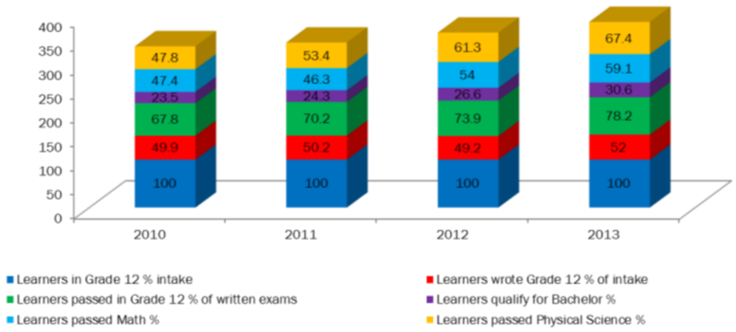

Figure 1: Nsc Results 2010-2013

Coupled with this Nel & Kistner (2009) and Jacobs (2010, p.67) found a distinct inflation of the original university application Grade 11 marks compared to the final NSC Grade12 marks. The research of Engelbrecht *et al* (2009, p. 297-299), Nel & Kistner (2009) and Jacobs (2010), therefore indicate that there is a significantly weak correlation between performance at university compared to Grade 12 NSC results. O'Connell (*Mail & Guardian*, December 2008, p.25) states that these students will battle to cope with the cognitive expectations required at higher education level.

2.5 Poorly resourced education environments and socio-economic backgrounds of South African students

The vast majority of modern day South African students come predominantly from marginalised and poorly resourced education environments and socio-economic backgrounds (CHE, 2013, p.58). This fact suggests that they would find higher learning challenging and, as a result, would most likely experience failure in the learning process (McGhie, 2012).

Taking into account the above facts, universities have been increasingly confronted with underprepared students entering the system and are challenged with bridging the gap from the school to university level at fundamental levels (writing, cognitive and conceptual deficits). Academics are pressured to increase throughput, deliver qualified graduates, and develop lifelong-learning attitudes and support poor and hungry students (CHE, 2013, p.66). Many academic support models have been followed (CHE, 2013, p.70-75) to maintain standards and increase graduation numbers. The latest suggestion of a Flexible curriculum (CHE, 2013) proposes that an additional year (i.e. four year BSc degree) is more beneficial and advantageous to accommodate underprepared students and lay a foundation for postgraduate studies.

3. PROPOSED FLEXIBLE CURRICULUM STRUCTURE FOR UNIVERSITIES

It has been proven that with more curricular space and time (Jacobs, 2010, p 258-259) underprepared students who enter HE can be moulded and supported to graduate within the minimum time. Nationally the higher education sector is addressing the "crisis" in HE with a proposal for undergraduate curriculum reform in South Africa: The case is made for a flexible curriculum structure, which has been published by the Council of Higher Education (CHE) in 2013. This proposal suggests the addition of an extra year to the norm for core undergraduate programmes, however, within a flexible structure that allows for the specific needs of the students ultimately to serve a diversity of students for improving student learning and overall performance (CHE, 2013, p.107). This new flexible curriculum aims to improve graduate output, enable better alignment of the curriculum with international conditions and standards and to provide equal and fair opportunities for the diverse array of South African students.

Final implementation of the proposal requires policy changes at national level, of which the main responsibility lies with the Department of Higher Education and Training (DHET). In addition, it is the responsibility of the higher education institutions to design and develop a curriculum which relates to the proposal (CHE, 2013).

3.1 University of Johannesburg: Four year degree model in Sciences

The University of Johannesburg (UJ), with specific emphasis on the Faculty of Science have already started to implement an extended curriculum in 2006 after the merger, in 2005, between the Rand Afrikaans University, Witwatersrand Technikon and Vista University (Soweto and East Rand campuses). The rationale for an extended curriculum was to provide a widening of access and wider participation for the new generation and diverse demography of students. The first intake into this programme was in 2004 and from then the programme has been refined to provide for a generic first semester from where students move into specific specialisation in the second semester. Due to the stigma of a name such as Extended the official programme has been changed to the B.Sc. Four Year Degree Programme since 2011.

The admission requirements of the four year curriculum are one APS score less than the mainstream three year degree for NSC Mathematics and Physical Science (e.g. 4 instead of 5). The four year degree has a flexible curriculum that extends the first year over two years with foundational support in language and computer competency. The first semester is a generic model where all the students do foundational content in mathematics, chemistry and physics (see figure 2)

TYPE	SEM 1	SEM 2	SEM 3	SEM 4	SEM 5	SEM 6	SEM 7	SEM 8
YR	YEAR 1		YEAR 2		YEAR 3		YEAR 4	
4 yr Ext BSc	MAT1AE1	MAT1AE2	MAT1AE3	MAT1B	MAJOR (i) 2A	MAJOR (i) 2B	MAJOR (i) 3A	MAJOR (i) 3B
	CEM1AE1	CEM1AE2	CEM1AE3	CEM1B				
	PHY1AE1	PHY1AE2	PHY1AE3	PHY1AE1				
	LANGUAGE FOR SCIENCE	LANGUAGE		BIC1B/ BOT1B/ ZOO1B	MAJOR (ii) 2A	MAJOR (ii) 2B		
		BIO1AE1	BIO1AE2					
	COMPUTER COMPETENCE						MAJOR (ii) 3A	MAJOR (ii) 3B
		GGR1AE1	GGR1AE2	GGR1B	MAJOR (iii) 2A	MAJOR (iii) 2B		
			YEAR 1		YEAR 2		YEAR 3	
Main stream 3 yr BSc			MAT1A	MAT1B	MAJOR (i) 2A	MAJOR (i) 2B	MAJOR (i) 3A	MAJOR (i) 3B
			CEM1A	CEM1B				
			PHY1A	PHY1B				
			BIO1A	BIC1B BOT1B ZOO1B	MAJOR (ii) 2A	MAJOR (ii) 2B		
							MAJOR (ii) 3A	MAJOR (ii) 3B
			GGR1A	GGR1B	MAJOR (iii) 2A	MAJOR (iii) 2B		

Figure 2: Extended BSc Programme (UJ)

After successful completion of the foundational modules, the students continue with these three modules (for another two semesters) and also have options to choose from Biology and or Geography in the Life and Environmental Sciences programme.

The class groups are smaller and the teaching staff is dedicated to ensure that students are provided with the fundamental content and skills to be successful in the years that follow on the first year. Students are also supported through more contact periods, help from tutors and additional support from learning centres and mentors. (UJ, 2014).

4. FOCUS OF THIS INVESTIGATION

This research paper focused on the comparative academic achievement of first-year Science Faculty students at the University of Johannesburg with specific emphasis on the biology modules. The main objective of this research was to compare the success of biology students in the three year programme, completing the Biology module in one semester with performance of students in the four year programme, completing the same Biology module in two semesters. Both these streams join in the same class in the second semester and the performance in this module is analysed. The hypothesis formulated suggests that the interventions implemented in the Four Year Degree programme can be considered as effective in developing the students' academic competency in biology relative to mainstream students.

5. METHODOLOGY

The academic achievement in the Biology modules (one semester for three year and two semesters for four year programme) as well modules that follow after the Biology when these students join in same modules. This is possible as the curricula of the two programmes are identical; the core obvious difference is the duration of the modules (two semesters in four year programme and one semester in the three year programme) and the outcomes are similar.

5.1. Participants and sampling

Purposive sampling was used when final results of students after completion of the one Biology module (mainstream) and final results of students after completion of the two semesters in the four year (extended programme) option for Biology 1A. Both these groups streamed into the second semester (1B) modules (they have the option of selecting one or more modules out of Botany 1B, Biochemistry1B and Zoology1B). Therefor students from the four year programme and three year programme will both enter the same 1B modules, attend the same classes and write the same exams and progress to the next year. The students in the three year programme will be first time entering students in the 1B module, but the students entering from the four year programme are already in their second year after completion of three semesters of foundational provision. Table 1 provides a demographic analysis of the participants.

Table 1: Demographic Analysis of Participants

Variable		3 Yr (Mainstream) (n=389)	4yr (Extended) (n=457)
Gender	F	61.9%	58.6%
	M	38.1%	41.4%
Ethnic Group	African	65.6%	85.3%
	Coloured	1.4%	1.5%
	Indian	5.8%	3.2%
	White	27.2%	10.0%
Gr 12 Profile	Ave APS	35.37	32.62
	Ave Life Sciences	79.34%	76.68%

5.2 Empirical data

In the dataset, over and above the comparison of the Biology results, there is also a comparison of the achievement in Botany, Biochemistry and Zoology, in the second semester (as mentioned above). Table 2 provides the lay-out of the analysis performed:

Table 2: Data Analysis

MODULES	3yr (mainstream)			4yr (extended)		
	2011	2012	2013	2011	2012	2013
Biology 1A10	X	X	X			
Biology 1AE1				X	X	
Biology 1AE2					X	X
Botany1B10		X	X		X	X
Biochemistry 1B10		X	X		X	X
Zoology 1B10		X	X		X	X

It is important to note that the three year degree Biology students and four year degree Biology students were combined and taught as a unit in Botany 1B, Biochemistry 1B and Zoology 1B modules respectively (no distinction between three year degree and four year degree students any more). This fact makes the results of the comparison extremely useful and meaningful to this research study.

A paired-samples t-test, including Pearson's product moment correlation coefficients, were conducted on the two pairs of first and second semester examination and final module marks, for the 846 students who enrolled for the different modules. Tables 3 and 4 below summarise the respective paired samples statistics, correlations and test findings in respect of the two sets of paired differences.

Table 3: Correlations

MODULE		BIO1A10	BIO1AE1/E2	BOT1A10	BIC1A10	ZOO1B10
BIO1A10	Pearson Correlation	1		.444**	.493**	.651**
	Sig. (2-tailed)			.000	.000	.000
	N	389	0	69	126	81
BIO1AE1/E2	Pearson Correlation		1	.678**	.537**	.464**
	Sig. (2-tailed)			.000	.000	.000
	N	0	457	78	92	53
BOT1B10	Pearson Correlation	.444**	.678**	1	.566**	.678**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	69	78	147	90	60
BIC1B10	Pearson Correlation	.493**	.537**	.566**	1	.614**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	126	92	90	218	72
ZOO1B10	Pearson Correlation	.651**	.464**	.678**	.614**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	81	53	60	72	134

** Correlation is significant at the 0.01 level (2-tailed).
a. Cannot be computed because at least one of the variables is constant.

Inspection of Table 3 shows the Pearson correlation for Biology 1A, Botany 1B (*r* = 0.444**); Biochemistry (*r* = 0.493**) and Zoology (*r* = 0.651**); are statistically significant ($p < .001$). Furthermore, Biology 1AE1/E2 ; Botany 1B (*r* = 0.678**); Biochemistry (*r* = 0.537**) and Zoology (*r* = 0.464**); have a statistically significant relationship ($p < .001$).

In Table 4 the statistics are shown. In the **Biology** modules (both programmes) are statistically significant ($p < .001$). The first semester **Biology** (mainstream) has as expected lower average of 53.46 (*SD* = 9.287) than the combined results for Biology (extended) average of 58.53 (*SD* = 7.613). In the second semester when students from both programmes enter the same modules the values are statistically significant ($p < .001$).

Table 4: Group Statistics

Module	Program	N	Mean	SD	Std. Error Mean
BIO1A10	MS	228	53.46	9.287	.615
	EXT	0[a]	.	.	.
BIO1A1E/2E	MS	0[a]	.	.	.
	EXT	324	58.53	7.613	.423
BOT1B10	MS	69	64.91	6.653	.801
	EXT	78	60.59	8.324	.942
BIC1B01	MS	126	66.94	9.179	.818
	EXT	92	62.66	7.398	.771
ZOO1B10	MS	81	58.80	9.285	1.032
	EXT	53	58.15	7.838	1.077

a. t cannot be computed because at least one of the groups is empty.

An independent samples t-test was conducted to enquire whether there is a significant difference between the performances of the mainstream and extended in the three modules in the second semester.

In Table 5 the independent samples t-test revealed a statistically significant difference between the mainstream and extended (*t* (143) = 3.496, (*p* = .001),

d =-801.505), with the marks of **Botany** mainstream (three year) (*M* = 61.91; *SD* = 6.653) better than the marks of the extended (four year) (*M* = 60.59; *SD* = 8.324).

The independent samples t-test revealed a statistically significant difference between the mainstream and extended (*t* (213) = 3.802, (*p* = .001), *d* =-801.505), with the marks of **Biochemistry** mainstream (three year) (*M* = 66.94; *SD* = 9.179) significantly better than the marks of the extended (four year) (*M* = 62.99; *SD* = 7.398).

In Table 5 the independent samples t-test revealed a statistically significant difference between the mainstream and extended (*t* (132) = .422, (*p* = .674),

d =.08), with the marks of **Zoology** mainstream (three year) (*M* = 58.80; *SD* = 9.285) equal to the marks of the extended (four year) (*M* = 58.15; *SD* = 7.838).

Table 5: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	**Sig. (2-tailed)**	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
BOT1A10	Equal variances assumed	3.178	.077	3.448	145	.001	4.323	1.254	1.845	6.801
	Equal variances not assumed			3.496	143.579	.001	4.323	1.237	1.879	6.768
BIC1A10	Equal variances assumed	4.562	.034	3.677	216	.000	4.273	1.162	1.983	6.564
	Equal variances not assumed			3.802	213.849	.000	4.273	1.124	2.058	6.489
ZOO1A10	Equal variances assumed	1.000	.319	.422	132	.674	.652	1.545	-2.404	3.707
	Equal variances not assumed			.437	123.598	.663	.652	1.491	-2.300	3.603

Levene's test indicated unequal variances for Botany (*F* = 3.178, *p* =.077, so degrees of freedom were adjusted from 145 to 143, and Biochemistry (*F* = 4.562, *p* =.034, so degrees of freedom were adjusted from 216 to 213).

The effect size was calculated using Cohen's d effect size values above (respectively *d* =-801.505 (Botany); *d* =0.52 (Biochemistry) and *d* =0.08 (Zoology)). The Cohen's d suggested a very large practical significance with regard to Botany, moderate to large practical significance for Biochemistry and small practical significance for Zoology.

5.3 Empirical synthesis

The empirical investigation generated the following noteworthy findings:

- **Access**: The extended programme provides access to more Black students and the widening of participation provides the students with a fair chance to pass the modules that follow.
- **Interventions**: The value added by smaller group and fundamental laboratory skills development of techniques and compulsory tutorials are two of the aspects that render foundational provision to extended Biology students, they are thus confident when required to apply in Botany, Biochemistry and Zoology.

6. CONCLUSION

Based upon students' ultra-positive lived experiences and their significantly (statistically and practically) achievement in the second semester modules (Botany, Biochemistry and Zoology), the influence of the new teaching and learning strategy on student learning in Biology cannot be ignored or overemphasised. At the heart of the project's success lies a collaborative and constructive interplay between students, staff and support structures (tutors, technology, adapted curriculum, to name but a few). This paper provided evidence of two streams of students entering the HE system with different school profiles and provided with an equal chance of passing mainstream modules after structured interventions have been applied.

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BIOLOGY LABORATORY PRACTICAL ASSESSMENT METHODS USED BY ETHIOPIAN UNIVERSITIES

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Abstract –The purpose of this study was to assess the biology laboratory assessment methods used by instructors in Ethiopian universities. Three universities were selected as case study. Five levels Likert scale closed ended questionnaires and open-ended questionnaires were administered to 26 instructors and 2 laboratory assistants. Structured interviews were prepared for few instructors and laboratory assistants. The result revealed that biology laboratory instructors usually use written examinations more than laboratory report form of assessment. The study showed that a practical method of assessing students' performance has received minimal attention. From the results of the analysis and the conclusions, it was evident that in biology laboratory classes, performance-based assessment needs to be used in preference to paper-and-pencil tests.

Keywords: Assessment methods, biology laboratory practicals, laboratory skills.

INTRODUCTION

Assessment is an integral component of the education process; it supports learning by providing learners with the opportunity to demonstrate acquired skills and knowledge, while determining their professional, vocational and academic achievement and the consideration (Ashford-Rowe, et al, 2014). The assessment of laboratory courses should be able to test student's competence over a wide range of practical skills (Bekalo and Welford, 1999). Hofstein and Lunetta (2003) stated that assessment tools should examine the students' inquiry skills, their perceptions of scientific inquiry, and related scientific concepts and applications identified as important learning outcomes for the investigation or the series of investigations. An important part of being a modern biologist is the ability to perform certain technical or manual skills in biology such as running gels, pipetting, recording, performing tissue culture and other skills. Among the various factors that affect the acquisition of these skill competencies is the assessment method of the biology laboratory practical. However, biology instructors assess knowledge mostly by grading exams, quizzes, papers and lab reports (Fitch, 2007).

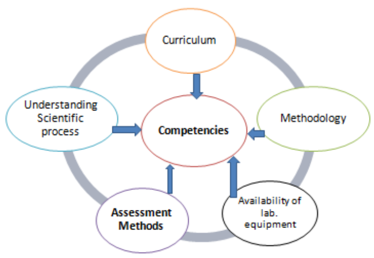

Figure 1: Conceptual model of the relationship of various factors with skill competencies

According to Hammann et al (2008), there are two general forms of tests: 'pen-and-paper' tests and 'practical' or 'laboratory performance' tests. Research has shown weak correlations between test scores from practical tests and pen-and-paper tests. Traditional modes of assessment failed to address adequately the development of practical laboratory skills considered to be useful by employers (Hunt, et al, 2012).

Practical work is one of the ways of assessing the objectives of teaching biology in which an opportunity is provided for testing application of scientific procedures, manipulative abilities as well as scientific skills (Ongowo and Indoshi, 2013).

The knowledge and skill of students in biology should not be measured only by paper and pencil examination items, but also in part by how well the students are capable of actually performing biology practical activities. This can be made by examine the competency in the skill sets. Craw (2009) defined laboratory performance assessment as a type of assessment activity in science in which students apply or demonstrate their scientific thinking skills. Craw suggested that implementing performance assessment as a teaching methodology helps to improve inquiry-based science education, promote the development of 21st century skills and competencies, involve students in the assessment process, provide teachers with valuable information to inform instruction, and as a tool for professional development. But teachers less likely to use more open-ended, authentic forms of laboratory performance assessments due to teacher background, experience, or subject matter taught. The implementation of more authentic forms of assessment becomes important for higher education (Ashford-Rowe, et al, 2014).

It was noted that the mode of assessment directly influences teachers' teaching methods, students' learning styles and attitudes towards practical activities, and the objectives of science practical work depend a lot on the mode of assessment of laboratory work adopted by the teachers and examination bodies (Giddings and Fraser, 1988, in Akinbobola and Afolabi, 2010).

Assessment of practical work encourage students to develop useful physical, technical and experimental skills and it also encourages other generic skills that are valued by employers and useful for students' real life authentic task and lifelong learning (Harris et al, 2007). The student's skills can be measured based on authentic tasks such as activities, exercises, or problems that require students to show what they can do. One of the most widely used of these is called performance assessment. The features of performance assessment are the use of a graded and authentic task. An authentic task is one in which students are required to address problems grounded in real-life contexts. Performance assessments in the science laboratory, students are graded on the performance of manipulating variables, using scientific apparatus, identifying hypotheses, making measurements and calculations, organizing and managing data, and the communication of results (Slater and Ryan, 1993). Such tasks are typically complex, somewhat ill-defined, engaging problems that require students to apply, synthesize, and evaluate various problem solving approaches (Shavelson and Pine, 1991). However, performance assessment requires more time to administer than do other forms of assessment and resource intensive (Harris et al,2007). Heyborne et al (2011) studied that the replacement of free-response practical examination questions with multiple-choice practical-examination questions have profound implications with regard to student performance and learning in the laboratory portion of an introductory college-level biology course. Hammann et al (2008) demonstrated that performance assessment is more time-consuming to administer and to code but is more appropriate than multiple-choice tests in providing the information necessary for planning new steps in the learning process which allow for a more detailed description of pupils' achievement and provides insights into qualitatively different strategies of planning experiments and analyzing data .

Whelan et al. (2010) reported that students' employability skill is a current concerns and have become the subject of considerable attention by governments around the world. Hunt et al (2012) stated that the aim of teaching practical laboratory skills can be best achieved by assessing those skills in the laboratory rather than assessing written laboratory reports or answers to examination questions. Then the practical assessment of students' performance of relevant laboratory skills has the potential to influence graduate employability as many graduates find work in biology related fields or biology laboratories. According to Hughes (2013), base standards should be established at a program, course or task level within and across countries for the employability of the graduates that could satisfy the demand of the employers.

The aim of this study was to investigate how undergraduate biology instructors assess the biology laboratory practical activities in some Ethiopian universities in order to advise higher education authorities and biology instructors on how to improve the assessment methods of biology laboratory.

METHODOLOGY

Research methods and design

An explanatory sequential mixed methods design was used and it involved collecting quantitative first and then explaining the quantitative results with in-depth qualitative data. In the first qualitative phase of the study, questionnaires data were collected from biology laboratory instructors and assistants from three universities. The second, qualitative phase was conducted as a follow up to the quantitative variable results to explain the quantitative results.

Instruments of data collection

Likert scale closed ended questionnaires and open ended questionnaires were administered to the sample respondents. Structured interviews were prepared for few instructors and laboratory assistants.

Population and sampling

Among the government universities in Ethiopia, three were selected as case study. There are two reasons why these universities were selected. Firstly, the universities have different age and recourses. Secondly, the location of the universities to the researcher was appropriate to manage data collection properly. Out of the 38 biology instructors and 3 laboratory assistants' 26 instructors and 2 laboratory assistants participated voluntarily in the study.

Instrument validation

Prior to administration, the questionnaires were submitted to a group of four biology professors for validation of its content. The reliability of the instrument was determined using pilot study. The reliability of the instruments (Cronbach's alpha 0.83) showed that the instrument has a high internal consistency (Tan, 2009). The collected data was analyzed using descriptive statistics.

RESULTS

The results show that about 46.4% of the instructors use lab report & identification of specimen type of laboratory examination and 35.7% of the instructors use laboratory report and written examinations (Table 1). From the instructor's questionnaires and interviews, the results indicate that the instructors believe that these forms of assessment help to evaluate the students' knowledge and skills, to include all concepts, to assess students' ability, to address the diversity of students learning style and to develop student's skills in writing lab reports. The instructors also mentioned that written examinations are appropriate methods because they help the instructor to check whether the students conducted the practicals individually, understood the practical and to evaluate how much the students remember of the observations they made.

Table 1: Assessment method of the laboratory practical activities

		University			Total	%
		A	B	C		
Assessment method	Paper &pencil	0	0	2	2	7.1%
	Identification of specimen	1	0	1	2	7.1%
	Lab report and attendance	0	1	0	1	3.6%
	Lab report& Identification of specimen	1	9	3	13	46.4%
	lab report &written	5	2	3	10	35.7%
Total		7	12	9	28	100%

DISCUSSION

Achievement of the objectives of science practical work depends a lot on the mode of assessment of laboratory work adopted by the teachers and examination bodies Akinbobola and Afolabi, 2010). The mode of assessment directly influences teachers' teaching methods, students' learning styles and attitudes towards practical activities (Bekalo and Welford, 1999). This study showed that instructors do not use performance-based assessment to assess the students' biology laboratory skills due to various reasons. More frequently, biology laboratory instructors use lab report, identification of specimen and written examinations. Among the reasons given by the instructors, they believe that the identification of specimen and written examinations help them to assess the students' knowledge and skills. All the reasons given by the instructors, point toward assessment of students concept knowledge but not skills. This may be due to the instructors experience and background.

In most biology laboratory examinations, specimens are usually displayed and students' would be able to write the name or category of the specimen. This is purely knowledge–based, simple recalling. The students are not expected to manipulate their skills.

Performance assessments require more time to administer than do other forms of assessment. In agreement to Silvestrone (2005), in this study, the major challenge facing laboratory instructors in conducting performance based assessment was the large class size. Silvestrone (2005) stated that the unique challenges of skill assessment are transferability of skills, use of time constrains and the increased risk for test anxiety. Over all, this study showed that a practical method of assessing students' performance has received minimal attention.

From the results of the analysis and the conclusion drawn, the following recommendations are made:

1. In biology laboratory, performance-based assessment should be undertaken in place of paper-and-pencil tests.
2. Universities should establish systems to check the mode of assessments for laboratory skills.

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"BUNGEE JUMPING" WITH PRE-SERVICE STUDENT TEACHERS: DEVELOPING LIFE SCIENCES STUDENT TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract–This study investigates the perceived pedagogical content knowledge development of pre-service student teachers involved in one of the first initiatives to establish teaching schools in South Africa. The purpose of this study is to develop student teachers' pedagogical content knowledge (PCK) by creating an opportunity for practical teaching experiences with the guidance of mentors (university lecturers) in order to bridge the theoretical-practical divide. Teacher training is being criticized for being too theoretical (Skillbeck & Connel, 2005) leaving student-teachers disappointed with their training (Korthagen, 2001). Mutemeri and Chetty (2011) did research on the university-school partnerships in South Africa and they found that student teachers go for practical teaching and experience in schools. Some student teachers end up in dysfunctional schools where they do not benefit from this experience at all. Universities therefore have to research innovative alternatives. One such development is the possibility of teaching schools associated with faculties of education- a similar practice as medical schools associated with academic hospitals. In this project the Faculty of Education of the University of Johannesburg entered into an agreement with a school near the campus- with the eventual aim to make this school a teaching school. However, this project is different to the normal approach to mentoring in teaching schools. The Japanese Lesson Study was used as a model. The participants, all final year education students, were divided in groups and each group had to teach the learners on Saturdays (at the University). (It is important to note that this particular school does not offer Life Sciences as a subject choice). Before each lesson the group had to meet with their mentor to plan the lesson and after each lesson there was a reflection session. This was in addition to their seven week experience at a public school. The research design is a qualitative case study with the third generation Cultural Historical Activity Theory (CHAT) (Engeström, 1987) being the theoretical framework. Data was gathered through interviews, focus group interviews, observations and reflections of the student teachers. The data is being coded and clustered into themes (Saldana, 2009). The themes from the different data sources will be triangulated to obtain theory. Some of the preliminary findings revealed that student teachers find this programme very beneficial to their pedagogical and subject matter knowledge development. They found it challenging to teach first language English speakers, because the majority of the student teachers are second or third language English speakers. Another theme that predominated was the student teachers' insecurities in the sense that the learners were very intelligent and asked challenging questions. This caused student teachers to realise the importance of thorough lesson preparation. In addition, working in groups led to tension as some groups found it difficult to work together. Whereas student teachers at the beginning of the year followed mainly transmission-mode approaches, this slowly paved the way during the year for more practical investigations and constructivist activities. Students indicated that a learner-centred approach is very important. Students also felt responsible for the learners' progression as they had to set assessment papers, moderate it and mark it. They were concerned about the learners' performance in these tests and how they would have to address poor performance if need be. The findings suggest that a programme where student teachers have the opportunity to teach learners in the company of peers and mentors is beneficial for the pedagogical content knowledge development of pre-service student teachers. Mentoring together with reflection are important factors in the development of these teachers' pedagogical content knowledge. This case study should be the subject of more research as an alternative way to develop aspiring teachers.

Keywords: South African teaching schools, theory-practice divide, mentoring, reflection, constructivist approach to teaching, community of practice, PCK development of student teachers.

INTRODUCTION

Education plays an important role in the development of a society. Furthermore, well qualified teachers play an important role in the success of an educational system. A well qualified teacher is not only able to make and educational system successful but also contributes to the healthiness of the system. Kahle (1999, p.2) stated that "*schools are only as good as their teachers*..." which indicated that long term improvement of results should focus on the strengthening of our teachers.

The Trends in Mathematics and Sciences Study (TIMSS) is an international benchmark which measures learners' performance in Science and Mathematics. South African learners took part in the TIMSS assessment during 2001 and 2003. Of the 38 countries that took part in 2001 and the 50 countries that took part in 2003, South African learners came last in Mathematics and Science both times (Howie, 2001; Howie, 2003,p.1-20). It is thus safe to say that not all is well in the South African educational system, especially on the Mathematics and Sciences front. Many contributing factors could be listed which includes poverty, lack of resources, negative learning cultures, bad infrastructure of schools and low teacher qualifications (Reddy, 2004). One of the big concerns in education was teachers' Pedagogical Content Knowledge (PCK) and Taylor's (2008) research indicated that most South African teachers would not be able to pass the NSC examinations of the subject they were teaching. It follows that teacher education should be innovative in addressing these problems for the future generation of South African teachers.

BACKGROUND

Internationally teacher education is in trouble (Korthagen & Kessels, 1999) as teachers, parents and politicians are dissatisfied with teacher education. Teacher training is being criticized for being too theoretical (Skillbeck & Connel, 2005) leaving student-teachers disappointed with their training (Korthagen, 2001).). Students expect to be told how to teach but are confronted with a lot of theory. Another point of contention is that teacher education is becoming the responsibility of schools where teachers are more or less "trained on the job" as school-based programs are favoured. Zeichner and Tabachnick's (1981) research showed that the educational conceptions were "washed out" during field experiences which is also supported by other researchers like Borko and Putnum (1996).

Edwards (1995) states that field-based and academy-centred ways of thinking and talking about teaching is not well blended in teacher education programs. Academy-centred discourse takes place between researchers and lecturers while the field-based thinking takes place in the classroom with teachers who are not conversant with the theoretical discourse about what they are doing. According to Korthagen and Kessels (1999) the traditional approach to teacher education has been characterised by the university experts introducing an extensive theoretical basis for teaching, leading to a situation where theory is presented without much connection to practice. The strong focus on knowledge based training has been shown to fail in influencing the practices of graduates of teacher education programs.

Korthagen and Kessels (1999) go further to state that there are three major causes of the transfer problem in teacher education. Firstly, the prior knowledge of the students differs from the theory they are taught at university and that their pre-conceptions of how to teach resist the change suggested by theory. Secondly, students need to experience a problem or concern with the teaching process in order to motivate them to study and find solutions to their difficulties (using theory). Lastly, teachers need quick and concrete answers to situations where they have little time to think. Theoretical knowledge is abstract and different from the action-guiding knowledge they need to make a decision.

Warford (2011) proposed that teachers should be taught in a Vygotskyan (1978) way which entails a three way conversation between:

- student teachers' prior believes about pedagogy
- the pedagogical content of teacher education programs
- the observations and learning during field placement.

In South Africa Mutemeri and Chetty (2011) did research on the partnerships between universities and schools with regards to the practical teaching experience that each student teachers has to undergo. What they found was that the relationship is extremely problematic as some of the schools feel they are forced to accept the learners and that the teachers are forced to be mentor teachers. Some students indicated that the school was not aware that the students were coming to their school and that they felt unwelcome. The teachers are not adequately briefed on what is expected from them and the students are awarded unrealistic marks. Some of the student teachers are sent to dysfunctional schools where they do not get feedback and do not have a chance to develop their pedagogical skills. Teachers at some schools still belief in rote learning instead of active learner involvement which is add odds with teacher training and the curriculum.

Furthermore, university lecturers expect the schools to teach the students the different teacher's administrative duties during their school visits. The researchers also found that students felt they were left to their own devices and that lecturers only turned up at the school for evaluation purposes and left them again. Some indicated that the teachers were horrible and that they did not learn anything from them. The researchers recommend an " *equal and more dialectical relationship between academic and practitioner knowledge*". (Mutemeri and Chetty, 2011).

This study investigates the perceived pedagogical content knowledge development of pre-service student teachers involved in a project where they take responsibility as teachers for two groups of grade 10 and grade 11 learners. The purpose of this study is to develop student teachers' Pedagogical Content Knowledge (PCK) by creating an opportunity for practical teaching experiences with the guidance of mentors (university lecturers) in order to bridge the theoretical-practical divide.

METHOD

This is a qualitative case study with the third generation cultural historical activity theory (CHAT) (Engeström, 1987) being used as the theoretical framework. Maximal Variation Sampling (Cresswell, 2005) was used as a purposeful sampling strategy as individuals from different contextual backgrounds were chosen to obtain multiple perspectives on the effectiveness of the program. The data was captured through observations, interviews, focus interviews and questionnaires that the students had to complete. The data is being analysed using the Saldana (2009) method of open coding and then inductively sorting them into sub-themes and the sub-themes into themes. Through this process theory will be created.

This research took place at the university, and learners from the selected neighbouring school wich do not offer Life Sciences were enrolled in Life Sciences at the University of Johannesburg Metropolitan Academy (UJMA) and were expected to attend classes on Thursdays or Saturdays. This school is being used in the same way as hospital based schools are used, it is a place where student teachers practice their skills in the presence of mentors. This is an opportunity to further enhance student teachers' PCK development.

PARTICIPANTS

The participants in this study are the student teachers, university lecturers, and the students' mentors. Although the learners were not the focus of this particular study they also formed part of this community as they were the clients of this project receiving a service. The students are all fourth year (final year) students studying to become teachers. Some of the students obtained a relevant science degree and then pursued a one year post graduate certificate in education, while other students opted for the teaching degree which integrates the content as well as pedagogical and philosophical components.

During the first year there was only one group of learners in grade 10 that were taught by the students. All the students that were taking Life Sciences methodology had to teach the class. The project grew and during the second year of the research there were two groups of learners being taught by students. The first group was now in grade 11 and still being taught on Saturdays while the second (new) group was in grade 10 and being taught on Thursday afternoons at the university. This research followed the first group as they were being taught on Saturdays which was the only day the researcher was able to observe lessons. In comparison to the first year of the project the students also had a choice whether they wanted to be part of this project, due to the large number of students enrolled for the module.

This intervention is an excellent example of a community of practice. The students were grouped into groups of four/five per session. They were given a topic to teach and they met with their mentor (university lecturer) to plan the lesson together. Their objective was to use a learner centred approach and they had to brainstorm their ideas with their mentor to come up with a suitable approach for the lesson. On the day of the lesson they presented the lesson by co-teaching where each student had a part of the lesson to present. The mentor together with other university lecturers from the sciences and technology department sat in on the lesson and served as back-up when things went wrong, which was more often than not! In some sessions the students who had to present the following session sat in and observed their peers teaching the lesson.

COLLECTION OF DATA

The researcher observed Saturday lessons over a period of one and a half years. The observations were made in an informal way by taking notes of students' presentation skills, pedagogy, overall interaction with the learners, content knowledge, PowerPoint slides and any factor that had an impact on the successful delivery of the lesson. Afterwards short individual interviews were held with the student teachers. Sometimes focus interviews were held with the whole group and one focus interview was held with a group of student teachers that observed a lesson presented by their peers. They were supposed to teach the following week.

The same questions were mostly asked, but sometimes given the events of the day additional questions would be asked. The questions that were frequently asked are the following:

1. How do you feel about today's lesson?
2. What was positive about today's lesson?
3. What was negative about today's lesson?
4. What would you change about today's lesson?
5. How does this experience compare to your experience when teaching at a public school?
6. What do you think is the value of this Saturday teaching for your own professional development?

One session was held in the computer laboratory and the questions added were focused on the value of using electronic media in the classroom. When there was conflict in the group questions were asked about the cause of the conflict and how to resolve it. During another session the fact that they had to set the examination papers and moderate it was raised during the interviews. Hence, issues that presented themselves during the session were also probed during the interviews.

A focus group interview was held at the end of the first year and the students were asked their overall opinion about the project and the value of the project for their own professional development. An interview was also held with the students' lecturer as well with the mentors to ascertain their views on the value and pitfalls of this project. During the second year the researcher joined reflection sessions between the mentor and the students after a lesson and in one session also joined the discussions.

The students also had to fill in questionnaires in the beginning of the year and then towards the end of the year, which provided a rich base of data to analyse. They also submitted written reflections on their teaching sessions.

DATA ANALYSIS

The data sources namely the interviews, focus group interviews, observations, written reflection and questionnaires are currently being coded and the codes are being grouped into themes and the themes are being sorted into sub-themes. The themes derived from the different data sources will be triangulated and through this process theory will be created.

PRELIMINARY RESULTS

Some themes that are emerging while the data is currently being translated into codes and themes are as follows: The first theme that seems to be prevalent in all the interviews that have been coded is that the students were very nervous during the first session. The one student compared it to "bungee jumping".

In all the interviews the students state that the learners at this school are very intelligent and ask difficult questions. At public schools where the students have to do their school based experience the learners are ill-disciplined and not interested in the lesson. The learners do not always ask questions or participate in the lessons. The learners at this school interact with them and want to know more about the content, which led to a lot of student teachers not being able to answer questions and having to save face by asking their peers or mentors to help out.

Teamwork also emerged from the data as a definite theme. Some individuals did not like working in a group, complaining that they had to do most of the work. It would then seem as if they took over the planning of the lesson, leaving the rest of the group to teach the minimum. This always led to conflict within the group. Another point of conflict was that some seemed to think they know more than the rest of the group, they would also bring up the fact that those students with a pure science degree knows more than those with only a teaching degree. The racial composition of the group also emerged as a theme during the focus interview with the group at the end of the first year. They commented about the fact that some groups were only white and some were only black and that they should be racially mixed. Some complained about the fact that some of the students were already full time teachers and this impacted negatively on their planning sessions as it was difficult to find a time which suit everyone.

In contrast to this, other groups loved working together praising the value of having your team there to help you when you are confronted by difficult situations while teaching. They also highlighted the fact that it helped to plan the lesson together as everyone had different ideas to contribute to the lesson. Some groups also indicated the value of the mentor or lecturer helping them to plan a lesson.

Another theme that emerged was that student teachers realised that they should plan thoroughly before they teach a lesson. This was the result of them not knowing the answer to questions or something else going wrong during a lesson. In some groups it looked like each student only prepared their part of the content and when one of their team members could not answer a question they were also not able to answer. This caused them to realise that you need to know and understand your content really well.

A new theme that emerged during the second year was the value of teaching in English as supposed to your home language. Most of these student teachers were second/ third language English speaking people and they found it challenging to teach English home language learners. They felt that this gave them a great opportunity to teach in English and to develop their skills.

Reflection was a skill that was honed during this research. The students were forced to reflect on their lessons by either writing a short reflection on their lesson, or attend a reflection session with their team members and mentor after the lesson.

Additionally, it emerged from the lesson observations that the student teachers pedagogical skills improved as the year progressed. They were increasingly able to connect the content to the learners' prior knowledge and everyday life. The presentations improved as they listened to the feedback on their first sessions. Another fact that was evident is that the students' content knowledge seemed to improve throughout the year as they prepared more extensively for their lessons in order to avoid being embarrassed.

DISCUSSION

This pilot project has a lot of potential to deliver better prepared teachers to teach in our schools. It forces the student teachers out of their comfort zones and challenge them to become better teachers. This is in accordance with Vygotsky's (1978) zone of proximal development which alludes to moving a student from his actual level of development to a potential level of development through the scaffolded mediation of a more capable other. In this case the students are confronted by highly intelligent learners which force them to operate at a higher level. The students are not only supported by a mentor (the lecturer), but also by peers.

The students are in the company of university lecturers and mentors who assist them in reaching this higher level of development through interaction during their lessons and afterwards in the reflection sessions. The reflection sessions assist the student to make a value adjustment in their thinking about their own teaching.

Hopefully this will lead to teachers who are lifelong reflective practitioners and who will be able to form collaborative partnerships with other teachers in their field of teaching.

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EXPLORING TEACHER USE OF NEWSPAPER ARTICLES IN PROMOTING A HUMANISTIC PERSPECTIVE IN SCIENCE TEACHING AND LEARNING

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Abstract–This qualitative study was conducted in Grade 8 and 9 Natural Sciences classes in Gauteng West District (D2). Interviews were conducted with five teachers; questionnaires were administered to seven teachers; and classroom observations were conducted with three teachers. The participants were conveniently sampled since the researcher works as a subject advisor in this district. The purpose of this study was to explore teachers' use of newspaper articles as a means of promoting a humanistic approach in science teaching, since the researcher noted that social issues were not infused into science lessons, although this was required by the South African National Curriculum Statement (NCS). The following research questions were posed: (1) What perceptions do teachers have on the humanistic approach in science teaching and learning? (2) What challenges do science teachers experience in implementing a humanistic approach? (3) How can teachers use newspaper articles to promote a humanistic approach in science? This study strongly suggests that print media can be used effectively to change teaching and learning in the science classroom and to make science more relevant to learners; as well as to develop critical and moral reasoning among learners. In response to implementation problems identified, a community of practice was formed and a website created containing resources for teachers.

Keywords: humanistic approach; socio-scientific issues; newspaper articles

1.1. INTRODUCTION

This study focused on promoting a humanistic perspective approach in science teaching and learning. Humanistic perspectives in the science curriculum include the social aspects of science, and the human character of science revealed through its sociology, history, and philosophy (Aikenhead, 2007). Research reports that many teachers overwhelmingly endorse a humanistic approach (Choi & Abd-El-Khalick, 2003; Van Driel, Beijaard & Verloop, 2001) but cite a lack of classroom materials as a factor impacting on its implementation (Bartholomew, Osborne & Ratcliffe, 2004). The purpose of this study was to explore teachers' use of newspaper articles as an easily accessible source of socio-scientific information; and to promote this approach in science teaching.

The study generated four themes on the perceptions of teachers on the humanistic approach. According to Theme 1, the humanistic approach develops learners who are socially responsible, critical thinkers, creative problem solvers and better decision makers as science is integrated with social issues. Theme 2 suggested that the humanistic perspective integrates moral reasoning with values of society, thereby supporting ethical decision making. According to Theme 3, a humanistic approach stimulates interest in the learning of science. Theme 4 identified the lack of quality support materials such as newspapers as a major challenge in the implementation of the humanistic approach in the science classroom.

Following a teacher development workshop and collaborative lesson planning, classroom observations revealed a shift in practice from a dominant teacher-directed approach to a learner-centred approach where learners were more involved in their learning. As a result of the reflections following the lessons, teachers were better able to engage learners on the issues that were highlighted in the newspaper articles. Through collaboration with teachers, a website for resource material was created on www.beautymoleki.com.

1.2 BACKGROUND TO THE STUDY

The interrelationship between science, society and environment is reflected in the Curriculum and Assessment Policy Statement (CAPS), which is an extension of the National Curriculum Statement (NCS). Specific Aim 3 from the CAPS states that: "Science learnt at school should produce learners who understand that school science can be relevant to everyday life." (Department of Basic Education 2012:10).

Although both the CAPS and the NCS policies are meant to facilitate the production of science from a humanistic perspective in the classroom, it is my experience as a subject advisor that this is not done in practice. Other authors have commented that that policy makers and politicians throughout the world have devoted much attention to the "what" of educational change, neglecting the question of "how" it should be implemented (Rogan & Grayson, 2003). These authors argue that a great deal of money has been wasted on good ideas that have never been translated into classroom realty.

It is against this background that the study was undertaken, and at a time when there was an increasing problem of accessing resources in science teaching and learning. The observation made from my visits to schools as a Natural Sciences subject advisor was that socio-scientific issues were not addressed in lesson plans and learners' books. This led me to scrutinize newspapers as a tool to enhance the humanistic perspective approach. Newspaper articles provide an intervention to address the challenge in this regard. Ekborg (2005) notes that daily topics such as HIV and AIDS, cloning and climate change relate to science, society and technology and are covered in daily newspapers easily accessible for use in science lessons.

1.3 CONCEPTUAL FRAMEWORK

The goal of science education is to improve learners' interest and knowledge, and the ability to integrate science with real-life situations (Osborne & Dillon, 2008). Aikenhead (2006) argues that one way to increase learners' interest is to introduce an approach that uses a humanistic perspective in science education. To understand the humanistic perspective approach, one must understand the features of this approach in science education, which have been variously expressed as: values, the nature of science, the social aspects of science, and the human character of science revealed through its sociology, history and philosophy (Aikenhead, 2003a).

Studies show that school science is often a preparation for studies in science and not for the use of science in society (Aikenhead, 2006). A humanistic approach to school science is intended to prepare future citizens to critically assess the role of science and technology in society, as science today is integrated with politics, economics and ethics in a complex way (Nowotny, Scott & Gibbons, 2002).

By stressing the social content of knowledge, science can be used as a tool for students to participate in social and political life, and to understand and act in a responsible way in this complex world (Ratcliffe & Grace, 2003).

Aikenhead (2003b) and Irwin (2000) assert that a humanistic approach should meet the following criteria:

1. The content in science must make substantial connection with social issues
2. It must focus on the human factor in science
3. The curriculum itself must be humanely taught

These criteria are given in Figure 1 which provides a representation of the humanistic approach to science teaching.

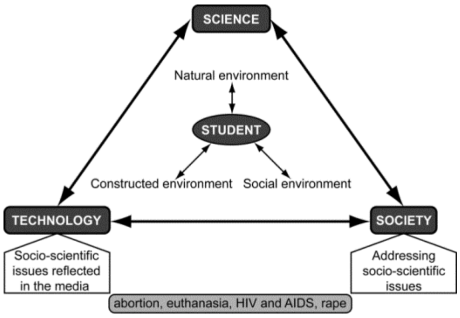

Figure 1: The integration of the humanistic approach into science teaching (adapted from Aikenhead, 2000)

As shown in Figure 1, the major premise of the humanistic approach is that learners should be the crucial source of the science curriculum. Proponents of this learner-centred approach to curriculum design are self-actualisers who believe that the function of a school science curriculum is to provide each individual learner with intrinsically rewarding experiences that contribute to personal liberation and development (McNeil, 1996; Moheno, 1993). Topics are based on learners' everyday experiences and concerns, such as how not to contribute to global warming and how to deal with issues such as abortion and HIV and AIDS. These issues form the cornerstones of investigations and discussions in the science classroom (Cheek, 2000; Fensham, 1998).

The humanistic approach also engages learners in developing higher-order thinking skills, which are developed when learners start evaluating data and communicating their findings (Ramnarain & Kibirige, 2010). Social skills (communicating findings) are developed as learners collaborate with one another; share ideas and challenge the ideas of others (Ramnarain & Kibirige, 2010). Brown (1992) advocates the following pedagogy to achieve humanistic goals:

- enquiry-based approaches and problem-based learning
- discussion methods that allow students to explore their conceptions and values
- feedback that focuses on developing understanding
- assessment methods that involve self, peer and collaboration, and include reflection on experience.

The humanistic approach may be facilitated in the science classroom through the use of newspaper articles as a tool to enhance meaningful learning and process skills (Ramnarain, 2010). Newspaper articles cover socio-scientific issues on a daily basis. From the researcher's observations, teachers struggled to connect real-life issues with science. They also lacked the time and skill to modify existing curricular materials. Consequently, this study was concerned with teachers' perceptions and experience of implementing a humanistic perspective in science, using newspapers articles as a resource through which to access socio-scientific issues.

1.4. RESEARCH METHODOLOGY

1.4.1 Research setting and participants

Participants who formed part of the sample were selected according to the following criteria:

- They had to be willing to participate in the study at the same venue and time specified.
- They had to obtain a consent form to participate in the study.
- They had to have experience in teaching Science in Grade 8 and 9 for more than five years.

Data was collected through teacher interviews, a teacher development workshop followed by teacher questionnaires and lesson observations. All participants attended the workshop (45 teachers), including the five participants who were interviewed before the workshop. The questionnaires were administered to only seven of the workshop participants (none of whom had been interviewed). Three of the questionnaire respondents then volunteered for the classroom observations.

1.4.2 Research design

A design-based research (DBR) process was followed in this study. The DBR process provides an important methodology for understanding how, when and why educational innovations work in practice (Brown & Collins, 1992). This methodology involves the systematic design, enactment, analysis and redesign of intervention strategies and tools (Brown & Collins, 1992). The strategy in this regard was the use of newspaper articles to address socio-scientific issues in the classroom. Figure 2 depicts the DBR phases followed in this study.

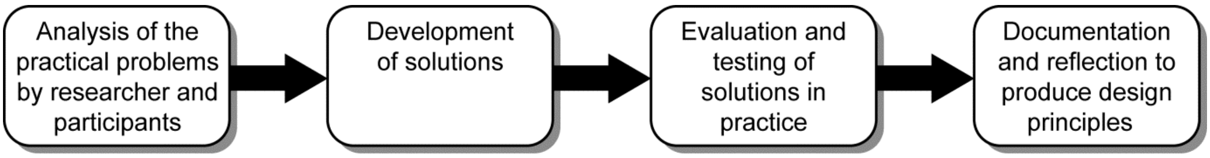

Figure 2: Design-based phases followed in this study

Phase 1: Analysis of the practical problems by researcher and practitioners

Data collected during this phase provided information regarding teachers' perceptions and challenges in implementing the humanistic approach in science teaching and learning. Interviews were conducted with five teachers to define the problems they experienced. Interview responses were audio recorded, transcribed, coded, categorised and themed using the Saldana (2009) coding method (see Figure 3).

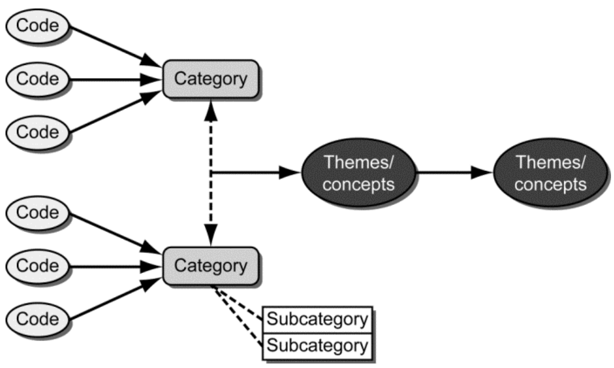

Figure 3: Saldana's codes theory model for qualitative inquiry (Source: Saldana, 2009)

Phase 2: Development of solutions

A workshop was conducted to explore the importance of using a humanistic approach in science education and how it has benefitted other countries in science, society and technology; and the philosophy behind this approach. Different newspapers from different sources were used. The aim of the workshop was to demonstrate how to use newspaper articles to create a real-life context in the science classroom, and how this approach can improve science teaching and learning. Teachers collaborated to design solutions to the challenges identified in the workshop. Seven teachers completed questionnaires after the workshop. Questionnaire responses were coded, categorised and themed using the Saldana (2009) coding method (see Figure 3). The coded interviews from Phase 1 plus the coded questionnaires from Phase 2 collectively contributed to the themes.

Phase 3: Evaluation and testing of solutions in practice

Classroom observations were conducted and analysed on how teachers explored newspaper articles in implementing a humanistic approach to science in the classroom, and to determine challenges they experienced using this approach. The videos were analysed using the Reformed Teaching Observation Protocol *(*RTOP) instrument, which is an observational instrument used in science classrooms to measure reformed teaching (Piburn, Sawada, Turley, Falconer, Benford, Bloom & Judson, 2000). According to Piburn et al., reformed teaching involves moving away from the traditional approach of teaching science towards an instructional strategy where learners debate social issues, formulate hypotheses and devise solutions to problems they confront. The RTOP analysis provided further information on challenges using newspaper articles to implement the humanistic approach.

Phase 4: Documentation and reflection to produce design principles

In Phase 4, strategies employed by the teachers were discussed with them based on their reflection and the results of the RTOP analyses. Necessary revisions were suggested for changing their traditional style of teaching to reformed teaching. Follow-up classroom observations were conducted with all three teachers based on these discussions and reflections.

1.4.3 Data collection

The following data was collected during the study: five one-on-one interviews, which can be referred to as “conversations with a purpose” (Collins, 1998). The aim of these interviews was not to answer questions, but to gain an understanding of teachers’ perceptions on the use of newspaper articles in implementing a humanistic approach. Therefore, teachers’ perceptions, as well as their experiences and challenges, were explored. Based on problems identified in the interviews, a professional development workshop was held. Seven teachers from the workshop answered questionnaires after the workshop, which explored the same questions as posed in the original interviews. An additional three teachers from the workshop participated in classroom observations followed by reflective sessions and a second round of classroom observations. Figure 4 depicts the phases of data collection used in this study.

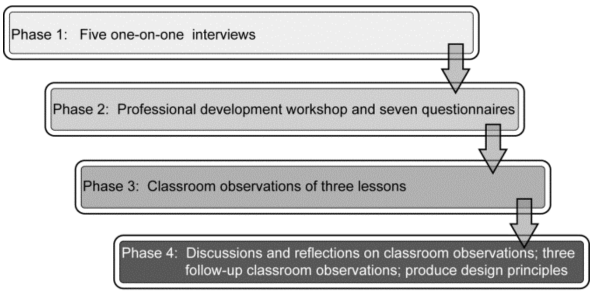

Figure 4: Phases of data collection in this study

1.4.4 Validity and reliability

Validity refers to the degree to which a method or research tool measures what it is supposed to be measured (Opie, 2004). According to Maxwell (1992), validity in a qualitative research study lies in “critical realism”, which involves accuracy and appropriateness. In this study, I used video and audio recordings to capture an accurate response from participants. The video recordings were transcribed so that the views of the participants were distorted or misrepresented.

External validity is the extent to which the findings of a study can be generalised and applied to other situations (Merriam, 1998). Although this study was confined to one sample of teachers from Gauteng West District, the problems that they identified may well apply to the broader population of teachers in the country, especially since the humanistic approach in science deviates from traditional practices used before the wave of curriculum reforms in South Africa since 1994.

Internal validity describes how congruent the findings are with reality from the participants' perspectives (Merriam, 1998). Member checking and peer review were used to validate the themes that emerged.

'Reliability' often refers to the degree to which another researcher would reach the same conclusions (Merriam, 1998). In qualitative research, however, Merriam describes reliability as determined by how consistent the results are with the data collected, rather than whether research findings can be replicated. In order to enhance reliability, an audit trail was explicated and findings were congruent with the existing body of knowledge in this area.

1.5 DISCUSSION OF FINDINGS

The study generated findings from three main data sources: interviews, questionnaires and classroom observations. In addressing research Questions 1 and 2, four themes were generated. Themes 1, 2 & 3 addressed the first research question, while theme 4 addresses the second research question. The RTOP analyses addressed the third research question (see Table 1).

Table 1: The relationship between research questions and findings

Research questions	Findings
1. What perceptions do teachers have on the humanistic approach in science teaching and learning?	Theme 1, 2 & 3
2. What challenges do science teachers experience in implementing a humanistic approach?	Theme 4
3. How can teachers use newspaper articles to promote a humanistic approach in science?	RTOP analyses

1.5.1 Discussion of themes

Theme 1: The humanistic approach develops learners who are socially responsible, critical thinkers, creative problem solvers and better decision makers as it integrates science with social issues

Five teachers were interviewed face to face in the individual interviews at the start of this study. The interviews are numbered sequentially. Teachers 1 and 5 asserted that a humanistic perspective in science using newspaper articles encouraged learners to become aware of their actions, hence making them more socially responsible. The following excerpts from the interviews support this theme:

> So, some of our kids are from informal settlement, they are doing these illegal connection. Their parents are telling them to do that. So, you'll teach them the live wire, you teach them all these kind of things. And they will practise at home. So to avoid such things, you must make sure that you've got the newspaper articles where they address the issue that the person that was found in, in, doing illegal connection, he was killed by those particular cable and then so on. You are trying to tell them, even your parents, make them aware that you are not allowed to do illegal connection, although you've got the scientific background of this, you are not an electrical engineer, you are a young scientist. (Teacher 1)
>
> We have people in hospitals who are using, people who are sick in our home who are using this uh, oxygen thing and then using electricity, if there is no electricity, the person can die also. (Teacher 5)

The views above reflect an understanding that knowledge is a human product which is socially and culturally constructed through the environment that people live in. This view correlates with findings from a study by Jarman and McClune (2002) that using newspaper articles that deal with the social and cultural environment of the learners can play a role in developing their critical-thinking skills in the science classroom. These skills may be developed in the science classroom by, for example, giving learners a case study or investigative activity based on a newspaper article dealing with illegal electrical connections (township lingo, *izinyoka*) or teenage pregnancy and HIV and AIDS allowing them to come up with a solution to the problem.

This approach was supported by Teacher 4, who stated that:

> By, let's say maybe, giving them something like a case study and let them do, the, the, the, the research on their own. Come up with different opinions, different ideas, different opinions. You know to unpack almost uh, the, the, the

> solutions on their own. You can give them the, the, the problem, pose the problem to them and let them brainstorm the uh, solutions on their own.

According to the American Association for the Advancement of Science (AAAS, 1989), inquiry-based education should be supported in the science classroom. Science teachers should assist learners in making meaning of scientific knowledge, and learners should no longer be regarded as passive receptors but as researchers discovering knowledge and developing skills. These skills may be improved by using hard media. As learners debate the socio-scientific issue about which they are conducting research, critical thinking emerges as they address questions such as why illegal connections escalate in townships in winter. Through critical discussions in a group – with the teacher as a facilitator – 'big' ideas on saving electricity may arise. Furthermore, awareness that illegal connections are dangerous as they take peoples' lives, should develop.

Theme 2: The humanistic approach in science integrates moral reasoning with the values of society

With regard to integrating a humanistic perspective in science with morality (as the value of society), Teacher 1 referred to how topical issues should be integrated in the teaching of science topics. This is evident from the excerpt below:

> … when you talk about HIV and AIDS, others they just burst into tears. Because they have just found out last week that their mother or their parents are HIV positive. So, it is very, very challenging and sometimes, as, as a teacher, those issues, they also affect you. And sometimes lack of information, which is killing our community and society. Because uh, last week I make an example, in, in my classroom that there are areas that you won't see the advertising that we are doing, free abortions, safe abortions. Because lack of information, our kids they think that when you sleep with a boy, a boy while you are menstruation, you won't get pregnant. Then they got pregnant.

However, he added that:

> [It is a] challenge that … even medical doctors, they don't know what time is the embryo having life. They are still debating about that particular issue. Even some new doctors [inaudible], they are against abortion, because the learners are using, the kids are using it as contraception. So, really, it's really a big societal issue. Our kids are not informed. And science teachers don't teach these things because they think that they are meant for LO.

It is also clear that in making moral and ethical decisions, learners need to understand the difference between fact, opinion and views. We need to stimulate critical-thinking abilities in our learners. Ethical issues provide a good entry point into the study of certain topics in science.

According to Aikenhead (2005), the humanistic approach to science and technology promotes human values, a connectedness with personal and social issues to reach inclusiveness and a learner-centred approach. The humanistic classroom incorporates a variety of values and knowledge fields, including personal knowledge, technology, ethics, politics and law (Aikenhead, 2005). Using this approach in the classroom engages learners in instructional activities and in formulating hypotheses on, for example, abortion, euthanasia and HIV and AIDS.

Theme 3: The advocacy of a humanistic approach arouses learners' interest in the science classroom

Teachers maintained that the use of newspaper articles in their teaching aroused the interest of learners in science. In their responses, teachers indicated that newspapers and magazines reflected issues that occurred in real-life situations (daily life). They even pointed out that learners do not interact with textbooks as easily as they do with hard media. Issues that are dealt with in newspapers are those that affect them directly, such as carbon-monoxide poisoning, and HIV and AIDS.

The benefit of using newspaper articles compared to textbooks is evidenced in the following quote:

> Learners are able to understand that science is not something which is done in the classroom. And science is not difficult because it's something which is happening on our daily life. It means now you are arousing their interest in scientific knowledge by newspapers. Because they like newspapers, they like magazines. What they don't like is textbooks. When you come to textbook is another formal thing and then they don't interact with textbook because they think the information is very difficult but with the newspaper the information is easy for them to interact with. (Teacher 1)

In the individual interview this teacher indicated that when dealing with the topic of reproduction in the CAPS Life and Living strand in Natural Sciences, it is imperative for the teacher to take into consideration the moral and cultural values of the learners.

The literature consulted for this study generally sees the humanistic approach as one that incorporates values, the nature of science, the human character of science, sociology, history and its relationship with technology (Aikenhead, 2003). As Teacher 1 also stated: "… and science is not difficult because it's something which is happening in our daily life."

Theme 4: Teachers consider the availability and quality of newspaper articles to be a challenge in implementing the humanistic perspective approach

In Theme 4, there are a number of challenges that the participants alluded to. However, we focus only on those that address the research questions. When implementing a humanistic approach in the classroom, understanding the language used in newspaper articles, designing worksheets, compiling questions and developing resource materials based on those articles are all challenges teachers face. Trying to determine fact versus bias or subjectivity is just as challenging. We were able to identify the implementation challenges teachers face through an analysis of teachers' responses to Question 8 in the questionnaires: What could be challenges in using newspapers in science teaching? Below are some of the responses. These responses cover issues of irrelevant content, inaccessibility and affordability:

> But sometimes we don't get the topic that you, you want to address, so you, you have to make copies from the one that you have, it's costly.
>
> … if I, I am to deal with a certain topic, I want, I, I need an article at that time, and then the article is not there ...
>
> … most of the learners don't access them easily.
>
> First challenge I can think of it is obvious that the newspapers definitely are not easily accessible. They are commercial.
>
> What makes you to not to use them too much? The thing is newspapers, I must first organise them for learners.
>
> Newspapers are expensive.
>
> The challenges could be, not all learners could afford to buy newspapers, as we know the family background they come from does differ.

Based on further analysis of the responses, some participants highlighted the problem of bias and unscientific journalism. They felt that some articles were not written objectively and they did not differentiate between facts and opinions. From one teacher's response, it was clear that articles were considered to be biased and that learners would be required to distinguish between facts and opinions, something they found difficult because of the language barrier, for example:

> The person that wrote that particular newspaper is not a scientist. The first thing they will be a lot of misconception.
>
> Not all articles are based on scientific facts and also not written objectively.
>
> You know of articles and alike because most of the learners cannot just bring that to school. And then the other issue of you are looking at the issue of biasness of writers.

The following issues emerged from the questionnaires and a few from discussions during the teacher-development workshop. They relate to language and the posing and solving of questions:

> The only, question maybe that can confuse them will be where they have to give the solutions of how they can be able to solve the problems.
>
> … what I usually do if I give them the article, because I, I first go through it and then, ask them the questions that they will be able to, to answer ...
>
> … the person that wrote that particular newspaper is not a scientist. The first thing. They will be a lot of misconception. The words used in the newspapers are not on the learners' level of that specific language comprehension.

Further teachers' responses during the development workshop indicated that teachers also felt that they had a lack of resources and that this presented a challenge in implementing a humanistic approach in the science classroom.

1.5.2 Implementation

The classroom observations and RTOP analyses addressed research Question 3. A key finding was the shift in practice from a dominant teacher-directed approach to a learner-centred approach where learners were more involved in their learning. As a result of the reflections following the lessons, teachers were better able to engage learners on the issues that were highlighted in the newspaper articles; and teachers were better able to facilitate group discussions. Ethics, responsibility and patient rights, myths and facts were also debated in relation to newspaper articles about HIV and AIDS. For example, as learners highlighted issues of sexual behaviour, teacher involvement in the discussion became limited. This moral aspect of science can easily be neglected in the traditional approach to teaching science.

With regard to the implementation of a humanistic approach, teachers indicated feeling uncertain and lacking the confidence to employ a learner-centred approach. This was especially the case when they taught the first lesson. They also expressed uneasiness about handling controversial issues of a social and ethical nature. Teachers found designing worksheets, compiling questions from articles, developing resource materials based on those articles and interpreting the language used in the articles to be challenging.

Although, the language of some newspaper articles posed a problem, when the teachers' preparation was thorough, they were able to intervene during discussions to clarify areas of difficulty. During lesson-plan presentation in the workshop, a worksheet was designed on acid rain, and teachers had no further problem designing activities based on the articles because these challenges were addressed in the teacher-development workshop.

1.6 RECOMMENDATIONS

The following recommendations are made with a view to facilitating teacher use of newspapers in promoting a humanistic approach in science classrooms.

1.6.1 Teaching strategy

When incorporating a humanistic approach in the science classroom, the teacher should design lessons that incorporate tasks that integrate science with real-life issues. Lessons should engage learners as members of a learning community so that they discuss and challenge each other's views on socio-scientific issues. Learners should also be encouraged to suggest creative and innovative solutions to everyday problems.

This recommendation is supported by the literature. For example, a survey of the use of newspaper articles in science by secondary teachers in Northern Ireland explored how teachers used hard print. The findings showed that many teachers used newspaper articles to support critical and creative science instruction (McClune & Jarman, 2010). They further stated that the teachers' intention of using newspapers was to link school science and everyday life. In addition, the survey aimed at developing the learners' ability to read and respond critically to science (McClune & Jarman, 2010). The United Kingdom report *Beyond 2000: Science Education for the future* states that "the curriculum should help students to be able to understand and respond critically to media reports of issues with a science component" (Millar & Osborne, 1998:121). The literature also supports active engagement, learning by doing and the importance of feedback (AAAS, 1989). These strategies were evident during the class debates in this study.

1.6.2 Teacher training and resources

Promoting the humanistic approach is a challenge in the teaching and learning of science. This research has shown that teachers' knowledge of the content on its own cannot develop a humanistic perspective in learners. Teachers need more than knowledge of the content. They need skills, a review of their teaching style and resources that will help them implement this approach. Therefore, teachers should be trained in the teaching method and skills required for this approach. This training should be piloted during curriculum information forums.

A documented failure of learners to learn science content meaningfully is that it lacks relevance to their everyday world (Osborne & Collins, 2000). A website where newspaper clippings can be accessed was created to solve the problem of the common complaint from teachers “but we do not have resources” (see www.beautymoleki.com). Further training and resources are required to enable teachers and curriculum designers to take this approach further. Writers and developers of classroom materials could also collaborate on the compilation of a resource pack comprising articles from different newspapers.

One of the strengths of this research is that we were able to use the research to move teachers from the traditional approach of teaching science, i.e. teacher-centredness, to learner-centredness, which embraces reform teaching. During the support visits, teachers’ lesson plans and learners’ activities shifted from content based to include a humanistic perspective. The traditional approach of teaching changed into reform teaching. However, change is a process that does not happen overnight and the importance of sustainable communities of practice is highlighted.

1.7 CONCLUSION

In this study, we explored teachers’ use of newspaper articles in promoting a humanistic approach in science. Teacher-development workshops were conducted to introduce the humanistic approach as a concept and show how it has benefited other countries in changing teaching-and-learning practice in science. Teachers were interviewed about their perceptions of the potential and challenges of using newspaper articles to infuse science teaching with a humanistic perspective. Questionnaires were also administered. Classroom observations were conducted in which teaching methods in implementing this approach were observed. After a follow-up discussion on lesson-plan preparation and presentation, teachers showed a great improvement in implementing this approach. Teaching style changed from the traditional approach to a learner-centred approach, which is advocated in reform teaching where learners engage in debate, hypothesis and come up with problem-solving ideas.

One of the themes that emerged from the teachers’ interviews indicated that the use of newspaper articles stimulates creative and critical thinking. The challenge is the lack of material and resources. A website was created to alleviate this problem. A community of practice was formed during teacher-development workshops. This has also encouraged teachers to continue to use newspapers in their classroom activities. This study shows that print media can be used effectively to change teaching and learning in the science classroom.

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EXPLORING THE USE OF IMPROVISED PHYSICAL RESOURCES IN THE IMPLEMENTATION OF INQUIRY-BASED SCIENCE TEACHING AND LEARNING IN GRADE 9 NATURAL SCIENCES

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Abstract–The need to implement inquiry-based teaching and learning of science at all levels, and its benefits to learners have been addressed by numerous studies. In South Africa, the introduction of the approach has met with tremendous challenges, such as the shortage of physical material resources (Muwanga-Zake, 2004). In addressing these shortages, the National Curriculum Statement for Natural Sciences advocates the use of improvised equipment (Department of Education, 2011). This design-based research (DBR) study investigated the implementation of the inquiry-based approach using improvised materials in Grade 9 Natural Sciences. The data was collected using interviews with the three teachers. The findings revealed that teachers held positive perceptions of the inquiry-based approach but felt that its implementation was hindered by a number of problems. The three teachers concurred that the use of improvised materials enabled them to implement the inquiry-based approach.

Key words: Inquiry-Based Teaching and Learning; Improvised Resources; Practical Work

1. INTRODUCTION

"Inquiry" has become a perennial and central term in the rhetoric of past and present science education reforms (Abd-El-Khalick et al., 2004); yet, it has remained elusive and very demanding. The South African school science curriculum advocates an inquiry-based approach to practical work. This imperative is expressed in the new Curriculum and Assessment Policy Statement (CAPS) document where Specific Aim One states that "the purpose of Natural Sciences is to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena" (Department of Basic Education, 2011:8). Earlier studies have indicated that the inquiry-based approach enhances learners' comprehension of scientific concepts (Duggan & Gott, 2002), allows learners to utilise a multiplicity of skills across disciplines (Warner & Myers, 2014), improves learners' understanding of the nature of science (Quintana, Zhang & Krajcik, 2005), enhances the development of learners' critical thinking skills and develops positive attitudes and perceptions towards science (Narode, Heiman, Lochhead, & Slomianko, 1987), initiates the development of learners' scientific investigation skills (Falk & Drayton, 2001), and improves learners' scientific literacy (Lindberg, 1990).

In South Africa, the introduction of the inquiry-based approach to practical work has met with tremendous challenges at the implementation level. One of the main challenges was the shortage of physical resources such as apparatuses and chemicals (Muwanga-Zake, 2004). Another challenge was teacher competency (De Beer, 2007). Hattingh, Aldous and Rogan (2007) have reported that the lack of resources for practical work is prevalent in most developing countries such as Kenya (Ndirangu, Kathuri & Mungai, 2003) and Nigeria (Okoye, 2002).

In addressing the issue of the lack of school laboratories and equipment, the National Curriculum Statement for Natural Sciences dismisses the myth that practical work cannot be taught in schools without fully-fledged laboratories with expensive and sophisticated equipment (Department of Basic Education, 2011). It is suggested that investigations can be carried out using improvised equipment that are normally familiar to the learners. The use of materials that are familiar to learners are expected to enhance their understanding of scientific concepts. In accordance with this view this study explored the use of improvised physical resources in the implementation of inquiry-based science teaching and learning in grade 9 Natural Sciences.

This study is located within a design-based paradigm. One of the merits of this method is that it enacts strong and reflective inquiry-oriented tendencies that support the continuous evaluation of design principles in-situ (Collins, 2004). This paper examines the first stage of the design-based research process with the following research questions:

- What challenges do grade 9 Natural Sciences teachers encounter in the implementation of inquiry-based teaching?
- What are the perceptions of grade 9 Natural Sciences teachers on the implementation of the inquiry-based approach?

2. CONCEPTUAL FRAMEWORK

This study is framed by inquiry-based education. In this section an overview of the inquiry-based approach is given which examines the factors that influence its implementation, and the problems that are encountered in the same process. Studies related to the implementation of the inquiry-based approach in South Africa are also explored. The paper then finally looks at the benefits of the inquiry-based approach in the teaching and learning of science.

2.1 The inquiry-based approach

Anderson (2002) argues that the inquiry-based approach can only be understood from an analysis of its components: scientific inquiry, inquiry teaching and inquiry learning. He states that a teacher's understanding of science as inquiry and learning as inquiry are fundamental to informing how they enact inquiry-based teaching. Earlier researchers have defined scientific inquiry as the diverse ways in which scientists study the natural world, using logic and imagination, and propose explanations based on the evidence derived from their work (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996). It is our analysis that scientific inquiry forms the base for both inquiry-based teaching and inquiry-based learning. According to Anderson (2002) inquiry-based teaching is characterised by the planning of activities during which learners are meant to develop their knowledge and understanding of scientific ideas and understand how scientists study the natural world.

The third category of the inquiry-based approach is inquiry-based learning. During inquiry-based learning learners are involved with the procedures of scientific inquiry. Anderson (2002) defined inquiry-based learning as an active learning process in which learners are engaged as they pursue knowledge. He elaborated further that during inquiry-based learning, learners are involved in learning, formulate questions, investigate widely and then build new understanding, meaning and knowledge.

The characteristics of the inquiry-based approach can best be understood by analysing the routine classroom interactions and operations of teachers and learners. According to Lederman et al. (2004) and the National Research Council (1996**)** the following are the major characteristics of the inquiry-based approach:

- Learners are engaged with scientifically-oriented questions.
- Learners give priority to evidence.
- Learners formulate explanations from evidence.
- Learners evaluate explanations in the light of alternative explanations.
- Learners communicate and justify proposed explanations.

2.2 Types of inquiry-based approaches

In the view of Crawford (2006) the inquiry-based approach ranges from structured inquiry (students are given a problem and an outline on how to solve it); guided inquiry (students are guided to figure out the solution method) and open inquiry (students must formulate the problem for themselves).

2.2.1 Structured inquiry

Bolte, Holbrook and Rauch (2012) argue that during structured inquiry, the teacher gives guidance to the learners through methods such as asking probing questions. The learners however have to generate explanations based on the evidence that they have collected (Banchi & Bell, 2008). The teacher's guidance is intended to elicit the learners' thinking processes.

2.2.2 Guided inquiry

With guided inquiry the teacher generally takes the role of the guide for the entire investigation process. During this process, the teacher encourages the learners by giving guidance on the research question and help to plan the learners' inquiry (Banchi & Bell, 2008; Bolte et al., 2012). The learners, however, come up with the design of their inquiry, and also have to test their hypothesis and derive conclusions from their inquiry.

2.2.3 Open inquiry

During open inquiry, learners are tasked with working on their own. According to Bolte et al. (2012), the learners are expected to come up with the questions, design and carry out the inquiry activities, and arrive at conclusions. In essence, learners operate in the same way that scientists do.

2.3 Factors influencing inquiry science in classrooms

This section looks at the factors that influence the implementation of the inquiry-based approach. The factors have been grouped into teacher factors, learner factors, curriculum factors, school factors and resource factors.

2.3.1 Teacher factors

It has been shown that teachers' inadequate pedagogical skills have influenced the way they teach science to the learners. Research conducted by Muwanga-Zake (2004) reported that many science teachers lacked content knowledge. Consequently their pedagogical content knowledge (PCK) was adversely affected. The inquiry-based approach requires the teacher to have an elaborate understanding of ideas and concepts in science (Anderson, 2002). Such an understanding allows the teacher to evaluate the development of inquiry skills such as the posing of hypothesis by the learners. In a related study on the influence of teachers' PCK on teaching, Chin and Kayalvizhi (2002) found that in cases where teachers' PCK is inadequate, they may fail to demonstrate to learners how to embark on inquiry-based education, such as the identification of variables.

Apart from their inadequate science background, teachers have also been found to be conservative in their practices, particularly in the way in which they teach and assess (Chan, 2010; Ramnarain, 2010). It is the view of Chan (2010) that teachers tend to adopt and maintain a traditional teacher-centred approach in teaching, giving rise to authoritarian and didactic patterns of instruction. The inquiry-based approach calls for teachers to change both roles and duties during their teaching. As shown by Anderson (2002), teachers would most likely resist relinquishing control of teaching and learning in their classrooms.

Teachers' beliefs about how to teach science has also been found to influence the degree to which they will implement the inquiry-based approach in their teaching. Bryan and Abell (1999) state that teachers' beliefs are instrumental in the implementation of the inquiry-based approach in various ways. This view is also held by Chan (2010) who argues that in some cases, teachers may not even notice the merit of the inquiry-based approach due to their beliefs about teaching.

2.3.2. Learner factor

Since inquiry-based approaches touch on the operations of both learners and teachers, research has likewise been directed in both directions. Research has found that learners sometimes lack the pre-requisite skills, such as planning and evaluation skills, needed for them to undertake proper inquiry-based learning (NRC, 1996). This lack of pre-requisite skills could be a result of inadequate teaching. The problem is particularly exacerbated by the nature of scientific inquiry itself, especially when it expects learners to work in the same way that scientists do (NRC, 1996). As such, it would not be easy for learners to attempt to follow similar routes used by scientists, since each route is dependent on prevailing contextual factors, which often vary.

2.3.3 Curriculum factor

The issue of restricted time during which the curriculum has to be completed, has also been reported as one of the key factors that influences the implementation of this approach. In most cases, teachers are under pressure from the authorities to complete the curriculum and produce excellent results (Ottevanger et al., 2007). Under such circumstances teachers are left with inadequate time to implement inquiry-based approaches, which also demands a lot of time.

The curriculum factor also includes Language of Learning and Teaching (LOLT). Inquiry-based approaches demand elaborate communication between the teacher and the learners, and among the learners themselves (Keys & Bryan, 2001). The inquiry-based approach also involves the implementation of instructions that are given to the learners. Both of these two cases present barriers to learners who are not conversant with the LOLT.

2.3.4 School factor

The administrative structure of a school regulates the teaching and learning processes within the school. The teachers' work, including the way they teach, the pace they teach at, and the type of assessment they have to follow are all determined by the administration of the school in the form of the school management team (SMT) (Edelson et al., 1999). Chan (2010) found in his Hong Kong study that in schools where administrative structures were open and progressive, more inquiry-based teaching and learning was used in the science classes, unlike the situation in more restrictive schools where the thrust was on adherence to protocol, leading to little or no inquiry.

Related to the administrative structure factor is the issue of school culture. Peterson and Deal (2002) define school culture as the background context reflecting the values, beliefs, norms, traditions, and rituals that build up chronologically as people in a school work together, consequently influencing the actions of the school population. School culture influences the motivational disposition of teachers, the way problems are solved, the way new ideas are implemented, and the way in which people interact and work together (Peterson & Deal, 2002). Although the school culture may not be written down, it however tends to covertly dictate expectations which every teacher has to meet, to the extent that in some cases, inquiry may not be an expectation and will be ignored (Peterson & Deal, 2002).

2.3.5 Resource factor

The lack of physical resources is one of the factors that affects the implementation of the inquiry-based approach in science teaching and learning (Anderson, 2002). Physical resources in this instance refers to the apparatuses and chemicals needed to carry out activities. In a study carried out by Musar (1993) under the auspices of the World Bank, the influence of physical resources on the teaching of science conducted in Zimbabwe, Sri Linka, Colombia and India indicated that the lack of physical resources was the main drawback to the implementation of inquiry-based activities (Musar, 1993). The author recommended that all governments involved in the study should emphasise the need for teachers to improvise physical material resources so as to enhance their teaching of the subject.

The issue of resources is also exacerbated by the teacher-pupil ratio. In research conducted by the Southern and Eastern Africa Consortium for Monitoring Educational Quality SACMEQ (2011) it was reported that the issue of the teacher-pupil ratio in South Africa has been found to be one of the problems that hinders the successful implementation of the inquiry-based approach in the teaching of science. The large class sizes were found to be difficult to manage and implementing the inquiry-based approach under these circumstances would become difficult given the approach's demand for closer teacher monitoring of the learners' progress (SACMEQ, 2011).

3. METHODOLOGY

The present study used a case study methodology. This research is located within the design-based paradigm. Figure 1 shows that this paradigm has four stages (Reeves, 2000):

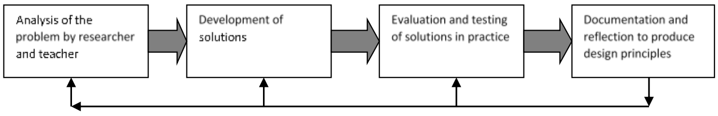

Figure 1: Design-based research stages followed in the study

(a) Analysis of the teachers' perceptions of inquiry and the problems they face.

(b) Development of solutions,

(c) Evaluation and testing of solutions in practice, and

(d) Documentation and reflection to produce design principles.

This paper will only focus on the first stage: the analysis of the teacher's perceptions of inquiry and the problems they face.

3.1. Data collection and analysis

In analysing the problem, unstructured interviews were held with each of the three teachers. The interview data were transcribed and later analysed using Saldana's approach (Saldana, 2009). This approach involves coding the data, and grouping related codes to form categories. The categories were subsequently grouped to form themes (Saldana, 2009). The themes are then discussed in the form of assertions.

3.2 The schools

3.2.1 Hozani High School

Hozani High School (pseudonym) has approximately 1 500 students. The school has fairly well-built structures that include some empty designated laboratories. The natural science teacher is stationed in one of the laboratories, and the learners come to him during their natural science periods. The designated laboratory does not have any apparatuses; the only resemblance of science teaching in this room is the few learner projects that hang on the walls. The average class size is 42 learners. The natural science teacher Mr Machonisa (pseudonym) is Zimbabwean and he has been teaching natural sciences since he immigrated to this country in 2007. He holds a Bachelor of Science and an education degree, specialising in chemistry and mathematics.

3.2.2 Philani High School

Philani High School (pseudonym), is located about 250m from Hozani High School. The school uses containers and other temporary structures as make-shift classrooms. There are no designated laboratories in comparison to the first school. The school has an enrolment of about 1 200 learners, the majority of whom come from nearby informal settlements. The classes have permanent bases, and it is the teachers who have to move to those classes to teach. There is insufficient furniture in the classrooms and some of the learners stand as the teacher teaches. The classroom was spacious enough for the class though. The teacher, called Ms Susan (pseudonym), is South African and has a teacher's diploma and an Advanced Certificate in Education (ACE). She has been working at the school since it started about seven years ago.

3.2.3 Metse High School

Metse High School (pseudonym) has approximately 1 400 learners. It is located roughly 10km from the other two schools. The school has very well built structures, although no rooms were designated as laboratories. Like at the second school, it is the teacher who has to go to the learners' classrooms. The average enrolment per class is 45 learners. The staffroom has an operating computer network, which seems to be underutilised. One prominent feature of this school is the lack of discipline. This is manifested through the number of learners who are seen loitering during lesson time. The teacher, a Zimbabwean man, Mr Ngoma, has a Bachelor of Education specialising in Physics. He has been teaching natural science since joining this school in 2009.

4. RESULTS AND DISCUSSION OF RESULTS

This section focuses on the results that we obtained from analysing the interview data that was collected. Assertions were generated indicating the teachers' perceptions of the inquiry-based approach and the problems that they faced when implementing it.

The following assertions were generated from the data.

Assertion 1: Schools do not have sufficient material resources to foster the implementation of inquiry-based approaches

During the interviews, each of the three teachers perceived the use of an inquiry-based approach to be effective in teaching science. However, despite this perception they indicated that the lack of resources was a serious drawback in the implementation of an inquiry-based approach in their teaching. This is evident in the following excerpt from Mr. Ngoma's responses during the interview:

> The inquiry-based approach is very important in as far as it helps learners understand the content, but however we face a lot of hurdles in implementing it. The schools are poor yet the curriculum keeps pressing with unrealisable demands relentlessly. We actually face a lot of problems with the shortage of resources in order to undertake investigations. Sometimes we just end up doing demonstrations.

Ms. Susan had the same view:

> This approach is very useful to the understanding and participation of our learners. The only problem is that it demands a lot of resources. The schools do not pay attention to our requests for resources. This makes the approach very difficult to implement.

This finding is similar to the findings of Anderson (2004) and Musar (1993) both of whom report that the shortage of resources impedes the implementation of the inquiry-based approach in schools world-wide.

Assertion 2: The use of improvised materials would enhance the implementation of the inquiry-based approach

All three teachers indicated that in their opinion the problem of resource shortages could only be alleviated through the use of improvised materials in their teaching. They were, however, not certain of the use of this approach in getting learners to do well in examinations. This is highlighted in the following excerpts from the interview responses of Mr. Ngoma and Mr. Machonisa. Mr. Ngoma said:

> Improvisation actually helps us to follow the inquiry-based approach in our teaching. We used to omit a lot of activities due to the shortage of the required materials, but now we can just do them with improvised materials. The only problem that I foresee is that our learners might not be able to apply the knowledge they gain through the improvised investigations, to answer the questions in the examinations that would be based on the use of conventional materials.

This sentiment is shared by Mr. Machonisa:

> Of course the use of improvised materials gives us relief when it comes to the undertaking of investigations, because we are no longer worried much about the financial implications. We can just get the materials from our environment to carry out investigations. Our problem however is the examinations. In my view the examinations should also ask questions that involve the use of improvised materials. In many cases, our learners won't be able to translate their knowledge based on improvised materials, to answer the exam's questioning them on the use of conventional materials. I see that as a big challenge. I don't know what can be done.

This finding is similar to that of Bhukuvhani et al. (2010) who argue that the use of improvisation improves learners' understanding of concepts that they would have found to be difficult.

Assertion 3: Learners lack the skills to engage in inquiry-based learning

During the interviews, the three teachers agreed that learners lacked the basic skills to undertake inquiry in their learning. They attributed this to the little exposure learners had to inquiry learning in the previous grades. Their view was that teaching at the lower grades generally disregarded the inquiry-based approach. As such, learners lacked the required skills at this level.

Ms. Susan stated the following:

> We try a lot to make the learners enjoy the benefits of inquiry-based learning. We nonetheless face a lot of problems with our learners. They greatly lack the inquiry skills to undertake investigations. It might be because of the learners' prior backgrounds in science. I think the parents' ignorance is a factor not to be ignored. In some cases, where we expect the parents to help the learners, it is possible that both the parents and the learners fail to understand the language.

This view is similar to that of Mr. Machonisa:

> You see our learners hardly understand the inquiry-based approach. When we sometimes put them in groups so that they can work, they tend to view this as if the teacher is being lazy. Sometimes they end up playing in the groups. As such, they do lack the skills to engage with inquiry learning. I doubt if they actually see its relevancy to their learning.

This finding is similar to that of the NRC (1996) that learners' lack of the pre-requisite skills to engage with the inquiry-based approach is one of the reasons behind the failure of this approach in the learning of science.

Assertion 4: The curriculum is exam-oriented

All three teachers indicated that one of the dilemmas that they faced in their desire to implement the inquiry-based approach in their teaching, was the curriculum. The general feeling that emerged was that the curriculum was too exam-oriented and that, ultimately, it was only the exam results that counted. The following excerpt from Mr. Machonisa's interview response indicates this:

> The personal desire to implement the inquiry-based approach is actually put off by the curriculum's insistence on the learners' mastering of the exam-linked content. This actually puts us under a lot of pressure from the school management team whose focus would be on the increasing of the pass rate. Anything else is inconsequential to them: learners must pass, and the school must be seen to be progressing. The worst part is that though the curriculum preaches about the need to implement the inquiry-based approach, on the contrary, the assessment at this level indicates very little of the inquiry-based approach, and as such, the approach is seen to be standing in the way of progress.

Ms. Susan corroborated Mr. Machonisa's views:

> We face the problem that the HOD is always checking that you are teaching the learners so that they may pass. Little regard is given to the need for the learners to understand the concepts. In one meeting the HOD went to the extent of telling us that if it means that the learners memorise and pass, then let it be, as long as they pass the examinations.

This is similar to the findings of Dudu and Vhurumuku (2012) that the curriculum and the schools give first priority to assessment at the expense of teaching approaches such as inquiry-based teaching and learning – despite the potential of the latter to develop better understanding on the part of learners. They concluded that curricula are exam-oriented, and the schools performance-oriented. Their suggestion was that the curricula should be revised to give teachers more space to practice open inquiry in their science instruction. It is arguable that in such cases learners are most likely to develop performance-oriented motivation (Bonney, Klemper, Zusho, Coppola & Pintrich, 2005).

Assertion 5: There is not enough time to complete the syllabus

All of the three teachers stated that one of the hindrances that they faced in the implementation of the inquiry-based approach was the unavailability of time. They mentioned that they faced a lot of problems when it came to completing the curriculum.

Mr. Ngoma states:

> You see the problem is, though we have a six-day cycle, the administration is reluctant to give us double periods. As such, carrying out investigations that need more than one period is a big challenge.

Mr. Machonisa had a similar view:

> Though the administration allows us one double period per cycle, we still face problems of time when it comes to the implementation of this approach. One such problem is that we have to prepare learners for circuit exams that come from the District. As such, the teaching is very much streamlined that you cannot manage to do anything that is not prescribed; otherwise the learners would fall behind with the curriculum, and will fail the circuit exams. In essence, the curricula prescriptions do not follow the inquiry-based approach. They just want the curriculum to be completed, and tasks done. This leaves us with neither time nor choice.

This finding concurs with that of Ottevanger et al. (2007) that the issue of time constraints is one of the major problems that teachers face in their implementation of the inquiry-based approach.

Assertion 6: Classes are too large

The teachers felt that class size posed a big challenge for the implementation of the inquiry-based approach. They argued that owing to class size, giving attention to each learners is hardly possible. They also linked the size of the class to the difficulties in managing classroom discipline. In this case, they might have felt that the classes were too large to control.

Mr. Ngoma said:

> One of the dilemmas that I face, is the size of the class. These classes are too big, and most of the learners need close monitoring. As such, even maintaining discipline becomes a problem because the learners fail to get your sufficient attention, and would consequently start all sorts of mischiefs in the class.

Ms. Susan stated:

> I can't necessarily complain about learner discipline; what I have realised however, is that I miss out a lot of teaching to a number of my learners due to the size of the class. At the end of most of my lessons I feel that I have not done sufficient justice to all of my learners. Sometimes some of them would still be asking questions when the period ends, and as such they might fail to understand some concepts.

This finding is similar to that of SACMEQ (2011) that the issue of the teacher-pupil ratio in South Africa has been found to be one of the problems that hinders the successful implementation of the inquiry-based approach in the teaching of science.

5. CONCLUSION

The study has indicated that the teachers interviewed held positive perceptions of the usefulness of the inquiry-based approach in letting their learners understand concepts in science. Teachers however felt that they faced a number of hindrances to achieve this. Among the problems that they face, was the lack of physical material resources that were needed to make inquiry-based teaching and learning a success. They also pointed out that learners' unfamiliarity with the inquiry-based approach was also a deterrent to the success of the approach in their teaching. The teachers also pointed out that there was a lack of apparatuses and chemicals which was another challenge to their effective teaching of science. The solution they envisioned here was using improvised, low-cost materials that would allow them to implement the inquiry-based approach.

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"ONE SIZE DOES NOT FIT ALL": CURRICULUM SUPPORT GROUPS AS STRUCTURED SUPPORT FOR TEACHERS' PROFESSIONAL DEVELOPMENT

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Abstract–The purpose of this paper is to show how the approach "one size fits all" cannot be successfully applied to teacher education in the South African education system. The opposite is in actual fact true– "one size does not fit all". To explain this concept the authors will not only contextualise the current "one size fits all" approach in continuous teacher education within the South African education system, but also suggest an alternative strategy based on curriculum support groups. The focus of this paper is on how teachers perceive the role of curriculum support groups in teacher development. This study followed a basic interpretive qualitative design. The theoretical framework which underpins this study is based on third generation Cultural Historical Activity Theory (CHAT), which provides a framework to understand learning from a social interaction perspective. Data was gathered from four curriculum support groups which consisted of Life Sciences teachers from 44 adjacent schools. Data was collected through focus group interviews, observations and needs analysis where teachers indicated their developmental needs. The findings suggest that curriculum support groups function as a community of practice which can address specific need expressed by teachers themselves for teacher development.

Keywords: curriculum support groups; teacher development; teacher education

1. INTRODUCTION

From the first democratic elections in South Africa in 1994, the education system has been subjected to constant change and restructuring (Mothata, 2000). Teachers of Life Sciences in particular have been subjected to ongoing curriculum change. The implementation of the National Curriculum Statement Grades 10–12 (Department of Basic Education, 2003) and the National Curriculum Statement Grades R-12 (Department of Basic Education, 2011) has meant constant changes within the subject of Life Sciences. Apart from these structural changes to the curriculum, Taylor and Vinjevold (2000) also draw attention to the meagre conceptual knowledge that some teachers have in the field of subjects that they are responsible for teaching in the South African context. These authors see this lack of knowledge as impacting negatively on the quality of teaching and learning activities within South African classrooms.

In the South African context the content knowledge of teachers in some situations is very poor (Kriek & Grayson, 2009; Ramnarain & Fortus, 2013). This leads to certain sections of the curriculum being omitted altogether from their teaching or taught very superficially. Teachers themselves are often unable to address the content with their learners as they do not understand the specific content. A study by Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) has also found that the poor subject knowledge of teachers hinders them from linking concepts to one another, which could enhance the learners' understanding of specific topics.

Curriculum change implies that teacher development should enable teachers to adapt to these required changes. Teacher development should focus on pedagogical content knowledge (PCK), a concept proposed by Shulman (1987). Schneider (2007) develops this concept further by arguing that PCK should include an understanding of the curriculum, specific approaches to the curriculum, strategies to enhance learners' thinking and the development of specific assessment strategies. Teachers must therefore have a sound understanding of the content of their particular subject and should be able to set and administer assessment tasks such as tests, exams and formal assessment activities.

Inadequate subject content knowledge impacts on the teachers' pedagogical content knowledge because these teachers are unable to change their methodology to address the needs of their learners. Inadequate subject content knowledge was already identified by Taylor and Vinjevold in 1999 as problematic and 15years later it is still a problem which hinders teaching in the South African context.

To address the lack of pedagogical content knowledge and changes within the curriculum, teachers should be provided with support structures, and carefully designed teacher development interventions. Teacher development in South Africa, however, often relies on single once-off workshops for all teachers (Bernstein, 2011), with the same concept being presented to everyone attending the workshop. These concepts vary and are usually selected from content knowledge, teaching methodology and skills development. All teachers are then subjected to the same workshop content at the same time. This was again evident in training initiatives for the implementation of the new curriculum.

A study by Mestry, Hendricks and Bisschoff (2009) emphasises the legacy of South Africa's racially divided past where teachers from the privileged cultural group received better training than others while cultural differences clearly existed. It is in this light that Rogan and Grayson (2003) developed the theory of curriculum implementation to serve as a guide for teachers, policy makers and organisations that provide training to teachers. This theory attempts to take the diversity of schools existing in a country like South Africa as well as the diverse competencies of the teachers into account. Little (1996) emphasises this diversity in her finding that the knowledge, experience and values of teachers differ. According to Rogan and Grayson (2003), the diversity exists in schools ranging from well-equipped, affluent schools to those with only the basic necessities and in the variety of knowledge and skills among South African teachers.

It is against this background that the role of curriculum support groups as a support structure for teacher development is suggested. In these groups the needs as voiced by the teachers can be discussed in smaller groups. This article focuses on the different teacher requirements established through needs analysis tools and the functioning of curriculum support groups as instruments to strengthen teacher support interventions through once-off workshops.

2. THEORETICAL FRAMEWORK

The theoretical framework used as a lens for this research is based on the third generation cultural historical activity theory (CHAT) as conceptualised by Engeström (1987). CHAT was selected as the theoretical framework as it explains learning from a social interaction and semiotic tool mediation perspective (Ogawa, Crain, Loomis & Ball, 2008).The theory of curriculum implementation as offered by Rogan and Grayson (2003) served as an intermediate theory supporting CHAT.

Rogan and Grayson (2003) point out that a lack of basic resources at schools can constrain the teachers and prevent them from functioning optimally, especially when the school cannot provide the basic resources required for the teaching of the subject. They also emphasise that teachers need to be well qualified and committed to ensure learner performance. The authors identified four capacity levels which can have an impact on successful curriculum implementation. This research however, limits itself to teacher and physical resources that impact on teaching in the classroom.

Regarding both physical resources and teacher factors in the successful delivery of the curriculum to learners, Rogan and Grayson found that not all schools in the South African context are equipped with similar physical resources. Resources in schools range from basic buildings in poor condition which consist of basic classrooms only to excellent buildings with one or more well-equipped laboratories and sufficient apparatus to enable practical work. Learning support material in schools also ranges from schools that use only textbooks to schools that have teaching and learning resources such as computers, models and well-equipped library resource centres. This inconsistency in physical resources and equipment demands teacher development which will be able to address the specific needs of the teacher as experienced in a specific context.

Because the qualifications of teachers in the South African context range from teachers who are under qualified for the position they are filling to extremely well-qualified teachers, teacher qualifications also play a role in the teaching quality in schools. Under qualified teachers are at a disadvantage as they not only lack content knowledge but also PCK skills, which impact on their teaching in the classroom. It is these differences which necessitate the call for a more specialised teacher development programme to address the inequalities which prevail in schools and teacher qualifications in the South African context.

According to the CHAT individuals can only understand themselves in relation to other individuals within a specific socio-cultural context. Development and learning are therefore not isolated events but more of an approach in the joint participation and the interconnectivity with other individuals in the process of knowledge construction. Individual learning then emerges from communication between individuals with the assistance of material and social mediators in a specific context (Fenwick, 2006). Within the activity theory, zones for development can be identified based on Vygotsky's zone of proximal development (ZPD). This does not form the final stage of development but acts as a process in development (Veresov, 2009). The ZPD represents the learning space in which an individual is located at a specific time. Within the ZPD, a teacher's individual development is the distance between the teacher's actual developmental level, where the individual can solve a specific problem without mediation, and the level of possible (potential) development, which refers to what a teacher can achieve through the mediation and scaffolding of a more competent peer. The ZPD signifies those functions that must still be established through scaffolding to reach the zone of *potential* development. In order to reach the ZPD, guidance is needed in collaboration with more knowledgeable peers. We share the view of Van Lier (2004) that in an expanded ZPD, scaffolding happens on four levels:

- Inner resources (resourcefulness, self-access)
- Interaction with less capable peers
- Assistance from more capable peers (scaffolding; mediation)
- Interaction with equal peers (if one member of a group undergoes developmental change, the other is also likely to do so)

Rogan and Grayson (2003) propose that, in line with Vygotsky's ZPD, the zone of feasible innovation (ZFI) can be identified. The ZFI should take place in manageable steps that take into account the diversity in the South African context. Support for teachers through training and development should take cognisance of the level at which the teacher currently operates when developmental strategies are planned. The type of support must be such that the individual teacher can either master the innovation at the level of the current zone or attempt innovation at a higher zone.

In the South African context the research of Cole and Engeström (1993) is also important. They identify an activity system operating where any learning takes place. They identify the elements of an activity system as comprising an object, a subject, instruments (artefacts), a community, and rules and division of labour. These elements form an integral part of one another. The activity system may be presented in a triangular form as is shown in Figure 1.

In this paper the "subject" refers to Life Sciences teachers in the Further Education and Training (FET) phase, with the "object" being teacher development, which addresses specific needs as identified by teachers. These needs range from subject content knowledge to teaching methodology and PCK development of teachers. The "instruments" refer to language as a cultural tool, semiotic tool mediation, resources and pedagogy, while "division of labour" refers to the interchanging role of teachers within this community. The "community" refers to the "curriculum support group" and comprises teachers, the group leader and the subject facilitator. Various rules compiled by the Gauteng Education Department govern the functioning of these groups, including formal meetings per year and language used for communication purposes.

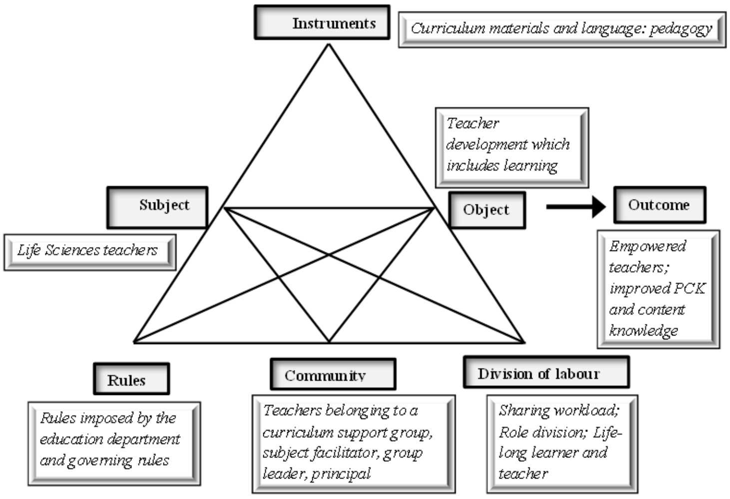

Figure 1: The different elements of the Cultural Historical Activity System in this research

Engeström (2008) expands the activity theory to indicate that there are multiple interconnected activity systems which partially share the same object. Activity systems are then part of a network of activity systems which in its totality comprises human society. Teachers who belong to the communities of curriculum support groups also belong to other communities, which include their community within a school, or they might teach more than one subject, therefore belonging to more than one community at a given time. Engeström (1987) points out that in any activity structure there are conflicts between individuals and the activity system itself. Inner conflicts express themselves as conflicts externally and influence other aspects of the activity system. There is therefore a duality within these tensions. Tension that is experienced by a member of the community can express itself to any constituent component of the activity system and can influence other or all components of the activity system.

These conflicts within the activity system can be the driving force for transformation within an activity system (Engeström & Sannino, 2010). Learning occurs when an initial idea is converted into a complex object. This then leads to the formation of theoretical concepts, which results in a changed form of practice. These contradictions become the driving forces for expansive learning, especially if a new object is identified during this process. By identifying new objects within the system there is movement within the zones of development.

3. CONTEXT OF THE RESEARCH

Taylor and Vinjevold (2000) propose that the knowledge foundations of South African teachers should be strengthened systematically through developmental learning. They indicate that the inadequate conceptual knowledge that some teachers have in the subject field that they are responsible for teaching in the South African context has a negative impact on the quality of teaching and learning.

Teachers should be able to use their subject knowledge in such a way that they can come up with new ideas in the teaching of the subject content (Darling-Hammond, 1998). They should also be able to use resources and other technology effectively in their classrooms. This means that teachers will be able to change their teaching methodology to suit the needs of their learners in the classroom. The teachers should be able to observe and understand alternative ways in which learners solve problems, and understand their own orientation in teaching, curriculum development and policies pertaining to their subject. They should then be willing to expand their knowledge by interacting with colleagues and transfer knowledge gained from textbooks and other resources into meaningful classroom practice.

3.1 Once-off workshops

In 2000, Kadar Asmal, the then Minister of Education in South Africa, specified that the knowledge base of teachers should be comprehensive in order for them to address learners' needs in their contextual environments. He therefore proposed an "Implementation Plan for Tirisano", which had as a priority the development of the professional quality of teachers in the country (Ministry of Education, 2000). The instrument to be used for this development was based on in-service training and once-off workshops on various topics. However, this approach did not succeed, mainly because in-service training based on a single workshop constituted an ineffective support structure for teachers wishing to implement change (Fullan & Stiegelbauer, 1991). Twenty years later, in a report for the Centre for Development and Enterprise (Bernstein, 2011), the same issue was reported on. Once-off workshops were still being used for training in South Africa, with information given to teachers in the expectation that they would passively receive and absorb the information (Nichols, 1997). Research indicated that teachers often perceived these once-off workshops as a waste of time as there was no follow-up to strengthen the information received (Thompson, Gregg & Niska, 2004).

The once-off workshop in the South African education system is also linked to the cascade model. Cascading implies that a single teacher (the lead teacher) attends the once-off workshop for development and reorientation of teachers in the implementation of curriculum changes. This teacher then conducts a similar once-off workshop for his fellow teachers at the school on the information received, but this carries a risk of diluting the effect of the training. Lead teachers often receive better training than those at the bottom of the cascade model (Coppard, 2004).

Thomson et al. (2004) argue that training is more effective when once-off workshops for teachers are reinforced with regular meetings, and the involvement of peer teachers tends to sustain any development. Teachers echoed this approach as more successful when they reported that they learn to a much greater extent from each other in small groups to plan, solve problems and test new ideas with their peers. In this way they will be continuous learners and will experience continuous support. Through their interactions they can then both receive advice from and give it to other teachers.

3.2 Development of curriculum support groups

In an attempt to supplement teacher development and reinforce training received at once-off workshops, curriculum support groups were formed in a particular district under the Gauteng Department of Education.

Support groups were already established in the Gauteng Department of Education in 2002, known as clusters at that stage, to ensure the implementation of assessment policy and the moderation of continuous assessment on a district level (Gauteng Department of Education, 2001).The expanded roles of clusters are discussed by Gryffenberg (n.d.) where clusters were used for curriculum implementation and teacher development.

It was, however, found that the functioning of the clusters declined to the level of moderation of portfolios only and that they therefore did not serve the intended purpose, namely the communication and cross-pollination of best practices to empower teachers. In 2009 the format of moderation was changed and the cluster groups disappeared. However, in one of the districts under the Gauteng Department of Education, it was decided to re-establish the "cluster" groups, but with a name change to transform the teachers' association of the term "cluster" with "moderation". The groups became known as "curriculum support groups", with the emphasis on teacher support and development.

3.3 Structure of the curriculum support groups

The members of a curriculum support group comprise the subject facilitator of the specific subject, a group leader and teachers from 10 neighbouring schools. Schools of the same geographical area with comparable contextual factors are grouped together. This research concentrated on the subject Life Sciences in a particular district under the Gauteng Department of Education. Grades 10, 11 and

12 teachers attend the same meetings of the curriculum support group, as some schools have only one teacher per subject and a different meeting for each grade would over burden these teachers.

4. METHODOLOGY

The research process followed for this paper was based on a basic interpretive design, namely to explore and interpret the perceptions of teachers. The study focuses on support to teachers within communities of practice. The researcher is employed as a subject facilitator in an Education District Office with comprehensive knowledge of the structures and context of the field of research. The researcher formed the main instrument for the collection of data. Multiple methods and focus group interviews, observation and needs analysis involving indications of developmental needs of the teachers were used.

The data gathering centred on four curriculum support groups. Initial selection included a total of 44 schools and the teachers responsible for the teaching of Life Sciences in Gr 10 – 12 were automatically included as members of the sample. Two of these groups consisted of teachers that teach in affluent schools. Schools are well equipped with laboratories, computer centres and well-stocked school libraries. Some teachers in these two groups also have higher degrees and are therefore well qualified. One group formed was located in the city centre. These schools have no or very basic equipment. Learners often do not have textbooks and the classes are usually overcrowded. No specialised classrooms, for instance laboratories, are available. Teachers have the basic qualifications for teaching. There is a high turnover of teachers within this group as a large number of schools tend to be independent schools where teachers receive a meagre salary. The fourth group was located in a previously disadvantaged community. Teachers have the basic teaching qualifications although there are a number of teachers within this group who have higher degrees. In these schools all learners have textbooks and schools are better equipped. A laboratory is often available although it is shared by more than one teacher and often by more than one subject. Some of these schools have libraries but they are often under-resourced.

Each curriculum support group consisted of teachers from 10 to 12 neighbouring schools. Teachers must be able to reach the meeting within a 30-minute drive from their schools. These meetings take place after school hours and one formal meeting is held per term. In some groups teachers tend to have informal meetings as well, which the subject advisor does not attend. Teachers teaching in Grades 10, 11 and 12 attend the same meeting.

The data collection methods employed in this research comprised focus group interviews, observation and analysis of needs for development compiled by the teachers. Observations were mainly unstructured and employed for enrichment of the data obtained through the interviews as outlined in the structure supported by Punch (2005). Ongoing observations on further development within the curriculum support groups were also made.

The transcripts of the focus group interviews were analysed and the data was organised into themes by coding as described by Neuman (2006). The analysis process of the activity system followed the example identified by Jonassen and Rohrer-Murphy (1999).

To ensure validity triangulation, verification by member checking process and long-term observation was used. Methodology triangulation implied the verification of initial interpretations of results by members to ensure the correct capturing of perspectives from the teachers. The research took place over a five-year period, wherein long-term observations were made during curriculum support group meetings. Reliability was established by addressing the same semi-structured questions in all four focus group interviews.

5. FINDINGS

The purpose of a curriculum support group as an activity system is to create a platform for teachers to form a subject-specific community that can act as a support system in which the enrichment of the subject knowledge of teachers and the development of PCK can take place. The ultimate aim is the improvements of the performance of the learners, in this case those taking Life Sciences.

This activity system comprise of different components. The community consisting of Life Sciences teachers from 10 adjacent schools, a curriculum support group leader and a subject facilitator. The principal also formed part of the community by allowing the teachers to attend the curriculum support groups. The subject selected for this research was secondary school teachers teaching Life Sciences in Gr 10 - 12. The instruments were the language used in the activity system and materials such as textbooks, policy documents and other artefacts. Rules that govern the system are imposed by the education department, but there are also rules governing the community. There is division of labour among the members within the activity system, which entails a task being shared among members for the benefit of all. Teachers can therefore share their workload. “Division of roles” refers to different roles that a teacher has to play. On the one hand, the teacher needs to develop their own PCK and thus play the part of a lifelong learner; on the other hand, the teacher must then be able to teach the new insights gained from the curriculum support groups to the learners in their own classroom.

The object of the activity system is teacher professional development, to reach the outcome of empowering teachers to enhance their PCK and in turn improve learner performance. For teacher development to be expanded and to become meaningful, different objectives must be established.

These objectives for the different meetings were expressed by teachers through the needs they identified for developmental purposes. The needs of teachers were identified with the implementation of the new curriculum. The new curriculum introduced new content topics such as evolution, a topic which did not form part of the previous curriculum. Teachers expressed uncertainties in teaching new topics as they indicated that they did not feel equipped to teach all new topics introduced into the curriculum.

Data analysis revealed that the different support groups identified different needs for their development. Needs identified by the city centre group and the previously disadvantaged community were mostly concerned with content. Content identified by these teachers, however, did not only include the new content introduced but also included content that was available in previous curriculums. This indicates needs identified by teachers are based on a more basic level. Teachers in this group are still grappling with content issues. All needs identified centred on teachers’ improving their own knowledge content base. As these schools are not well equipped, no needs for using digital equipment to enhance their lessons were identified. Content identified by the teachers from the two groups from the more affluent schools and who were better qualified were only based on the new content, although very few teachers identified this as a need. Needs identified centred on the use of computers in the classroom to enhance their teaching practices. More knowledgeable peers explained to the teachers how to develop PowerPoint presentations and use animation in the classroom. Teachers also identified as a need electronic two-way communication between teachers and learners for homework activities. Teachers identified support in expanded opportunities for their learners and development opportunities for themselves. They asked for knowledgeable outside agencies to share their expertise with them on topics such as electron microscopy, cancer research and indigenous knowledge systems.

Teachers identified aspects of development in PCK as they identified aspects of methodology which will support weaker learners in their classroom. They also expressed the need to be exposed to interesting and stimulating ways to present their lessons.

Teachers in these two groups identified a need to share tasks among themselves to develop a larger databank which can be shared among the schools. They also expressed the need know about best practices of teachers from other schools within their own support group. There is division of labour among the members within the activity system, which entails a task being shared among members for the benefit of all. In this way teachers can share their workload.

The object of the activity is teacher professional development, to reach the outcome of empowering teachers to enhance their PCK, and in turn improve learner performance. In order for teacher development to be expanded and to become meaningful, different objectives must be established.

Analysis of the focus group interviews indicated that the curriculum support groups created a platform for the teachers to learn from one another. These activities allowed for enrichment and included the sharing of information and the gaining of knowledge on subject content and teaching methodology. As mentioned previously the issues discussed differed in the different groups, as contextual factors and problems encountered by teachers differed. Teachers perceived a sense of development and empowerment as part of the support groups.

Teachers also established informal support structures amongst themselves. They gained encouragement and assistance from both their fellow teachers in the formal support group, as well as from the subject facilitator. In this process useful information and advice supporting them in their teaching activities were gained, especially in the light of the changes in the curriculum and new forms of assessment expected on a continuous basis in teaching.

6. DISCUSSION

Needs expressed by the teachers in the different groups call for more specialised teacher development in smaller groups which can be addressed by curriculum support groups. As these needs were identified after once-off workshops had already been implemented by the Department of Education, this indicates that teachers need ongoing support even after they attend a developmental workshop. The findings clearly indicate that teachers need specific support and needs identified by the department are not necessarily the same as those identified by the teachers themselves.

As the cascade model remains the norm in teacher development for the Gauteng Department of Education, curriculum support groups can act as a supportive structure for teacher development. Small groups (Thomson et al., 2004) of teachers can meet regularly to collaborate on curriculum issues (Darling-Hammond, 2003) on an ongoing basis (Hopkins, 1990). More knowledgeable teachers can share their content knowledge as well as methodology expertise with less experienced teachers, especially in terms of best practices.

Rogan and Grayson (2003) indicate that teachers in South Africa function on different levels because of historical differences in teacher training and as some schools are better equipped for teaching and learning than others. The support groups identified on the lower levels of the profile of implementation, based on the Vygotskian concept of zones of feasible development as outlined by (Rogan & Grayson, 2003), focus on subject content knowledge in their meetings. Groups on higher levels of the ZFI increased their focus to include PCK as well as creative ways of teaching certain aspects of Life Sciences. The content knowledge base of teachers on the lower levels of feasible development must first be built effectively before aspects such as PCK can be addressed.

As the groups comprised a smaller number of teachers within the curriculum support group, teachers could experience greater cohesion to express their needs and uncertainties within a group. More experienced teachers or the subject facilitator could address these needs immediately within the group, which could address misconceptions and ambiguities that prevail within the group.

Teachers in all four groups of the study indicated clearly that they had learned within the groups, which indicates that curriculum support groups can indeed form a supportive structure for teacher professional development. The support groups can then function as a vehicle to address the diversity that exists between South African teachers in various schools, as described by Rogan & Grayson (2003). As schools with the same contextual features are grouped together within the support group structures, specific needs of teachers from a similar context can be addressed. This also implies that the needs of schools with different contextual factors can be addressed in similar fashion as it meets the specifications as set out by Lieberman (2000).

Misconceptions and shortcomings within teachers' own content knowledge can be clarified in interaction with one another, while they acquire new skills and gain strategies for implementing alternative teaching approaches that can be used in the classroom. The learning taking place in the group is based on mediated action as specified by Vygotsky. Scaffolding activities can be mediated for teachers to reach their zone of *potential* development (Veresov, 2009).

In this research, CHAT has been used as a lens to focus on the dynamics within the activity system of the curriculum support groups. In this activity system, teachers support each other in their professional development. This system provides a social structure within which teachers can work towards identified common goals by using cultural tools, language and artefacts. Outside agencies can also provide support within this system to enhance the teachers' understanding of more specialised concepts.

Through the division of labour, the workload of teachers can decrease as they divide the tasks between themselves and then distribute the resultant resources to all the members of their community. A large knowledge and skills databank can be developed, which can be used in the classrooms of all members within a support group.

The members of the curriculum support group as a learning community consist of the subject facilitator, the group leader and the other teachers. During various meetings the subject facilitator, group leader or invited guests or teachers who form part of the learning community can act as mediators in the learning process. Learning then forms an interconnectivity between people, as Fenwick (2006) suggests.

Developmental zones are also identified in this research. Teachers on different levels of development tended to set different objectives for reaching the goal within their developmental process. As schools with different contextual features experienced different problems which needed to be addressed, the objectives to reach the goal within the groups differed from one another.

This study was based on a small sample size and on research conducted in a single subject, namely Life Sciences. Generalisations cannot therefore include the entire population of Life Sciences teachers in all educational settings. However, findings in this research can act as an example of a support system for addressing some of the problems that have been identified in the education system in South Africa. Curriculum support groups can address the problems mentioned above and identified in the contributions of Rollnick and Brodie to the report of the Centre for Development and Enterprise (Bernstein, 2011) and the research of Taylor and Vinjevold (1999; 2000).

7. RECOMMENDATION

To support once-off teacher development workshops, which are still the norm in South Africa, curriculum support groups can be established to address specific needs expressed by teachers in different contexts. These groups can provide specific assistance in subject content knowledge and PCK. The support groups can be extended to other subjects and to other provinces in the South African context, especially in the FET phase where subject-specific content is specialised.

8. CONCLUSION

As outlined in this paper, the authors found that the approach of "one size fit all" cannot successfully be applied to teacher training and development in South Africa. The opposite was proven to be the truth regarding the South African context, that "one size does not fit all". An alternative strategy based on curriculum support groups was suggested for the education and development of teachers in the South African education system. Professional development of teachers within these support groups can strengthen once-off workshops held by the Department of Education. Teachers are able to support one another on an ongoing basis in their own development and strengthen concepts and skills learned in workshops attended by them.

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TEACHERS' UNDERSTANDING AND RESPONSE TO CURRICULUM POLICY IMPLEMENTATION IN SCHOOLS

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Abstract–Many explanations on how best policies could be implemented in the different set-ups have been developed and piloted by different scholars with interest on policy implementation. However, implementing curriculum policies in schools has been very complex task for teachers than it is in the policy prescriptions. The realities of implementing policies as intended remain a complex task for teachers which always reflect an inherent tension between how teachers understand and respond to policies. Teachers are exposed to challenges where they have to receive, understand policy intensions and respond to policy that challenges their habitual patterns of teaching, schooling and that seem to threaten the conventional disciplinary curricular structures that comprised of fixed timetables, textbooks bound and little room for outdoor-activities with hands-on dominated activities. This paper reviews and extends the growing body of knowledge on policy implementation literature that applies cognitive frames to the study of policy implementation. This paper further seeks to understand policy implementation from a cognitive perspective whereby a key dimension of the implementation process is to develop an understanding on how teachers' experiences and practices influence the ways in which they understand and respond to the transformative and instructional policies that guide their teaching processes. Drawing on a data from semi-structured interviews and scheduled observations, the paper seeks to report on the findings of the study conducted on curriculum policy implementation in the South African context with reference to Environmental Education within Natural Science in grade 9. To develop a better understanding of what encourages and discourages teachers to respond to the policies, the paper further aims at shading some insights on what influences teachers' response to curriculum policy implementation.

Keywords: Curriculum policy, implementation, experiences, practices, cognitive frameworks

1. INTRODUCTION

This paper examines teachers' implementation of curriculum policy of Environmental Education within Natural Science in grade 9 in schools within the South African context. The paper intends to shed some light on what underlie teachers' understanding of and response to curriculum policy implementation and will further share insights on what influences teachers' response to curriculum policy implementation. It is also the intention of this paper to report on the findings of the study conducted on curriculum policy implementation in the South African context with reference to Environmental Education within Natural Science in grade 9.

This paper seeks to understand policy implementation from a cognitive perspective whereby a key dimension of the implementation process is to develop an understanding on how and why natural science teachers interpret and respond to the transformative and instructional policies that guide their teaching practices in ways they do. Although the implementation of environmental education has been introduced as a cross-curricula subject in the curriculum, there has been little attention paid on how teachers should implement this curriculum. This lack of attention on how teachers should implement curriculum innovation is not unusual; as Carless (2004:640) has noted, "how teachers implement changes in pedagogy is an important area which does not receive sufficient attention". Hence, the purpose of this paper is to further understand what encourages and discourages teachers to respond to the policies in those specific ways.

2. CONCEPTUAL FRAMEWORK

Environmental education, as an educational strategy, has emerged since the 1970s. The field has been supported by a body of literature, including numerous research studies, which has established theoretical frameworks for the learning and teaching of environmental education. In this field, the positivist, interpretivism and critical science currently guide the research; although acceptance of interpretivism is increasing within education, positivism remains the most dominant research paradigm for both education and environmental education (Mrazek (1999:96). The positivist perspective believes in empiricism, the idea that observation and measurement is the core of the scientific endeavour (Henning 2004:82-85).

I draw on theoretical and empirical literature from a cognitive perspective on the policy implementation process. Undertaking a comprehensive review of the literature on the implementation of educational policy was not mainly to develop an understanding on the interplay between policy and practice as most studies reported much on that. But the main aim is to explore in depth, a seldom-explored dimension of how teachers as implementing agents interpret and respond to the policy that challenges their habitual patterns of teaching regarding the implementation of environmental education as a cross-curricula component. As mentioned earlier on, that a number of studies within this area of policy implementation were basically on teachers' response towards the policy. This paper differs from those other studies in that it is basically about the teachers' understanding of the policy that challenges the teachers' habitual patterns of teaching and involving two subjects which are Environmental Education and Natural Sciences taught simultaneously.

The notion of power to decide what should be done or ignored in the process of policy implementation play a significant role, as currently understood in policy analysis (Spillane, Reiser & Reimers 2002:387-512). The cognitive dimension demonstrates how this power to decide acquires content based on the interplay between the policies that attempt to direct practices and the ways in which that direction is constructed by local implementers. The cognitive framework has, therefore, been selected among the other perspectives for its ability to explain better the implementing agents' understanding of the implementation process of the policy. This ties well with this paper because the aim of the study is to develop an understanding of teachers' interpretation of the transformative policy. The cognitive perspective takes into account basic information about abstract ideas, the influence of motivation and effects, and the ways that social context and social interaction affect sense making. As such this perspective was helpful in considering issues like where teachers find themselves operating, and the kind of people available for their support and for social interaction in developing an understanding of what encourages and discourages them to make sense and respond to the curriculum policy in the ways they do.

Scholars have increasingly applied a cognitive framework in studying the policy process (Surel 2000:495-512). Cognitive frames have also been used in studies of policy implementation in education by Cohen & Weiss 1993, Spillane 2000 and Kember 2000, public policy by Weiss 1990 and Argyris & Schon 1978, political science and sociology and social psychology by Whitty 2002. Within these areas scholars have investigated how various dimensions of the sense making process influence the implementation process. However, as already mentioned that the rationale or the purpose of this paper is different from the other policy implementation studies, a cognitive framework has been applied with the aim of developing an understanding on how and why do natural science teachers interpret the policy and respond to it in the ways they do regarding the implementation of Environmental Education within the Natural Science subject. By illuminating the interpretive or sense making dimension of the implementation process, the cognitive framework is designed to underscore the need to take account of and to unpack teachers' understanding of and about policy. Moving beyond this, the cognitive framework help in articulating how teachers construct their understanding of the policy message, construct and interpretation of their own practice as a result.

A cognitive perspective maintains that behavioural changes have a fundamental cognitive component. From this perspective, a policy message about changing implementing agents' behaviour is not a given case that resides in the policy signal (e.g. legislation, brochures, regulations etc.) (Spillane et al. 2002:387-512). Policy messages are not inert static ideas that are transmitted unaltered into local needs and conditions. Conceptualizing the problem of implementation in this way focuses attention on how teachers as implementing agents construct the meaning of a policy message and their own practices and how they view their teaching practices (Spillane et al 2002:387-512). According to Coburn (2001:2), sense making is not a simple decoding of the policy message in general, but the process of interpretation that draws on the individual's rich knowledge base of understandings, beliefs and attitudes. Differences in interpretation or in acting on understandings are necessary aspect of the human understanding process. To explore the influences on implementation, there should be an exploration of the mechanisms by which teachers understand the policy and attempt to connect their understanding of the policy with classroom practice.

Spillane (1998:35-36), maintains that the local implementation of policy involve adaptation, a process in which policy is redefined to fit local conditions and in which local conditions are sometimes adapted to fit policy. He contends that educators interpret policies in light of their local visions; policies that fit local visions are implemented and those that do not are opposed. According to Spillane (1998:35-36), scholarship drawing on developments in the cognitive sciences, suggest that local educators' interpretation of policy is more complex. Interpreting policy involves teachers constructing ideas about instruction and the ideas they construct are influenced by not only the policy but also their beliefs, knowledge and dispositions.

Therefore, to better understand how teachers interpret the policy and to explore the mechanisms that influence their' interpretations of the policy and also to understand what forms the basis of encouragement or discouragement towards their response and sense making of the policy, the study adopted a cognitive framework developed by Spillane et al. (2002:387-512). The cognitive framework, in a broad sense, takes into account basic information processing as well as the complexities and influences involved in the processing of information about abstract ideas, the influence of motivation and effects and the ways that social context and social interaction affect sense-making (Spillane et al 2002:387-512). This paper on teachers' understanding and response to curriculum policy of Environmental Education within Natural Science is located within this perspective in order to illuminate the complexities and influences involved in process of sense making, the influence of motivation and also the ways that social context and social interaction affect their interpretation of the policy. This framework involves three stages in characterizing sense making in the implementation process. These are individual cognition, situated cognition and policy signals.

Stage 1: Individual cognition

Within this component an exploration of teachers as individual sense maker takes place, paying attention to how teachers as individual notice and interpret stimuli and how prior knowledge, belief and experiences influence the construction of new understanding. Cognitive science scholarship suggests that what individuals' make of new information has much to do with their prior knowledge, expertise, values, beliefs and experiences. This component of cognitive framework involves applying these mechanisms of comprehension and sense making to an analysis of teachers' interpretation of the policy and complex practices of learning and teaching (Spillane et al. 2002:387-512). Zerubavel (2000: 214) contends that individuals do not make sense of their world in vacuum, but their sense making is situated in a particular "thought of communities" including but not limited to professions, nations, political parties, religions and organizations. With this in mind, it is important to understand that teacher response and interpretation of the policy is influenced by number of things of which they are part. These issues also govern them, for instance the system of school organization. The impact of the education system upon teachers' decision-making in relation to teaching and learning also influence their understanding of the policy (Clatcherty 1993:23-40).

Stage 2: Situated cognition

After exploring teachers as individual sense maker paying attention to those issues that influence their interpretation of the policy in the process and also how their prior knowledge, beliefs and experiences influence their policy understanding, then the attention move to their situational context. It is also imperative to understand the situation or context of the implementing agents. This is because not only prior knowledge, belief and experiences affect their understanding of the new information but also the context or situation within which the implementing agents found themselves operating (Spillane et al 2002:387-512). It is therefore become crucial to consider how aspects of the situation influence what implementing agents notice and how they interpret what they notice. In this case I will then also focus on the situational context of teachers and try to develop an understanding on issues like social interaction, social contact, motivational influence and how these influence their understanding of the policy. According to Whitty (2002:139) teachers' beliefs, prior knowledge and experiences might have a positive influence towards the new information (policy) but the situational context might be the one that affects their sense making of the policy, especially in schools where bureaucratic and authoritarian practices still prevail. Within such condition, implementing agents turn to ignore or alter that new information to suit their interest or agenda (McLaughlin 1991:171-178).

Stage 3: The policy signals

Although policy might be treated as one element of the situation, it comprises special significance in considering issues of implementation. The design challenge involves representing idea about instructions in ways that enable the implementing agent's understanding of the policy. Inherent in this task is a critical tension between the abstract and the concrete in communicating the idea (Spillane et al. 2002:387-512). Therefore, is becomes crucial to ensure a smooth flow of communication between policymakers and policy implementers. Such communication between the two will help in solving problems that are the results of the gap between the policymakers' decisions and what local implementers could afford. Policy implementers usually ignore the policy that seems to be difficult for them to understand and implement only the one that seems to be easier or fit their interests and agenda. Firestone (1989:151-164) in his support to the claim mentioned that implementing agents fail to notice, intentionally ignore or selectively attend to policies that are inconsistent with their own interests and agenda. Policies that fit implementers' agendas are more likely to be implemented and those that do not are more likely to be either opposed or modified so that they do fit (Spillane et al. 2002:387-512). The implementing agents' ability to ignore policy is in great part a function of the nature of that work, which involves unpredictable human relations not reducible to programmatic routine or easily regulates and monitored from above. At this stage teachers need support from both the principal and the department. This is the crucial stage whereby if enough teachers support in the form of teacher development, training, networking etc. is not sufficiently provided, policy implementation is deemed to be affected and result in failure.

3. RESEARCH METHODOLOGY

To achieve the purpose of this paper a qualitative approach was used, the study was conducted within the qualitative research design because the intention was to collect descriptive data or people spoken or written words and this is one major distinguishing characteristic of qualitative and quantitative research paradigms (McMillan & Schumacher 1997: 48) A case study research design was applied and an investigation focused on grade 9 Natural Science teachers of the General Education and Training band of the sampled schools in the Capricorn District of Limpopo Department of Education.

Semi-structured interviews and observations as data collection techniques or instruments were used because they allowed the researcher to learn more about the central phenomenon of interest, teachers' views, interpretation and also how they respond to the curriculum policy.

Verbatim transcriptions of the recordings were done and subsequently themes were identified and categorized accordingly. Data collection and analysis were done continuously in order to build a coherent interpretation of the data. According to De Vos, Strydom, Fouche & Delport (2011) in Taole (2013:41), continuous research analysis gives the researcher the opportunity to check the data as well as identify the emerging trends and the ideas that need to be followed up.

4. RESULTS AND DISCUSSION

There are themes which emerged from study on curriculum policy implementation of Environmental Education within Natural Sciences in schools, the following themes will be discussed namely, the process of construction and interpretation of teachers' own practice, the influence of motivation and effects on teachers' understanding of the curriculum policy, teachers' situational and social interaction during the process of curriculum policy implementation, teachers' ability to interpret and understand policy messages, relationships between policy makers and policy implementers with regards to policy implementation and teacher – support for a successful curriculum policy implementation.

4.1 The process of construction and teachers' interpretation of their own practices

The gap that exists between policy makers' construction of and policy implementers' interpretation of curriculum policy impacts on the successful implementation of a curriculum policy. Teachers as policy implementers are expected to implement the curriculum policy as intended by the policy makers. As such, teachers struggle to interpret the curriculum policy accordingly because they are not the ones who formulated the policy. Teachers highlighted that although they are expected to teach Environmental Education concepts within the Natural Science subject, their interpretation of how they should teach the concepts is not the same and also that their local environments does not offer equal opportunities to enhance such learning. As such they end up teaching these concepts in ways that best suit them. Within the conventional perspectives decision makers use their knowledge to identify the action that implementers should take. In order words, those who make or decide what should be in the policy are seldom those responsible for the policy implementation. Within the same perspective appears to exist the separation of knowledge and action that is problematic conceptually as well as in practice (Reimer et al. (1997:71). In most situation people who generate knowledge are not the same people who formulate the policy, who are not the same people who carry out the policy implementation. In such a situation it becomes difficult to and almost impossible for implementers to have the same knowledge and understanding as policy makers for them to implement the policy as intended.

4.2 The influence of motivation and effects on teachers' understanding of the curriculum policy

There are different factors that influence teachers' interpretation and response to curriculum policy implementation. Motivation amongst other factors, play a key role in influencing how and why teachers respond to the curriculum policy implementation. The findings of the study on teachers' understanding of and response to curriculum policy implementation revealed that teachers implement what is possible the way they have been doing because it has been working for them and yielded the expected results and they only embrace the policy intensions for administration purposes.

Teachers indicated that because of poor support they receive from curriculum advisors with regard to curriculum policy implementation they have continued to teach the same way they have been teaching in the past. Spillane et al. (2002:387-512) mentioned that implementation agents fail to notice, intentionally ignore or selectively attend to policies that are inconsistent with their own interests and agendas for many different reasons. They are likely to implement policies that fit their agendas and those that do not are more likely to be either opposed or modified to fit to their interests. Some explanations that are influential to policy implementation focus on the inability of principals to formulate clear policy outcomes or to adequately supervise the implementation process. The inability of state or federal policymakers to craft clear and agents and agencies can undermine local policy implementation (Spillane et al. 2002: 387-512).

In one of the schools visited, the Natural Science grade 9 teacher is a principal of that school; the teacher indicated that it is very difficult for him because he does not often meet with the curriculum advisors to share the challenges with. When teachers meet with the curriculum advisors, they do not always have answers to all the challenges teachers raise and that affect the principals' role of supervising the implementation process at schools. Hope (2002:40-44), in his support to the claim, contends that with the implementation of educational policy there are some considerations for principals to ponder because successful policy implementation also is dependent on principals' ability to influence teacher and staff behaviours. The findings of the study conducted by the department has however revealed that curriculum advisors do not have sufficient knowledge and skills to offer teachers the support they require (Department of Education 2009: 154). It is therefore necessary for the curriculum advisors to be properly trained for them to be in better position to train teachers for the success of curriculum policy implementation in schools. Adding on that, the behaviours that a policy targets for change and the magnitude of the changes sought affect the like hood of successful implementation. This is because policies that press for incremental changes are more likely to endanger positive response and the implementation process.

They further mentioned that some conventional account allow for implementation problems resulting from implementing agents' understanding or misunderstanding. Implementation as a minimum includes shared understanding among participants concerning the implied presuppositions, values and assumptions that underlies the whole process. If participants understand these then they have a basis for rejecting, accepting or modifying the policy in terms of their own school, community and class situation.

4.3 Teachers' situational and social interaction during the process of curriculum policy implementation

It is also imperative to understand the situation or context of the implementing agents. This is because not only prior knowledge, belief and experiences affect their understanding of the new information but also the context or situation within which the implementing agents found themselves operating (Spillane et al 2002:387-512). It therefore becomes crucial to consider how aspects of the situation influence what implementing agents notice and how they interpret what they notice. The process of understanding and interpreting the curriculum policy implementation of Environmental Education within Natural Sciences happens to teachers individually as they are found in different school set-ups. Different teachers during the interviews shared their experiences on how their interpretation of the curriculum policy implementation has been influenced by poor social contacts. Teachers are found to be working in isolation and not able to share their frustrations that come with the policy implementation process with others. In a school where the principal is the Natural Science teacher in grade 9, the teacher interpret and respond to the policy in a way that meet the needs of the school. Unlike with other schools, his is located in deep rural village and the school is not well resourced, the school does not have enough classroom, classes are overcrowded, no staff-room or the principal's office. This lack of resources was evident during the classroom observations and also how that influences the way the teacher teaches in the classroom. In most cases the teacher will also make use of the local language to explain some of the concepts for learners to understand what the topic is all about. The teacher also indicated that the policy intensions regarding curriculum policy implementation are not possible to his school environment because of the school's and learners' needs which leaves no space for practical implementation of such.

4.4 Teachers' inability to interpret and understand policy messages

Issues affecting the implementation of policy vary from one school, organization or institution to another. Similar findings have been revealed as aspects that influence the implementation of educational policy and such have an impact on the results. Hope (2002:40-44) as he puts it, "transforming educational policy into practice, regardless of the level from which it emanates is not an easy task". There can be many obstacles to implementing policy including implementers' indifference or apathy towards the policy, lack of resources, insufficient time for implementation and disagreement about how to achieve results.

Spillane (1998:33 - 43) goes on to say the factors influential to policy adaptation process include individual and institutional agenda, community attitudes, material resources and time. Local educators interpret policies in light of their local vision; policies that fit local visions are endorsed, while those that do not fit are opposed or modified so they do fit. The top-down organizational system is found to have influence on the policy. Morris et al. (2003:71 -84) contends that within centralized organizations, there are often problems with the transmission of policy intent from the most senior level through the mid-level managers to the point of delivery. It has been mentioned earlier on that the inability of principals to formulate clear policy outcomes or to adequately supervise the implementation process is due to poor interpretation of the curriculum policy which sacrifice its successful implementation. Teachers mentioned that at times they find it very difficult to follow what the curriculum policy expect them to do due to their inability to interpret and understand the policy messages. Teachers feel they were not afforded enough time to understand the curriculum policy messages before implementation, also the resources that they have at their disposure affect the successful implementation of the curriculum policy. Teachers pointed out that they do not have sufficient human resource support to depend on for the successful curriculum policy implementation of Environmental Education within Natural Sciences and that makes it very difficult to meet the policy intensions and teachers end up implementing what is possible.

4.5 Relationships between policy makers and policy implementers with regards to policy implementation

The communication of policy is often overlooked yet important dimension of policy implementation. Such policy communication can be in many forms, it can be written in legislation, it can come in the form of a memorandum from the state or district officials; it can be expressed individually from district personnel to principals and from principals to teachers; or it can be communicated in a group setting such a workshop. It therefore remains very crucial that the policy is well communicated equally to the stakeholders involved and such communication should respect the knowledge and situational expertise of the individuals or policy implementers. That process should also consider that enough opportunities are given to policy implementers to engage in dialogue and interpret the policy with their colleagues in order to develop shared understandings of what they are being asked to implement. Without such opportunities, teachers will continue to implement what is possible and ignore what seem to challenge them based on their experiences and beliefs. Policy implementers usually ignore the policy that seems to be difficult for them to understand and implement only the one that seems to be easier or fit their interests and agenda.

For a successful curriculum policy implementation communication remains crucial and it should provide time and resources for policy implementers to better understand and embrace it. In communicating a policy, the policy makers should assist policy implementers to understand the integration of the policy message within the local context and their own experiences while still serving as mechanisms by which local knowledge is communicated to district or state. It should therefore be noted that without time and resources to engage in discussions and communicating the content of policy in a meaningful and credible manner, it remains unlikely that current educational policy will be as effective as it could be. As raised by one teacher that the fact that they work in isolation affects how they interpret and respond to the same policy. The teacher indicated at that school there are two teachers offering Natural Science in grade 9 and both implementing Environmental Education within the same subject but each teacher respond to the curriculum policy implementation differently, in order words each teaches the way it best suits his or her learners. The way in which they interpret and respond to the curriculum policy implementation depends on how they interpret the policy. Inadequate or lack of communication among the agents' and agencies results in misunderstanding of the policy that affects its implementation.

4.6 Teacher – support for a successful curriculum policy implementation.

The objective of teacher support training and development is to capacitate teachers in the correct way of implementing curriculum policy in order to achieve quality education. According to Brynard and De Coning (2006) in Brynard & Netshikhophani (2011:60 – 72), capacity includes the intangible attributes of leadership, motivation, commitment, willingness, courage and endurance that are needed to transform theory into practice.

Teachers' frustrations with the curriculum policy implementation of Environmental Education within Natural Science subject are the results of poor or lack of teacher support in the form of training and development. Teachers indicated that although the department does provide them with support, such support is very limited to 2- 3 days and at most does not respond to their needs. They mentioned that they have not been trained on how to implement environmental education as a cross curricula subject but they are expected to teach the environmental themes within natural sciences. Mostly, teachers indicated that they are implementing CAPS without proper training on the policy implementation. Teachers felt that they were supposed to have been trained properly on the implementation of the policy and curriculum advisors should ensure that practical applications of the new knowledge should be provided for. As already indicated earlier on, that curriculum advisors are not well equipped to assist teachers with all challenges they come across. Hence it remains necessary for them to be properly trained in order to be in better position to assist and support teachers for the success of curriculum policy implementation in schools. Teachers felt that there should be a balance between the prior knowledge and new information when changes are introduced. Teachers responses discussed above indicate a feeling of inadequacy on their part to handle new information and therefore they feel that they need more training. Training remains the most viable option for informing teachers of the developments in the curriculum. According to Jacobs, Vakalisa & Gawe (2011:186), curriculum implementers need to be prepared for and supported in the successful execution of their task. They further add that it would be unfair to expect teachers to implement a written curriculum successfully if they had not been properly prepared to do so.

5. CONCLUSION

This paper examined teachers' understanding of and response to curriculum policy implementation of Environmental Education within Natural Science subject in schools. The paper shared some lights on how and why teachers respond to the curriculum policy implementation in school, also factors influencing teachers' curriculum policy implementation were discussed. Teachers, school managers or curriculum support staff members play a crucial role in this matter. In some schools, principals are perceived by their teachers as unenthusiastic about environmental learning. They are reluctant to participate in environmental initiatives that support the implementation of environmental education policy in the curriculum. As a result of poor support from the principals, teachers are bound to respond to the curriculum policy in ways different to the interpretation of the policy. Some of the principals' knowledge on environmental learning is still very shallow.

Another issue that remain a challenge with teachers responding to the curriculum policy rest also on the fact that if given an opportunity to attend workshops on the implementation of a curriculum policy, there remain uncertainty with the principals. In some cases, as alluded to by Maila (2003:51-53) the principals feel that teachers withhold some of the information while reporting back to the other staff. At the moment, this is one of the burning issues that teachers are experiencing; teachers attending teacher-training workshops find it difficult to explain as according to the trainer who facilitated the entire teacher-training to other teachers.

Most teachers' response to and their interpretation of the new curriculum policy as individuals, is influenced mostly by the old school of thoughts where teachers use to work individually, what and how they teach in the classroom was their own responsibility.

In order for teachers to interpret and implement curriculum policy in schools as intended, it is necessary that they are involved and informed about the curriculum change processes well in advance. The objectives of the curriculum policy change should be made clear and ensure that they are all in the similar understanding of the processes involved and are clear of their roles. That should also consider teachers' beliefs, knowledge and experiences about classroom practices as the main implementers of curriculum policy in schools because policy implementers make sense of new information based on their existing knowledge.

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THE AWARENESS, PERCEPTIONS AND EXPERIENCES OF GRADE 9 NATURAL SCIENCES TEACHERS OF THE ROLE OF LEARNERS' SOCIO-CULTURAL BACKGROUND IN TEACHING AND LEARNING

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Abstract–This study investigated teachers' knowledge about Grade 9 learners' socio-cultural background, and their perceptions and experiences of the role it plays in the teaching and learning of Natural Sciences in township schools. The study adopted a qualitative case study design and involved three Natural Sciences teachers from three different township schools as participants. Data was collected through interviews, observations and analysis of documents. Open-coding was employed for the analysis of data. Findings indicated that teachers were knowledgeable about their learners' socio-cultural and economic background. In addition, teachers used analogies, artefacts and examples which incorporated learners' beliefs and cultural practices. In relation to practical work, teachers sometimes used materials which were readily available to the learners and this endeavour provided pedagogical opportunities for the learners to interact with the materials in a meaningful and authentic manner. As such, teachers' pedagogical content knowledge could be fundamentally transformed through insights into learners' cultural practices and beliefs.

Keywords: Pedagogical Content Knowledge; Socio-Cultural Background; Cultural Practices

1.1 INTRODUCTION

This study explores the role of knowledge about learners' socio-cultural background in the pedagogical content knowledge (PCK) of three Grade 9 Natural Sciences (NS) teachers in three different township schools. The study investigates teachers' knowledge about Grade 9 learners' socio-cultural background, their experiences, and perceptions of the role this kind of knowledge plays in the teaching and learning processes of some NS topics. The study asserts that knowledge of learners' socio-cultural background is a key requirement for meaningful presentation of science to Grade 9 township learners. Contextual knowledge enables science teachers to engage in multiple pedagogical and instructional strategies which make science more relevant.

1.2 BACKGROUND

Research has shown that South African learners perform comparatively lower than learners from other countries in international science assessments such as Trends in International Mathematics and Science Study (TIMSS) (Naidoo, 2004; Reddy, 2004). Local matric results in the sciences have not improved over the years in both quantity and quality. For instance, Physical Science results for learners who achieved 40% level and above were 28.3% in 2008, 20.6% in 2009, 29.7% in 2010, 33.8% in 2011 and 39.1% in 2012 (Department of Basic Education, 2013). Learners from disadvantaged communities have performed far worse than learners from advantaged communities. A science classroom in South Africa comprises learners from diverse backgrounds. Therefore, one area which calls for attention is whether science teachers are knowledgeable about their teaching contexts, and whether they use appropriate strategies to make science more relevant and meaningful. This is pertinent because educational reform in South Africa envisions schooling where all learners have the opportunity to succeed (Frempong, Reddy & Kanjee, 2011). However, this requires a system and schools that are inclusive and supportive of all learners' success.

1.3 CONCEPTUAL AND THEORETICAL FRAMEWORK

This study employs social constructivism, whose proponents propose that learners bring to the science classroom established world-views that were formed during previous years of experience and learning. Learning is viewed as a social process that takes place in interaction with the social and cultural environment (Loyens, 2007; Stears, 2009); thus, the social contexts in which learning occurs and which learners bring to the learning environment are crucial (Gredler, 1997). It has been proved that learners' existing knowledge is both the necessary building blocks and impediments of learning (Duit, 1996). Learners hold tenaciously to their world-views and much effort is required to challenge, revise and restructure their world-views during science teaching. The learners' socio-cultural background is therefore important as it is a major component of social constructivism (Wandersee, Mintzes & Novak, 1994).

Research has shown that the way learners respond to and benefit from school and other educational settings and experiences is influenced by their socio-cultural environments (Mclnerney, 2010). Barnett and Hodson (2001) assert that scientific ideas and their relationship to ideas learners already have present different opportunities for the design of teaching and learning activities by science teachers as they encounter learners from diverse backgrounds (Lemmer, Meier & Van Wyk, 2006).

Cultural diversity is not adequately represented in teaching and learning materials, resulting in quality instruction favouring dominant cultural groups (Trowbridge, Bybee & Powell, 2004). In cases where the science curriculum or textbooks attempt to address diversity, Keane (2008) notes that usually they comprise a traditional "bit that fits" into the existing syllabus. Given such a situation, one would agree with Tharp (1989), who laments the absence of an education programme which reflects learner cultural differences.

In view of the above, Bouillon and Gomez (2001) label schools as being in communities but often not of communities. Consequently, science pedagogy is disconnected from the everyday life of the community, so learners do not realise the utility value of the skills acquired in school. In most cases, a cultural clash occurs within the science classroom when the culture of science conflicts with that of the learner, thereby forcing the learners to abandon or marginalise their life-world concepts and reconstruct new (scientific) ways of conceptualising in their place (Jegede & Aikenhead, 1999). In situations where science teachers do not understand the cultural norms that guide their learners' thinking and behaviour, they misinterpret or miss entirely what learners understand (Gay, 2000). Learners are then fast-tracked from one topic to another.

Science teachers should therefore build up knowledge about what to teach (subject matter knowledge), how to teach (pedagogical knowledge), and under what circumstances their teaching occur**s** (contextual knowledge). Trowbridge et al. (2004) insist that this is possible if science teachers employ culturally relevant teaching approaches that engage diverse learners through the use of cultural artefacts, examples, analogies and community resources familiar to learners. Incorporating learners' socio-cultural background validates learners' various experiences (de Beer, 2010) and has a positive influence on engagement in the classroom community and on attitude towards science in general (Jegede & Aikenhead, 1999). Some learners may suffer psychologically when culturally insensitive teaching approaches and culturally unfriendly teaching materials and examples are used in the science classroom (Jegede & Aikenhead, 1999) and this adversely affects their success.

The current study attempts to explore how teachers' understand their township teaching environment and how they use this knowledge as part of PCK to provide appropriate learning experiences for their learners. Teachers' knowledge is conceptualised as three domains which are dynamically transformed to PCK.

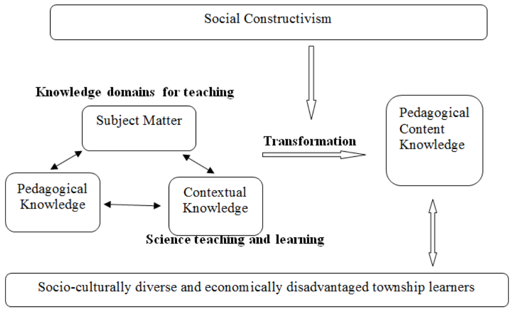

Figure 1: The interrelationships in the knowledge domains envisioned by the study Adapted from Suh (2005)

The study therefore seeks to determine NS teachers' knowledge of diverse learners' social, religious, economic and cultural experiences and how this influences the design and implementation of teaching strategies that make science more relevant and meaningful.

1.4 RESEARCH QUESTIONS

1. What do Grade 9 Natural Sciences teachers know about learners' socio-cultural practices and beliefs in relation to teaching topics in Natural Sciences?

2. How do the teachers incorporate learners' socio-cultural experiences, practices and beliefs in the teaching of topics in Natural Sciences?

3. How do teachers perceive the role of learners' socio-cultural background in the teaching of Natural Sciences?

1.5 METHODOLOGY

1.5.1 Research design

The study employs a qualitative case study research design to allow an in-depth exploration of classroom practices, using multiple forms of data collection (Creswell, 2005). Using Patton's (2002) notion of purposeful sampling, three Grade 9 Natural Sciences teachers from three different township schools were selected.

1.5.2 Data collection

Data collection involved pre-lesson interviews using a structured interview schedule to identify teachers' knowledge of learners' socio-cultural background. This was meant to determine how the teachers' PCK is framed before actual teaching takes place. Using the Reformed Teaching Protocol (RTOP), five lessons were observed to determine the role of teachers' knowledge of the learners' socio-cultural background. Post-lesson interviews probed the teachers' thinking and understanding in relationship to their knowledge domains and pedagogy. Additional information was obtained through analysis of documents related to the teaching and learning process.

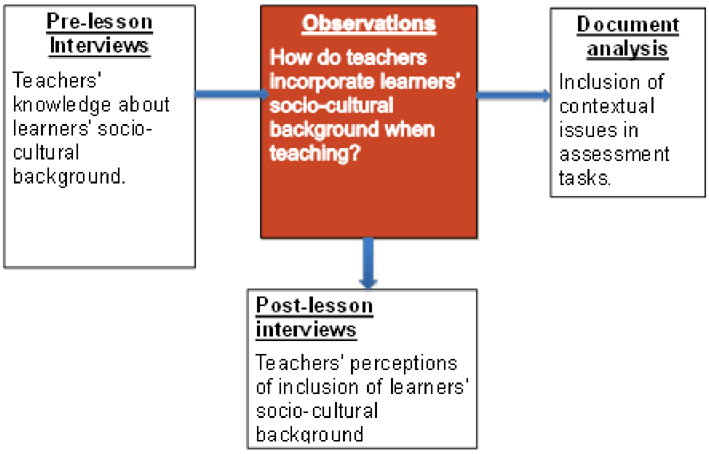

Figure 2: Summary of the research design

1.5.3 Data analysis

Data was analysed using the constant comparative method, which is closely associated with Grounded Theory (Merriam, 1998). Open, axial and selective coding (Strauss & Corbin, 1990) ensured rigour in the analysis. This process allowed themes and patterns to emerge from the multiple sources of evidence, in this way forming categories (Saldana, 2009). These themes were first identified separately for each participant, and then collectively identified when the three cases were compared. Figure 3 provides an example of how the coding was done.

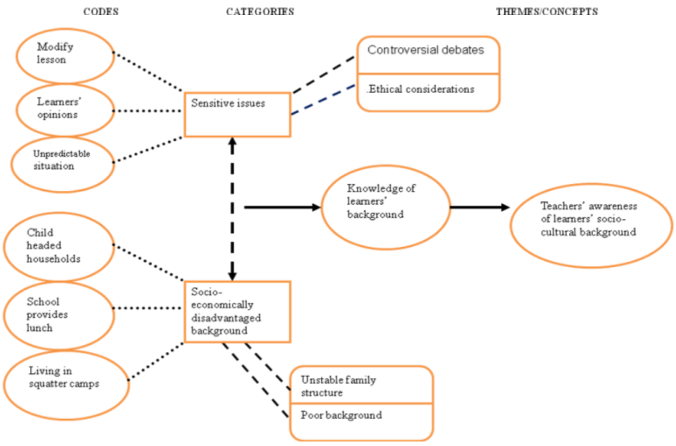

Figure 3: Framework for data analysis Adapted from Saldana (2009)

1.6 FINDINGS AND DISCUSSION

Data is presented in three main themes which are: 1.Teachers' awareness of learners' socio-cultural background; 2. Teachers' experiences in incorporating learners' socio-cultural background when teaching; and 3. Teachers' perceptions of the role of learners' socio-cultural background in the teaching and learning of Natural Sciences in township schools.

1.6.1 Teachers' awareness of learners' socio-cultural background

1.6.1.1 Learners' socio-economic background

The three participants, Thuli, Paul and Chauke indicated that the majority of their learners came from socio-economically disadvantaged backgrounds with unstable family structures. Some learners came from child-headed households or lived with one parent or grandparents because either one or both parents were deceased. One participant stated that the majority of the learners were sheltered by a local church orphanage home because they had either been displaced from their homes due to loss of parents or they were attending court sessions as victims of abuse. Some lived in informal settlements where there were no basic facilities such as roads, water and electricity. In the three schools, only a few learners came from well-provided for homes with both parents, which Thuli and Chauke said were distinguished by being "more presentable" than others. Paul had a different experience:

> You can't even tell that some learners come from squatter camps because the parents try their best to make sure they have proper uniforms.

He pointed out that he got to know about some learners' poor background when the learners came late and spoke about the long distances walked from the informal settlements. According to Paul, the majority of learners from poor backgrounds perform better than learners from advantaged backgrounds. Thuli also talked of illiterate parents who continuously request her to inform them of their children's performance so that they can offer support. They regard their children's education as gateway out of poverty.

1.6.1.2 Relationships in class

Learners are conscious of their inadequacy in terms of economic status. Thuli indicated that when she requests learners to check information on the internet, some learners feel uncomfortable about taking out their "cheap phones". However, because learners have sympathy for each other, the few who have better cell phones are willing to share. The concept of *Ubuntu* enables learners to share with and empathise with each other. The learners showed that they practise communalism at home; which was reproduced in the science classroom.

Participants were uncomfortable with dealing with certain topics owing to their knowledge of the learners' socio-economic background. For example, Thuli had a dilemma about how to deal with the topic of foetal alcohol syndrome, which her learners discussed under the subject Reproduction. The task required learners to discuss the questions:

> Some pregnant teenage girls abuse alcohol so that they get a higher grant from the government, is it fair?

and

> Is it only impoverished communities which are affected by this problem?

In Thuli's words:

> This is a touchy issue because some of their parents or siblings are actually alcoholics, so as a teacher you don't know how far to go with the discussion and where to draw the line.

She stated that some learners do not participate in such a discussion. One can presume that such apathy in class discussions could either be because the learners are deeply hurt by the realisation that ethically what their sisters are doing is wrong or they feel their family situation is exposed in public. Such learners may harbour the same sentiments as the teenagers in the question and would not tolerate any criticism.

The study found that teachers make an effort to help less privileged learners so that they catch up with the rest of the class. For instance Chauke, who is also an IT coordinator in the school, provides additional information to learners with no access to the internet at home for their assignments and projects. Thuli and Paul give more time to their learners to do assignments and projects as they share the few computers at the schools after hours. Participants empathised with learners who are less privileged.

1.6.1.3 Language

The participants reported that the Department of Education (DoE) designated the three schools according to particular African languages which are taught in those schools: School 1 – IsiXhosa, Isipedi and IsiSotho; School 2 – IsiZulu, IsiXhosa and IsiSotho; and School 3 – Setswana, Sesotho and IsiZulu. Though Thuli is Sipedi, Paul IsiZulu and Chauke Tsonga, they have learnt to speak their learners' languages over the years. In one school, learners of the same ethnic group were placed in the same class and this makes it easier to code switch for the purposes of explaining a science concept. As Chauke points out:

> Code switching helps me in explaining using their languages since most of them do not understand English.

The three participants acknowledged facing challenges with code switching when some scientific terms are not readily available in the vernacular. Examples mentioned included processes such as melting and smelting which can mean the same word “ukhuncibilika” in Zulu and Xhosa and words such as “define” and “explain” where one word “chaza” is used to mean both. In such situations, the participants indicated that they resorted to exemplification to bring out the meaning. This shows the inadequacy of vernacular languages in science teaching. To explain this problem Chauke stated:

> I remember last year, despite discussing in class that the purpose of reproduction is to make sure the species does not become extinct, some learners were adamant that it’s meant to grow their surnames, meaning having more members of the family.

In this participant’s view, learners are unresponsive to his teaching but an analysis of the learners’ answers reveals a language problem. These learners had difficulty in expressing scientific terms but they had understood the concept. It is important to note that if the teacher had clearly explained to learners the similarities between what the learners believed to be the purpose and the scientific reason, then they might have adopted the scientific explanation of the importance of reproduction. Teachers should conceptualise learners’ experiences and reasoning and then use them to explain the science concepts positively.

1.6.1.4 Learners’ traditional beliefs and practices

All participants acknowledged the diverse backgrounds of their learners. Participants encountered challenges when some cultural practices such as initiation arise during lessons on circumcision. It took the participants a great deal of time to convince learners that medical circumcision was as good as traditional circumcision. To quote Paul:

> For them it’s more of an initiation into manhood than anything else.

Learners who received medical circumcision were viewed as having cheated. Learners treasure their cultural practices and any deviation from the “norm” is inappropriate. This reveals a sense of belonging and identity on the part of learners. Participants indicated that once they detect such sensitive issues they incorporated learners’ feelings to avoid cultural clashes.

Superstition plays an important role in learners’ world-views. The participants pointed out that the learners bring many superstitions to class which makes it very difficult to relate to science. For example, issues about lightning arise when discussing electrostatic force. Chauke explained:

> A learner narrated a strange event that happened in his home in the rural area when there was a clear sky that day and lightning struck their cows and all disappeared. He said later a man was found herding the cows by the river.

The participants said they were hesitant to query what learners bring to the science class which could either mean that they have the same belief systems as their learners or they do not know how best to tackle these issues in class. Here are some of their responses:

> Paul: I don’t want to be caught in the cross fire (laughing).
> Chauke: It’s a challenge; these things may be happening between neighbours.

The participants indicated that the learners find such issues interesting. Learners would relate ways in which they protected themselves from being struck by lightning which range from placing a tyre on the chimney to covering mirrors to prevent lightning from bouncing to them when it strikes as they believed that lightning is caused by evil people. Learners tried to explain scientifically how the tyre protects them. The participants indicated that learners were quick to point out that a car is never struck by lightning because tyres offer this same protection and could therefore similarly safeguard learners’ houses.

When discussing how she dealt with lightning issues in the classroom, Thuli said she first asked learners to discuss the positions or locations of objects, places or people who have been struck by lightning. She would explain the concept of electrostatic force and explore the different cases where learners have experienced electrostatic force. For example, the click sounds and light produced when one removes one's clothes at night. At the end she revisits the learners' prior experiences.

Incorporating learners' socio-cultural practices and beliefs makes the teacher modify strategies, explore different ways of explaining, design experiments and improvise in order to enhance learners' understanding. Teaching is contextualised and done specifically for a group of learners. Teachers should always be "on their toes" to prepare suitable strategies and activities which engage learners fully in learning. Participants explored learners' experiences before dismissing them. They made a fervent attempt to use scientific concepts or explanations that relate to learners. Participants acknowledged that it is not always easy to proffer scientific explanations in line with the learners' background or experiences. The participants' PCK was expressed before teaching during interviews.

1.6.2 Teachers' experiences

1.6.2.1 Cultural beliefs and practices in science teaching

One participant asked learners to explore the importance of circumcision. Different answers were given by learners ranging from traditional and religious to medical. Some learners singled out circumcision as a sign of a boy achieving manhood and his introduction to adulthood. Learners failed to separate circumcision from the traditional process of initiation. While other learners mentioned the Jewish cultural importance of circumcision as an agreement between God and Abraham entered at adulthood, others pointed out issues of hygiene and reducing the risk of contracting STIs and HIV/AIDS.

The participant provided learners with a newspaper article entitled, "Boys die in the mountains during initiation" for discussion. Learners were vocal in defending their cultural practices despite what the article stated. Because some learners were already incensed by the exposure of their cultural beliefs and practices, remarks such as, "*Ufana nabafazi*", meaning "you are like women" were uttered by one learner referring to those who advocated medical circumcision.

However, the same could not be said about learners in another participant's class where the learners showed no enthusiasm for the topic. The participant explained that it was "uncultural" for the learners to speak about the initiation process. This could be true for learners from that particular cultural group but not for every learner. The participant did not provide a stimulating activity linked to the learners' background as it was noted that the incorporation of learners' socio-cultural background in the teaching of NS always stimulated lively debates in most of the lessons observed in the other participants' classes.

These observations revealed that learners were not ashamed to talk openly about their cultural beliefs and practices. Learners showed that they were tolerant of each other's contributions on their cultural practices and beliefs, as they identified with the practices at home. At times discussions became intense and the teacher would ask questions that would aim at getting learners to view issues in a different way or appreciate the other person's point of view.

Knowledge of the learners' background enabled the participants to structure work and activities around issues that addressed learners' everyday experiences. As a result, all learners were included during the teaching and learning process.

In a lesson on fertility, learners were asked to discuss the following: In some countries some women are paid to donate eggs that scientists can use in their studies, is it a good thing?

The learners' responses touched on issues of ethics, beliefs and scientific culture. Learners felt that these women may end up barren as the practice would offend the ancestors; a traditional belief. One boy said, "*amaeggs azopela*", meaning "all eggs will be used", to which Thuli responded by referring him to the answer to a question she had asked before which showed calculations of the number of eggs a 30-year-old woman could produce every month for 10 years. Through probing questions on how scientists can carry out research on reproductive diseases if women do not donate the eggs, learners understood the reasons. To show how convinced he was, one learner pointed out that these women should not be paid as it should be an act of charity.

Thuli tried to employ strategies that took into consideration the learners' feelings by allowing learners to critically reflect and evaluate their own ideas and decisions. The presentation touched on issues about learners' ethics, beliefs and scientific culture. This helped the participant to provide a balanced response to the learners' questions and arguments. Learners' views encouraged the participant to explore issues which were not in her original plan. The participant therefore demonstrated her PCK when she modified her teaching strategies in order to explore and address issues arising from the learners' contributions.

1.6.2.2 Integration of topics from different grades

Because Chauke is also a Grade 8 NS teacher, he managed to link a topic covered in Grade 8 with the topic on gaseous exchange in Grade 9. He referred learners to a diagram which illustrated the relationship between photosynthesis and respiration in plants. It was at this point that Chauke made reference to the taboos related to certain forests or specific plants which was discussed as a traditional way of managing conservation. He concluded by asking learners to reflect on the objective of these traditional beliefs in conservation as the respiratory process could not happen without the plants.

1.6.2.3 Practical work

During practical work, Thuli designed activities to suit her group of learners and used resources readily available in their homes. For example, in an activity that required learners to use gelatine, wool and needles, which are all items available at home. Learners could manipulate the materials easily because of their familiarity with them. The learners were not disadvantaged by the lack of these materials at home; instead they used seeds, buttons. They used these items to make models of animal cells, which are shown in Figure 4.

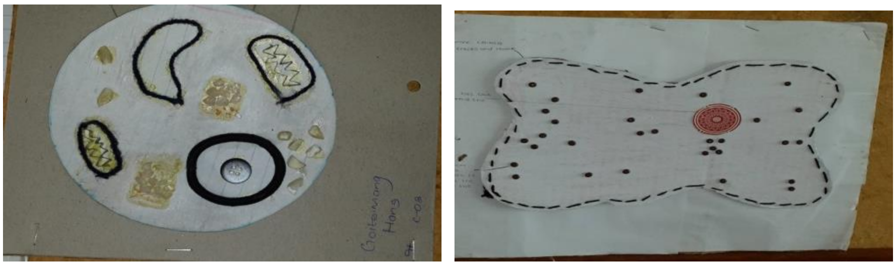

Figure 4: Models of animal cells

1.6.2.4 Use of analogies

One participant used an analogy to explain the movement of oxygenated and deoxygenated blood in humans.

> Chauke: You see we have roads, streets and paths where we walk and drive our cars, the same applies in the circulatory system, the veins and arteries are the roads and streets. We have roads where cars move in one direction and the others move in another direction. The same applies to de-oxygenated and oxygenated blood which moves in different blood vessels.

The learners showed that they now understood the process better. Certain concepts are too abstract for learners to conceptualise, so using examples or analogies familiar to them makes learners understand these concepts. It should be noted that the analogy helps learners when the sole purpose is to demonstrate the direction of the flow of blood and the need for blood vessels. It also demonstrates that as blood circulates it carries different things in the same way cars, buses and motorcycles move along the same road. However, learners may end up thinking that oxygenated and deoxygenated blood carries the same substances in the same way that roads generally carry the same vehicles. Learners may also think that blood movement stops at certain points in the vessels as cars do at traffic lights. Nothing is said about the need for a pumping mechanism that makes the movement continuous, in this case the role of the heart in the circulation system.

In another lesson, the same participant used another analogy to demonstrate how blood oxygen is replenished in the lungs and carbon dioxide is breathed out. He referred to deoxygenated blood as containing "dirt" that needs to be cleaned in the laundry – which in the body are the lungs. He said:

> You see when your clothes are dirty, you take them to the laundry for cleaning and then you take them back and wear them. In the same way, when blood is dirty, it is taken to the lungs for cleaning and carbon dioxide is removed and oxygen taken in.

In this particular case, it was important to specify to the learner that the only dirt removed by the lungs is carbon dioxide as the other "dirt" is removed by other body organs in different systems. This was discussed with the participant in a post-lesson interview. It would have been interesting to see learners' responses to questions on the topic to establish whether they managed to separate the concepts from the analogy

1.6.2.5 Language and assessment

In one lesson, a participant decided to test his learners and I decided to observe the process and also analyse the test items. Question 3 was of great interest. Learners were required to provide labels for the parts numbered 1 to 5 on a micrograph of an animal cell. Some learners raised their hands to ask, one learner in her home language, whether they were meant to draw the cell. The teacher explained the same question in English and then asked them to read the instructions carefully. He again repeated the question in Sesotho the language of all learners in that class. He then inquired what the other learners wanted to ask and they indicated that they had the same question. It can be deduced that the learners did not realise the importance of reading instructions carefully before attempting to answer. Another reason could be that these learners did not understand the question due to their poor understanding of the English language which is the medium of testing. This is unlike the teaching and learning process where the teacher can explain the concepts in the vernacular language where possible. In a test the teacher cannot go through question by question translating them into the learners' home language. It is a challenge for teachers and learners as there is no room for any other language. This may result in poor performance as, in terms of language, there is a difference between what happens in class and in testing. It can therefore be concluded that code switching cannot help learners during tests or examinations. One of the participants pointed out that to avoid such situations, she makes it a point that her learners always try and answer questions in English during the lesson.

1.6.2.6 Classroom management

When teachers establish a good relationship with their learners and identify with the learners' socio-cultural background, they can freely communicate with their learners on sensitive issues without offending the learners. Teachers may use a belief system in managing learner behaviour in science classes. For instance Thuli said,

> I always refer them to the initiation process where they are taught to be a man in the community. So I would ask them, is that how a man behaves and immediately they change.

In another incident a learner came to class in his traditional clothing, claiming he had a calling from the ancestors to be a traditional healer *sangoma*. The participant and other learners related very well to him, so when he became problematic, she asked,

> What do your ancestors say? Is it alright for you to behave in this way?

Thuli pointed out that the boy was not offended, instead he corrected his behaviour. However the learners' cultural beliefs and practices posed challenges to the other two participants who viewed it as a problem. Here is what they said about learners who undergo traditional initiation:

> Paul: When they come back, they misunderstand their initiation because they have been told that they are now grown up men, they not only look at you as the teacher but as a grown man like them, so they expect you to give them some respect and treat them like equals.
>
> Chauke: These boys become "big headed"; they think they are now men because that's what they are taught. It is a challenge in class and outside as well because these learners are convinced they cannot be treated like young children in class so they command a lot of respect and recognition, even in the manner in which I should talk to them.

From such incidents it is clear that learners are not ashamed to practise their beliefs at school. Learners were tolerant of each other's cultural practices and beliefs because they may identify with the traditional practice at home. It would therefore be inappropriate for science teachers to pretend such practices do not exist.

1.6.3 Teachers' perceptions of the role of learners' socio-cultural background

1.6.3.1 Teacher's reflection of own teaching

The participants acknowledged that the incorporation of learners' socio-cultural background in the teaching and learning process motivated learners, as evidenced by improved learner classroom participation. They acknowledged that their teaching helped some learners understand, made them dismiss, or make sense of their previously held ideas whereas others did not change. However, they also pointed out that many misconceptions arise from the learners' world-views and it takes a great deal of time for the participants to establish correct scientific concepts. One participant said:

> It is not always easy for the teacher to come up with scientific explanations of learners' cultural practices and beliefs.

The participant indicated that after teaching scientific concepts, she makes a review of the learners' previous knowledge to see whether she could detect any change in their understanding. The participant expressed frustration as she reflected on her teaching and its value, particularly when learners did not apply skills learnt. Young teachers like Thuli find themselves in difficult situations where they need to exercise roles beyond just their teaching job when dealing with their learners' experiences. An example Thuli cited was when one of her Grade 9 learners fell pregnant and she did not know how best to help that child during class discussions that involved reproduction.

The participants admitted that incorporation of learners' prior knowledge, experiences and beliefs helps a lot in situations where learners share. They also appreciated the community role in building up scientific knowledge by encouraging learners to ask questions of the adults at home. However, participants also complained of extra work in planning, consultations with the community, dealing with emerging unplanned issues, and time consuming class discussions.

1.7 DISCUSSION OF FINDINGS

By incorporating learners' socio-cultural background in the teaching of NS, teachers utilised the strengths that learners brought to the science classroom, which included their everyday experiences, beliefs and cultural practices and their rich indigenous knowledge systems. This is in line with de Beer's assertion (2010) that the content of science is not the only informant of teaching but also the lives of learners in their communities or homes.

Meaningful scientific skills and knowledge is acquired when attention is given to concept development, knowledge construction and their application in context of the teaching and learning of science. Ezeife (2003) insists that the integration of indigenous knowledge such as folklore, myths, legends and taboos in science and mathematics education, will help address current issues of low enrolment and academic performance of students from indigenous cultures. This explains why the teachers in this study experienced more participation in their science classes. The learners were identifying with the kind of scientific knowledge taught in class.

In this study, teachers used both English and the learners' home languages to explain scientific concepts. This is crucial as the exclusive use of foreign language for science instruction could be detrimental to the acquisition of scientific concepts among indigenous communities, such as townships, and may lead to learner disaffection and disengagement from school (Asabere-Ameyaw & Ayelsoma, 2012). Contemporary African societies have developed into a hybrid cultural society which is a product of coexistence between indigenous and modern factors (Nsamenang, 2003).

Therefore, in as much as teachers' are incorporating learners' socio-cultural background they should be cautious that no learners are excluded.

1.8 CONCLUSION

This study found that the teachers were aware of the learners' socio-cultural background. When they incorporated it into the teaching of science, learners were generally motivated. However, it was also found that the teachers' needed to plan their lessons thoroughly beforehand. Teachers needed to be prepared to modify their lessons anytime because of the contributions made by learners in the classroom. It can, therefore, be concluded that as an additional key benefit, the PCK of teachers could be fundamentally transformed by having insights into learners' cultural practices and beliefs.

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THE INTERACTIVE EFFECT OF OUTDOOR ACTIVITIES AND SCHOOL LOCATION ON SENIOR SECONDARY STUDENTS' ENVIRONMENTAL PROBLEM SOLVING SKILLS IN BIOLOGY

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Abstract–This study examined the effects of outdoor activities and school location on students' environmental problem solving skills in Biology. 240 students were selected from four purposively-sampled secondary schools in Oyo State, Nigeria. A pre-test, post-test control group, quasi experimental design was adopted. Four instruments were used: Students' Test of Environmental Problem Solving Skills, Instructional Guide for teaching with outdoor activities, Conventional Method and Evaluation Worksheet for assessing the teachers. Three hypotheses were tested at 0.05 level of significance. Findings showed a significant main effect of outdoor activities on students' environmental problem solving skills [$F(1,231)=33.215$ $P<.05$] , significant main effect of school location on students' environmental problem solving skills [$F(1,231)=36.230$ $P<.05$]and significant interaction effect of treatment and school location on students' environmental problem solving skills [$F(1,231)=3.771$ $P=0.05$]. It is recommended that outdoor activities should be included in the secondary school biology curriculum to bring about effective teaching of environmental education and consequently, acquisition of problem solving skills.

Keywords: Outdoor activities, Environmental Problem Solving Skills (EPBS), Environmental Education, school location.

INTRODUCTION

This section consists of the background to the study, statement of the problem and significance of the study.

Background to the study

From the agrarian period up to the industrial and now the revolutionary periods, man's attention on the environment in order to harness the resources for survival and sustenance/development has increased tremendously. In fact, life would not exist without the environment. Unfortunately, this same environment on which man depends solely for life is being depleted day to day and despite the awareness that is being propagated towards sustaining the environment, the attitude of man has not really been positive towards the environment. The interaction with the environment, coupled with man's nonchalant attitude to the environment, has resulted in the deteriorating state of the environment (Ogunbiyi, 2007). Human activities such as crude oil exploration, emission of dangerous gases from mining operations, fumes from exhaust pipes of automobiles and industrial machines, the exploitation of forest for economic tree and animals, as well as the exploitation of the rivers for fishes, and various forms of soil erosion, all have negative influence which contribute to environmental degradation (Ajitoni,2005).

The interaction of man and his environment has resulted in the imbalance within the ecosystem. This imbalance is manifested in various environmental problems like air pollution, water pollution and land pollution, oil spillage, gas flaring, desertification, flooding, soil erosion, bush burning and indiscriminate waste disposal (Ogunbiyi, 2007).

According to Ogunbiyi (2007), the Nigerian environment continues to face series of environmental problems which can be attributed to various factors, prominent among which are: low level of awareness about the consequences of our actions on the environment, our poverty level and the adoption of non-sustainable modes of development. This has called for radical solutions such as the need for conservation, preservation, environmental awareness, environmental knowledge, environmental attitude and environmental skills for sustenance of the present environment.

Environmentalists, educators and scientists have advocated a shift from technical and scientific solution to behavioural modification through environmental education (EE). So far, efforts geared towards sustaining the environment have included enactment and enforcement of laws and awareness through activities such as environmental sanitation. In fact, all the countries of the world are also affected by the rate of depletion of the environment which called for a Climate Change Conference in Copenhagen in December 2009 during which ways of addressing the problems were deliberated upon. Earlier, there has been a call to the need for sustaining the environment by bodies/organisations such as UNESCO, UNAIDS, WORLD BANK, etc which brought about the introduction of environmental concepts such as pollution, conservation, natural resources, family planning, ecology, health, etc into the school curriculum.

In response to the need for Environmental Education in our formal education system towards the creation of an environmentally literate citizenry, curriculum development efforts in the form of infusion into the existing curriculum has been made (Olagunju, 1998) and is still going on in several other disciplines (Ogunleye, 2002). Efforts at improving Environmental Education learning strategies such as the use of full and quasi participatory learning (Ajitoni, 2005); use of video drama by Aremu and John (2005) and outdoor educational activities in primary schools by Olatundun (2008) have also been made.

Globally, the use of outdoor and indoor activities has been identified as activities that sensitize learners towards environmental issues, by addressing the affective domain, and hopefully will lead to enhanced interest and more positive attitudes towards the environment. Such activities can be conveyed using both verbal and non-verbal strategies in problem solving approach (UNESCO-UNEP, 1990; Olagunju, 2005). Despite all the efforts being made, it has been observed that students' still exhibit negative environmental attitude. An example, as cited by Ogunleye (2002), is the survey study conducted by Mansaray and Ajiboye (1993) to investigate the Nigerian students' prevailing knowledge, attitude and practices in relation to environmental issues in social studies. They reported that students exhibited poor knowledge, negative attitude and harmful practices towards a healthy environment. This is also evident in observations of how students litter the environment with ice cream nylons, papers, pure water nylon, sweet wraps etc.

The formal school or education system constitutes the fundamental and universal criterion needed to achieve this worthwhile or desired behavioural change or awareness. EE requires a 'student-initiative education' in the sense that it is fundamentally problem oriented. The inadequate environmental ethics, ignorance and inadequate environmental awareness, knowledge and skills in pupils and students in particular, can only be removed through such education (Ogueri, 2004).There is therefore the need for a methodology that will make the students utilize the knowledge acquired from the educational system in sustaining the environment. The need of the hour is to have environmentally conscious citizens who are concerned about saving the environment from disasters. It might happen only when people are knowledgeable about their environment and associated problems; are aware of the solutions to these problems and are motivated to work for that (Ahove, 2001). This naturally means that an increase in knowledge portrayed in the right way can bring about a change in attitude and behaviour of the public. The more we learn the better we realize the worth of our environment.

It appears that if there is a change in approach from the usual practice of verbal instructions from textbooks to a method where the students are allowed to learn by direct contact with nature, there might be an improvement in academic performance of students in Biology (Edet & Inyang, 2008). Biology instructions ought to be carried out in a manner that students develop the higher cognitive ability (Nwachukwu & Nwosu, 2007). Secondary school students are usually receptive and strongly motivated. They are also capable of assimilating an environmental education that is: (i) value-oriented (ii) community-oriented, and (iii) concerned with human well-being (Ahove, 2001).

School location which is the area or place where the school is situated tells a lot about the availability of resources, the facilities such as laboratory and other equipment, the social environment existing there and many more. School location is classified as rural - (indigenous/traditional communities in Ibadan) and urban – (well developed and planned residential areas in Ibadan metropolis). This in effect may eventually determine the level of knowledge acquisition and skill acquisition by the learners. However, the specific problem of teaching science in urban and rural environments and whether urban subjects perform significantly better than their rural counterparts when specific strategies are used have not been adequately investigated (Akubuilo, 2004).

The need for knowledge acquisition, attitudinal change and achievement of problem solving skills among secondary school students, especially towards the environment and environmental problems, thus forms the basis of this study.

Purpose of the study

The broad objectives of this research work are to:

1. identify if there will be any change in the environmental knowledge of secondary school students after their exposure to outdoor educational activities:
2. find out if there will be any change in the environmental problem solving skills of secondary school students after their exposure to outdoor educational activities; and
3. find out if the location of students' school will have any influence on their environmental knowledge and problem solving skills after exposure to outdoor educational activities

Statement of the problem

Teaching science for utility is one of the goals of science education. A situation where students who are exposed to years of science instruction are still unable to tackle simple problems in their environments is highly undesirable and this occurs because such students have not grasped the vision of science application purposes (Ige, 2003). The problem this study seeks to address, therefore, is to investigate the effect of outdoor activities on secondary school students' environmental knowledge and problem solving skills. It is to reveal how outdoor activities could bring about functional and holistic environmental education and an all-round national development and systemic change. The study further seeks to examine the effect of school location on subjects' knowledge and problem solving skills of environmental issues and concepts.

Hypotheses

The following null hypotheses were tested at 0.05 levels of significance.

Ho 1: There is no significant main effect of outdoor activities on students' environmental problem solving skills.

Ho 2: There is no significant main effect of school location on students' environmental problem solving skills.

Ho 3: There is no significant interaction effect of outdoor activities and school location on students' environmental problem solving skills.

Theoretical Framework

The theoretical framework of this study is based on Constructivist Theory and Experiential Learning Theory. Experiential learning, a school of thought associated with John Dewey, is the process of making meaning from direct experience. Constructivism is a theory of knowledge (epistemology) which argues that humans generate knowledge and meaning from their experiences.

Students would be allowed to obtain a holistic knowledge through experience especially based on direct confrontation with practical environmental and social problems so as to bring about meaningful and significant learning. Based on their personal experience using the outdoor educational activities, students would be able to construct knowledge of the processes and things involved in the environment and are able, through constructive thinking develop problem solving skills, to tackle the issues and problems within the environment.

RESEARCH METHODOLOGY

This study adopted a pre-test, post-test control group, quasi experimental design to determine the effect of outdoor educational activities on secondary school students' environmental knowledge and skills in Ibadan metropolis, Nigeria.

The following variables were used for the study:

Independent Variable /Treatment

(a) Outdoor educational activities, and (b) Conventional teaching method/lecture method

Dependent Variables

(a) students' environmental problem solving skills(EPBS), and (b) Knowledge of environmental concepts

Moderator Variable - School location

The researcher selected 240 Senior Secondary School Two (SS II) students from four purposively selected secondary schools in urban and rural areas of Akinyele and Ibadan North Local Government Areas of Oyo State. Two schools were selected from the urban area while two schools were from the rural area. The purposive sampling technique was used to assign the schools to experimental and control groups for the study. This was done to ensure that the schools to be used do not fall majorly in either the rural or the urban areas. Two out of the four schools were assigned as experimental group and two as control group. Intact classes were used. The Biology teachers of the schools were included in the study.

Instruments

The following instruments were designed and used by the researcher in this study:

- Students' Test of Environmental concept knowledge in Biology (STECKB)
- Students' Test of Environmental Problem Solving Skills (STEPSS)
- Instructional Guide for Teaching with Outdoor Activities(IGTOA)
- Instructional Guide for Teaching with Conventional Method (IGTCM)
- Evaluation Sheet for Assessing Teachers

Students' Test of Environmental Concept Knowledge in Biology (STECKB)

This is an instrument consisting of twenty multiple choice objective test items. Each item has four options (A-D) and was designed to test the level of acquisition of knowledge in Environmental Education concepts and students application of knowledge attained in their everyday life. It is also designed to know how well students can express their understanding to the Environmental Education concepts in relation to their personal and societal needs. The instrument covered topics such as environment, natural resources, conservation, pollution, solid wastes, erosion, desertification and deforestation. This test was trial-tested to ensure its reliability using Kuder Richardson formula (KR_{21}). The reliability co-efficient of the test was calculated as 0.80.

Students' Test of Environmental Problem Solving Skills (STEPSS)

This is an instrument designed to allow students express their own solutions to problems in the school and home environment as deemed fit. It consists of two problem statements relating to environmental problems in the school and at home to which the students are expected to proffer solutions and present an outline of how they will go about solving the problems. The items were designed to test the level of the students' understanding of environmental problems and involvement in constructive thinking and activities for sustaining the environment. The reliability was tested to be 0.90.

Instructional Guide for Teaching with Outdoor Activities (IGTOA)

This is an instructional guide for teachers participating in the experimental group. It contains the statement of topic, objectives and the procedure expected to be followed by the teachers in teaching of EE concepts during outdoor activities. This was prepared and used in the training of teachers to allow for uniformity in the teaching method.

Instructional Guide for Teaching with Conventional Method (IGTCM)

This is an instructional guide for teachers participating in the classroom using the conventional method/lecture method of teaching. It contains the statement of topic, objectives, instructional materials and the procedure expected to be followed by the teachers in teaching of EE concepts in the classroom. This was prepared and used in the training of teachers to allow for uniformity in the teaching method.

Evaluation Sheet for Assessing Teachers (ESAT)

This instrument was designed to be used in evaluating the teachers' effective use of the instructional guides during the teaching process. It shows their presentation of concepts, mastery of the topics, use of materials and activities as directed and how effective their presentation will be for the

FINDINGS OF THE STUDY

Data collected were analysed using descriptive statistics such as frequency counts, means, percentages and standard deviation and inferential statistics such as Analysis of Covariance (ANCOVA). The hypotheses were tested at 0.05 levels of significance. Multiple Classification Analysis (MCA) was also used to determine the magnitude of the differences of the various groups. The result of this study and the summary in the tables are hereby presented using the research hypotheses as guide.

Table 1: Descriptive Statistics of Post- Test Environmental Knowledge according to Treatment, Gender and School Location

						Mean	Std. Dev.	N
Treatment	Experimental	Gender	Male	Location	Urban	13.08	2.701	24
					Rural	9.14	2.748	29
					Total	10.92	3.350	53
			Female	Location	Urban	11.83	2.710	36
					Rural	9.35	2.627	31
					Total	10.69	2.930	67
			Total	Location	Urban	12.33	2.754	60
					Rural	9.25	2.666	60
					Total	10.79	3.111	120
	Control	Gender	Male	Location	Urban	12.71	3.494	35
					Rural	10.00	3.375	24
					Total	11.61	3.672	59
			Female	Location	Urban	10.72	2.909	25
					Rural	9.56	3.093	36
					Total	10.03	3.049	61
			Total	Location	Urban	11.88	3.385	60
					Rural	9.73	3.188	60
					Total	10.81	3.448	120
	Total	Gender	Male	Location	Urban	12.86	3.176	59
					Rural	9.53	3.048	53
					Total	11.29	3.525	112
			Female	Location	Urban	11.38	2.823	61
					Rural	9.46	2.867	67
					Total	10.38	2.993	128
			Total	Location	Urban	12.11	3.081	120
					Rural	9.49	2.936	120
					Total	10.80	3.277	240

Table 1 above presents the descriptive statistics of students with respect to environmental knowledge. It comprises the mean score, standard deviation and numbers of students involved in the research. A detailed study of the table reveals that in knowledge acquisition, the mean score of the rural experimental group was less than that of the urban group. This may be due to availability of more resources and the qualification levels and exposure of the teachers. Also, the performance of the male students as revealed in the total mean score was better than that of their female counterpart.

However, there was the need for further statistical clarification using the Analysis of Covariance - an inferential statistical method - to test the hypotheses in order to show if the differences in the mean scores were significant or not. It was also used to make up for the initial differences that may exist between the groups since intact classes were used.

Descriptive statistics on students' environmental problem solving skills

Table 2: Descriptive Statisics of Post- Test Environmental Problem Solving Skills according to Treatment, Gender and School Location

						Mean	Std. Dev.	N
Treatment	Experimental	Gender	Male	Location	Urban	12.96	3.277	24
					Rural	9.24	3.952	29
					Total	10.92	4.080	53
			Female	Location	Urban	11.94	33.55	36
					Rural	6.90	3.859	31
					Total	9.61	4.376	67
			Total	Location	Urban	12.35	3.334	60
					Rural	8.03	4.046	60
					Total	10.19	4.281	120
	Control	Gender	Male	Location	Urban	9.11	4.391	35
					Rural	6.42	4.736	24
					Total	8.02	4.689	59
			Female	Location	Urban	7.92	3.487	25
					Rural	5.78	3.595	36
					Total	6.66	3.678	61
			Total	Location	Urban	8.62	4.051	60
					Rural	6.02	4.063	60
					Total	7.33	4.243	120
	Total	Gender	Male	Location	Urban	10.68	4.380	59
					Rural	7.96	4.511	53
					Total	9.39	4.627	112
			Female	Location	Urban	10.30	3.926	61
					Rural	6.30	3.734	67
					Total	8.20	4.306	128
			Total	Location	Urban	10.48	4.142	120
					Rural	7.03	4.161	120
					Total	8.76	4.489	240

Table 2 presents the descriptive statistics of students with respect to environmental problem solving skills. It comprises the mean score, standard deviation and numbers of students involved in the research. A detailed study of the table revealed with respect to solving of problems related to the environment, the total mean score of the experimental group was greater than that of the control group. Also, the total mean score of the male students was higher than that of their female counterparts. Finally, the urban students performed better than the students in the rural area. These findings were subjected to further statistical clarification which was done using the Analysis of Covariance - an inferential statistical method was used to test the hypotheses in order to show if the difference in the mean scores were significant or not. It was also used to partial out any initial differences that may exist between the groups prior to treatment so that any difference obtained in their performance could be attributed to the effectiveness of the treatment since intact classes were used.

Ho1: There is no significant main effect of outdoor activities on students'
(a) environmental knowledge, and, (b) environmental problem solving skills.

1a Main effect of treatment on students' Environmental knowledge

Table 3: Summary of2x2x2 Analysis of Covariance (ANCOVA) of Post- Test Environmental Knowledge according to Treatment, Gender and School Location

		Type III Sum of Squares	d	Mean Square	F	Sig.
Source	Corrected Model	510.1580	8	63.769	7.164	.000*
	Intercept	1526.209	1	1526.209	171.455	.000*
	KNOW_PRE	2.206	1	2.206	.208	.619
	TREATMENT	.787	1	.787	.088	.766
	GENDER	39.893	1	39.893	4.482	.035*
	LOCATION	307.076	1	307.076	34.497	.000*
	TREATMENT*GENDER	5.407	1	5.407	.607	.437
	TREATMENT*LOCATION	23.413	1	23.413	2.630	.106
	GENDER*LOCATION	32.661	1	32.661	3.669	.057
	TREATMENT*GENDER* LOCATION	.012	1	.012	.001	.970
	Error	2056.244	231	8.901		
	Total	30560.00	240			
	Corrected Total	2566.400	239			

Ho1a-There is no significant main effect of treatment on students' environment knowledge.
The result of 2x2x2 Analysis of Covariance (ANCOVA) as presented in Table 3 reveals that there was no significant main effect of outdoor activities on student environment knowledge (F=0.088 .P>0.05).The hypothesis was therefore not rejected. Although the experimental group performed better with the use of outdoor activities, the difference when compared with the control group was not significant. This was subjected to further tests using the Multiple Classification Analysis as shown in table 4 below.

Table 4: Multiple Classification Analysis (MCA) on Post Test Environmental Knowledge by Treatment, Gender and School Location.

Grand Mean = 10.80

Treatment +category		N	Adjusted for Factors and Covariates	Unadjusted	Adjusted for factors and Covariates	Eta	unadjusted	Beta
Treatment	Outdoor activities	120	10.79	10.82	-0.008	0.003	.018	.006
	Conventional method	120	10.81	10.78	0.008		-0.018	
Gender	Male	112	11.29	11.19	0.486	0.139	0.394	0.113
	Female	128	10.38	10.46	-0.425		-0.344	
Location	Urban	120	12.11	12.02	1.308	0.400	1.225	0.375
	Rural	120	9.49	9.58	-1.308		-1.225	

The Multiple Classification Analysis (MCA) as presented in Table 4 reveals the performance of each group. It shows that the experimental group performed better (X= 10.82) than the control group (X=10.78). Although the treatment has a positive effect, it was not significant.

Main effect of treatment on students' environmental problem solving skills.

Table 5: Summary of 2x2x2 Analysis of Covariance (ANCOVA) of Post- Test Environmental Problem Solving Skills according to Treatment, Gender and School Location.

		Type III Sum of Squares	d	Mean Square	F	Sig.
Source	Corrected Model	1375.905	8	171.988	11.549	.000*
	Intercept	4970.725	1	4970.725	33.782	.000*
	KNOW_PRE	.227	1	.227	.015	.902
	TREATMENT	494.645	1	494.645	33.215	.000*
	GENDER	95.267	1	95.267	6.397	.012*
	LOCATION	539.535	1	539.535	36.230	.000*
	TREATMENT*GENDER	8.485	1	8.485	.570	.451
	TREATMENT*LOCATION	56.158	1	56.158	3.771	.053*
	GENDER*LOCATION	2.023	1	2.023	.136	.713
	TREATMENT*GENDER* LOCATION	13.064	1	13.064	.877	.350
	Error	3440.078	231	14.892		
	Total	23226.00	240			
	Corrected Total	4815.983	239			

Ho1b: There is no significant effect of outdoor activities on students' environmental problem solving skills.

The result on Table 5 shows that there is a significant effect of outdoor activities on students' environmental problem solving achievement. (F=33.215, P< 0.05). The hypothesis was therefore rejected. This means that student exposed to outdoor activities improved in their environmental problem solving achievement (x=10.19, SD=4.281) than their counterpart (x=7.33 SD=4.243) although the level of achievement is still low which is just a bit above the average mark.

Table 6: Multiple Classification Analysis (MCA) on Post-test Environmental Problem solving Achievement by Treatment, Gender and School Location

Grand Mean = 8.76

Treatment + category		No	Adjusted for Factors and Covariates	Unadjusted	Adjusted for factors and Covariates	Eta	Unadjusted	Beta
Treatment	Outdoor activities	120	10.19	10.21	1.443	0.320	1.456	0.325
	Conventional method	120	7.33	7.30	-1.443		-1.456	
Gender	Male	112	9.39	9.39	0.635	0.132	0.614	0.128
	Female	128	8.20	8.22	-0.555		-0.537	
Location	Urban	120	10.48	10.44	1.725	0.385	1.678	0.375
	Rural	120	7.03	7.08	-1.725		-1.678	

The Multiple Classification Analysis (MCA) on Environmental Problem Solving Achievement as presented in Table 4 Shows that the experimental group performed better than (X=10.21) than the control group (X=7.30). The table further shows that the treatment contributed 10.6% to Environmental Problem Solving Achievement.

Ho2: There is no significant main effect of school location on students'

(a) environmental knowledge, and (b) environmental problem solving skills.

Main effect of school location on the students' environmental knowledge

Ho2a- There is no significant effect of school location on students' environmental knowledge.

From Table 3, the result shows that the effect of school location on students environmental knowledge was significant (F=34.497 P<0.05). The hypothesis was therefore rejected. Table 3 showed that students in the urban area obtained higher mean score in environmental knowledge than people in the rural area. Observation from table 4 shows that school location had a Beta value of 0.375. This implies that school location accounted for14% of the variation in students' environmental knowledge.

Main effect of school location on students' environmental problem solving skills.
Ho2b: There is no significant main effect of school location on students' environmental problem solving skills.

The result of Table 5 shows that there was a significant effect of school location on students' environmental problem solving skills (F=36.230 P<O.O5). The hypothesis was therefore rejected. This shows that school location has influence on students' environmental problem solving skills. The urban students achieved more of environmental problem solving skills (x=10.48 SD=4.142) than the rural students (x=7.03 SD=4.161). Table 6 shows that school location had a Beta value of 0.375. This implies that school location accounted for 14.1% of the variation in students' environmental problem solving skills.

Ho3: There is no significant interaction effect of outdoor activities and school location on students' (a) environmental knowledge, and (b) environmental problem solving skills.

Interaction effect of Treatment and school location on students' environmental knowledge.
Ho3a: There is no significant interaction effect of outdoor activities and school location on students' environmental knowledge.

Result from table 3 shows that was there no significant interaction effect of outdoor activities and school location on students' environmental knowledge (F= 2.630 P>0.05). The hypothesis was therefore not rejected.

Interaction effect of Treatment and school location on students' environmental problem solving skills.
Ho3b: There is no significant interaction effect of outdoor activities and school location on students' environmental problem solving skills.

The results of Table 5 reveals that there was a significant interaction effect of outdoor activities and school location of students' environmental problem solving skills (F=3,771 P<0.05). The hypothesis was therefore rejected.

The nature of this interaction was however was determined by plotting an interaction graph of treatment by location. This is shown in figure 1 below.

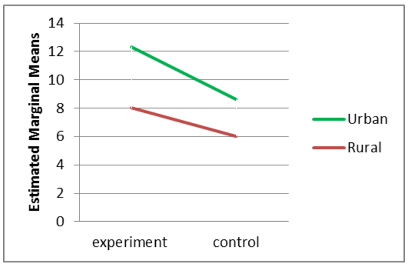

Figure.1: Graphical representation of the Interaction effect of Treatment and School location on students' Environmental Problem Solving Skills

This graphical representation reflects an ordinal interaction between treatment and school location. This indicates that in both urban and rural schools, the experimental group performed better than control rural group. This shows that the urban group acquires better skills in solving environmental problems than the rural group.

DISCUSSION OF FINDINGS
Research studies previously carried out on outdoor education activities has shown it to be very effective in impartation of knowledge, attitude and skills in the life of various individuals at different educational levels varying from the primary to the tertiary level. This present study was carried out to extend the various studies carried out. The study investigated the effect of outdoor activities on

secondary school students' environment knowledge, attitude and problem solving skills. It also examined the moderating influence of gender and school location on the students' environmental learning outcomes.

The students were exposed to real environmental situations around so that they could from their experience, construct knowledge and build up attitudes and a sense of problem solving towards the problems in their environment to make it a better place to live in. This, in a way was of greater advantage than the conventional lecture method that involves only an impartation of information by the teacher which may not make use of instructional materials that would bring about the expected learning outcomes.

SUMMARY

The research work was embarked upon with the purpose of finding out the effect of outdoor activities on secondary school students' environmental knowledge, attitude and problem solving skills. It further examined the effects of gender and school location on subjects' knowledge and problem solving skills on environmental issues and concepts.

The study was carried out on 240 senior secondary school II students from four schools in two local government areas of Ibadan in Oyo state using a pre-test, post-test control group, quasi experimental design. The instruments used comprises Students' Test of Environmental Concept Knowledge in Biology (STECKB), Students' Test of Environmental Problem Solving Skills (STEPSS), Instructional Guide for Teaching with Outdoor Activities, Instructional Guide for teaching with conventional method, Evaluation sheet for assessing the teachers. Reliability and Validation of instruments were done before they were used in the main study. Data analysis was done using descriptive statistics (mean and standard deviation) and inferential statistics (Analysis of Covariance - ANCOVA).

The summary of the result is as follows:

- There was an improvement in the environmental knowledge of students exposed to treatment. The treatment had a significant main effect on students' environmental problem solving skills.
- The study revealed that there was a significant main effect of school location on students' environmental knowledge and problem solving skills.
- There was no significant interaction effect of treatment and school location on students' environmental knowledge. There was a significant interaction effect of treatment and school location on environmental problem solving skills.

Implications of findings

The study was necessitated to find a way of bringing about functional and holistic environmental education and an all-round national development and systemic change, acquisition of knowledge for utility, especially towards the environment, which has been observed to play a vital role in all facets of life.

The outdoor activity was seen to be effective in achieving this. Thus for students, it is expected they make maximum use of outdoor activities as an opportunity to improve upon their learning and problem solving skills. Their participation and involvement in positive environmental activities will better their lives and eventually lead to societal development.

The implication for teachers, according to the findings, is that teachers in the rural schools need to improve upon their use of outdoor activities so that the impact expected will be manifested in the students.

CONCLUSION

Various researches about EE, either in its inclusion in curriculum (Olagunju, 1998; Ogunleye, 2002) or the strategies for teaching it in various subjects (Olatundun, 2008; Ajitoni, 2005) among others has been extensive in recent years. This study has revealed that the use of outdoor activities in teaching environmental education particularly in biology is relatively effective in bringing about improved knowledge and very effective in bringing about environmental problem solving skills in students. The location of the school has proved to have a great effect in determining the student's knowledge and problem solving skills of environmental issues and problems. Outdoor activities from this study is therefore recommended in bringing about increased knowledge and especially positive predisposition of people to and ability to solve present imminent and future problems that relate to the environment.

Recommendations

The following recommendations are made based on the findings of the study.

1. Curriculum Planners: The result of this study has shown the need for curriculum planners to include outdoor activity as one of the methods required in the curriculum, especially the student/teacher activities to bring about effective impartation of knowledge and problem solving skills. Furthermore, the need to decongest the Biology curriculum which is already overloaded to give enough time for outdoor activities needs to be looked into. This will make the method have more significant effect on students' knowledge.

2. Teachers and Students: Outdoor activities have been observed to have brought about increase in knowledge and significant change in problem solving skills by students. Therefore outdoor activities are recommended for teaching and learning of environmental education and even ecological topics in Biology.

Limitations of the study

The study was conducted in only two (2) out of all the local government areas of Oyo State Nigeria. There is need to replicate the study using more schools and local government areas to have a more generalized conclusion.

Time constraint was another limiting factor. The secondary school curriculum is overloaded and so the time needed for outdoor activities was not enough for the kind of knowledge needed to be imparted to the students.

The population of students in a class to be handled by a teacher is so vast that to get information or the needed facts across during teaching requires a dedicated teacher and students that are ready to learn. Unfortunately, the achievement of students in Biology has not been impressive. Thus the major problem of teaching and studying Biology identified among other things is that the populations of students in most cases are disproportionate to the number of teachers handling the subject (Nwachukwu & Nwosu, 2007). The overpopulated classroom can be seen here as a limiting factor to acquisition of knowledge. It is the effectiveness of the manipulations of classroom interactions that help the student to achieve more in cognitive objectives (Nwachukwu & Nwosu, 2007).

Areas for further studies

The following suggestions for further studies are made.

A replication of the study using more secondary schools in other local government areas of Oyo state or from the six geo-political zones of Nigeria to have a more valid generalization /conclusion could be made.

There are a lot of other moderator variables that can be considered apart from gender and school location. These include: teacher factor (experience, qualification, and psychology); student factors (socio-economic status of parents, subject specialization, psychology, level of intelligence and exposure), cultural beliefs and so on.

The development of outdoor activities as part of the school curriculum would go a long way in ensuring the acquisition of knowledge and skills that would help in building the right personality for the environment in which we live.

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THE THEORY OF 'EVILUTION': CHRISTIAN TEACHERS' AND LEARNERS' PERSPECTIVES ON EVOLUTION

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INTRODUCTION

The theory of evolution was included into the National Curriculum Statement (NCS) for Life Sciences and implemented in the Grade 12 curriculum in 2008, followed in 2009 and 2010 by certain concepts of evolution being introduced to the Grades 10 and 11 curriculum. Some substantial content was subsequently added to the Further Education and Training (FET) curriculum when the new Curriculum and Assessment Policy Statement (CAPS) was introduced in 2012. Anecdotal evidence indicates that the initial incorporation of evolution was not welcomed with the same enthusiasm by all teachers, learners, parents or schools (De Beer, 2010; Sanders & Ngxola, 2009). One reason, among many, being rooted in the religious background of the communities. For fundamentalist Christians or Muslims, believing in evolution would imply that one does not believe in the Bible as the word of God, or of Allah in the Koran, respectively.

Evolution is seen as blasphemous in certain religious circles, whereas for most biologists it is a fundamental part of science, facilitating an understanding of biological concepts (Dobzhansky, 1973; Sandoval, 2003). As a multidisciplinary topic that stimulates higher order thinking, many authors argue that the teaching of evolution is integral to the holistic development of a learner, and as a scientist as it is one of the most comprehensive theories as it takes different lines of evidence and combines them in the most plausible theory (Berger, 2006; Dempster & Hugo, 2006; Lever, 2002).

Very little research data is available on South African Christian teachers' and learners' views on evolution as supposed to countries such as the United States of America (USA) and the United Kingdom (UK), where there is a rich body of data available. For instance, research has shown that 13% of American high school biology teachers still teach creationism as science, with 16% of those still believing that God created humans in their present form, about 10 000 years ago, with no evolutionary changes (Moore, 2009). Furthermore, 45% of Americans do not accept the argument of evolution through natural selection (Baumgartner, 2009).

One of the greatest barriers in South Africa is the lack of subject knowledge of the educators (De Beer, 2010; Sanders & Ngxola, 2009), mainly due to it not having been part of many teachers' tertiary education (Dempster & Hugo, 2006). The basic concepts are not understood by some Life Sciences teachers and are therefore open to misinterpretation. Scott (2000) presents different views of creation on a continuum, with fundamental creationism on one end and evolution on the other. While the NCS envisage teachers accepting evolution, that many are creationists is problematic for the teaching of it.

Barbour (2000) in Anderson, (2007) places the relationship between science and religion into four categories. The first being that science and religion have conflicting stances and opposes one another. The second category perceives the two disciplines as mutually independent, religion focussing on the metaphysical world whereas science focusses on knowledge built on empirical evidence. Thirdly, science and religion could be seen as in dialogue with scientists and theologians communicating reverently with one another. The fourth category views religion and science as integrated or intertwined, in a mutual relationship. Whilst the last three categories do not pose problems for the teaching of evolution, the first is usually associated at either extreme with creationists and atheists, and may result in a teacher abdicating his duty and not teach evolution or teaching it in a way that antagonises learners.

Seeing that evolution is such a relatively new topic in the Life Sciences curriculum and there is little literature available on it within a South African context, this study strived to identify barriers to the teaching and learning of it in the country, focussing specifically on religious issues in the Christian classroom. In this study FET learners was involved in order to determine the views they had before and after being taught evolution. This study formed part of a trilogy, with Yalvac (2011) having focused on the lived experiences of Muslim people, and Reddy (2012) on the lived experiences of Hindu learners and teachers in South Africa.

A mixed method approach was used to identify the lived experiences of Life Sciences learners. This was an explanatory sequential mixed method study (Cresswell, 2007), with strong elements of phenomenology, because we wished to capture the learners' opinions, experiences as well as their possible religious objections. The focus was to describe the essence of the lived experiences of the Life Science learners, then to view this through the lens of Cultural-Historical Activity Theory (CHAT), in which the Life Sciences classroom would be viewed as an activity system, in which tensions might arise. Conceptual Change Theory was employed as the theoretical framework.

CONCEPTUAL CHANGE AS THEORETICAL FRAMEWORK

Schilders et al. (2009) regard the term 'worldview' as a framework of beliefs and ideas through which an individual interprets and interacts with the world. This allows a person his or her own perspective of the world and provides a lens through which new experiences and information can be made sense of. De Beer and Henning (2011) write that many South African Life Sciences teachers do not have a Bachelor of Science degree, but only teaching diplomas obtained at institutions with limited resources. This then contributes to insufficient content knowledge when teaching evolution. The worldview held by these teachers, which is greatly influenced by their religion, is often given greater priority than the theory of evolution. Teaching is directly influenced by a teacher's worldview, as is learning (Cavallo & McCall, 2008), and the pressure society places on a person can overpower attitudes and so play a major role in the teaching and learning of a topic.

Learners enter the classroom with their own worldviews and misconceptions, therefore increasing the challenge of teaching evolution. Learning about evolution and accepting it as a plausible theory often requires an adaptation of one's worldview, and the Life Sciences classroom becomes the arena in which the worldviews of the teacher and learners meet. Tensions exist under the surface because of conflicting worldviews, so it is the role of the teacher first to develop a scientific viewpoint based upon the learners' pre-scientific conceptions (Van Dijk, 2009). The authors suggest that these pre-scientific conceptions and the knowledge and beliefs of the teacher should both be studied, with specific reference to the teaching of evolution.

In order for learners to reach their potential they need to be conceptually competent and it is the role of the teacher to guide them away from their naïve conceptual understandings of a specific concept and so become conceptually competent. This could be a daunting task since every learner is unique and enters the classroom with diverse mental abilities, educational backgrounds and preconceived ideas. They may have naïve understandings of the content the teacher is presenting, and these need to be scaffolded and shaped into novice concepts and then into competent concepts (Disessa, 2002). In order to scaffold learners from naivety to competence one needs to understand how knowledge is constructed.

Knowledge construction is an active process and thus makes learning and understanding an active process as well (Piaget, 1964). Ginsburg (1985) elaborates on Piaget's view and states that to gain an in-depth understanding of a concept one has to rediscover it for oneself. Piaget claims that active cognitive development in children occurs due to three essential processes, namely assimilation, accommodation and equilibration. A concept is assimilated if the incoming information is transformed in order to fit within an existing way of thinking (Siegler, 1995). Ausubel (1985) explains that this process is used to acquire knowledge, when "New information is linked to relevant, pre-existing aspects of cognitive structure and both the newly acquired information and the pre-existing structure are modified in the process." This shows that meaningful learning of new concepts occurs when new information is actively assimilated into an existing knowledge framework.

Secondly, Siegler (1995) explains that the way in which people adapt their ways of thinking to new experiences leads to the accommodation of information. When an experience does not fit into the existing knowledge framework after it is assimilated it perturbs the person and implies that the experience must be changed. Thirdly, an interaction between existing ways of thinking and new experiences, where both assimilation and accommodation can exist, gives rise to equilibration, the epitome of Piaget's system and one that assures active and meaningful learning (Siegler, 1995).

The worldviews of many Christian teachers and learners are constructed around a religious upbringing which in their view is in conflict with the theory of evolution. Accommodation is therefore a necessary process in order for meaningful learning to take place. The conflict between worldviews inhibits the process of accommodation because it often depends on the influence of a person's culture and society (Hardy & Hardy, 1997). The theory of evolution is anathema to many fundamentalists as it is in direct conflict with their creationist worldview and contributes to the formation of many misconceptions. In order to accommodate and assimilate evolution into one's worldview one must accept conceptual change.

Most secondary school Life Sciences learners have been exposed to some opinions about evolution from the community to which they belong before they enter the Life Sciences classroom, whether from parents, religious leaders or the media (Cavallo & McCall, 2008). The more deeply embedded these are, the more difficult it is to replace or challenge them with scientific explanations at school. In order to understand evolution, fundamentalist Christians may need to experience radical conceptual change, a process in which a person who has insufficient knowledge to build on or comprehend a new concept, must restructure his or her thinking to accommodate it (Pintrich et al., 1993).

Howe (1996) summarises the model of conceptual change as follows:

1. Learners formulate their own opinions about natural phenomena, some of which may be misconceptions, before entering the classroom.
2. The teacher now needs to determine what these opinions are then present learners with sufficient evidence in order to lead them to the realisation that their assumptions are incorrect.
3. The learners are then more informed and can thus accept the scientific explanation instead of their initial opinion, which they then realise is no longer logical in the light of the available scientific evidence.

Learners can only change their worldviews if they are considered as contextual factors when they are taught scientific concepts (Duschl & Gitomer, 1991). This model has been criticised because it does not take into consideration the contextual factors of the learner and is thus regarded as cold conceptual change, which expects new knowledge to be objectively built into existing knowledge frameworks, and only from a cognitive level (Henning & De Beer, 2010). The influence of personal experiences, emotions and socio-cultural interactions with people in one's community leads to warm conceptual change (Pintrich et al, 1993). Hynd (2003) uses the terms 'belief change' with conceptual change, arriving only at 'warm' conceptual change, in other words, one can only acknowledge conceptual change when there is also acceptance, so learning about evolution and not also accepting it does not constitute true conceptual change.

It is however more difficult to accomplish warm conceptual change than 'cold' conceptual change because it is driven by factors such as the elements of human emotion and belief systems that are difficult to measure. Cold conceptual change is not a viable vehicle as it does not take into consideration those contextual factors that influence learning and comprehension. The acceptance of evolution into a person's worldview could thus not be achieved by using cold conceptual change.

Evolution is viewed as a controversial topic by many teachers and learners, and Pintrich et al. (1993) state that cold models of conceptual change should have to widen their views to include 'hot', factors, such as motivational, social and historical issues that could facilitate or hinder it. This is needed in order to achieve controversial conceptual change; therefore teachers should know the worldviews of their learners in order to facilitate conceptual change on topics perceived as controversial.

METHODOLOGY

Quantitative and Qualitative data was collected by conducting a survey in the form of pre- and post-test questionnaires which were completed by 73 Grade 12 Life Science learners from a predominantly Christian school in Johannesburg that was administered before and after the teacher taught the section on evolution.

The first items in the questionnaire focused on the religious identity of the learners, and to which denominations they belonged. Learners' view of evolution could have been influenced by the teachings they received at church as all churches have their own views on evolution. These teachings could have led to the creation of preconceived ideas and even possible misconceptions in the learners' minds. This section of the questionnaire tried to ascertain these possible preconceived ideas. The next question asked how often they attended church activities, because the more they attend church the more they are likely to be exposed to the doctrine and views of that institution or its personnel. The following question asked what the learner's role in his or her church community was, based on an assumption that if it was an active one it would reflect a strong desire to be more informed about the doctrine and views of the church. These roles varied from normal members to technical support, musicians and even Sunday school teachers. The rest of the questionnaire was divided into three sections.

Section A

Section A focussed on the Biblical knowledge the learner had. This included questions on three text verses and the general theme of each. All three were generally used in different churches. We then asked questions that pertained to the major events in the Old Testament that most Christians ought to know, or at least have been exposed to in church, including the creation, the ten plagues of Moses and the Ten Commandments. Learners were then asked if they had ever heard one of their preachers preach against evolution. The reasoning behind these questions should also be seen in the context of two recent studies on Life Sciences teachers' and learners' experiences of evolution.

Yalvac's (2011) study focused on the experiences of Muslims regarding the teaching and learning of evolution, whilst Reddy's (2012) focused on those of Hindu teachers and learners. In the former case, Yalvac found that the Muslim teachers and learners had a very good understanding of the principles of Islam, a strong fundamentalist worldview, and therefore a strong rejection of the theory of evolution. It is interesting to note in Yalvac's study how teachers used Islamic literature to discredit evolution. In strong contrast, Reddy's research indicated that Hindu teachers and learners did not have any problem in including evolution into their worldviews. She supplies two possible reasons for this. Firstly that the Hindu religion is partly grounded in the concept of reincarnation, and since Hindu people accept this principle they find it easy to conceptualise the theory of evolution. Secondly that most of the participants in her study only had rudimentary knowledge of the Hindu scriptures. This gave rise to the question of a possible correlation between religious (scriptural) knowledge, and acceptance of evolution as a unifying theme in biology.

Section B

This section focussed on the learners' knowledge of evolution. The first question being about the age of the Earth, one of the most controversial issues in the debate on evolution and creationism. The learners' answers to this question showed their predisposition to this debate. They were then asked to define four terms, namely species, natural selection, mutation and evolution, to ascertain their understanding of the topic. The following question elicited their thoughts on a possible ancestor of humans, to shed further light on possible religious bias.

Section C
This section asked the learners to describe their own feelings and those of their parents on learning evolution in the Life Sciences classroom. They were also asked if they foresee using this knowledge in the future.

After analysing the questionnaires the learners were then grouped into one of five categories based on the comparison between their answers of Sections A and B and their responses in section C. Those who answered out of a strong creationist register were placed in the religious category, though of these some were not as opinionated as those in the religious category and so were placed in the religious-neutral category. The next category was for learners who showed a neutral view on evolution and were placed in the neutral category. The fourth category was for learners who answered out of a scientific register but had many misconceptions about evolution, these being placed in the evolution-neutral category. The final category, for learners who answered out of a scientific register and had an accurate concept of evolution, were placed in the evolution category.

The quantitative data generated from the post-test was then compared to those of the pre-test to observe any changes in the responses of the learners. Coding (Saldana, 2009) was used to analyse the data that was generated from the learners' responses in Section C to categorise these responses into themes.

RESULTS
Quantitative data generated from questionnaires
A total of 73 learners participated in the pre-test and 62 in the post-test. A total of 47% of the participants belonged to the Dutch Reformed Church, 10% to Evangelical Reformed Church and 9% to the Apostolic Faith Mission. The remaining 34% did not specify to which denomination they belong.

In this survey, 63% of the participants indicated that they attended church once a week. A total of 13% attended church activities more than once a week; 20% attended church infrequently and fewer than 1% never attended church. The remaining 3% did not indicate the frequency with which they attended church activities.

Some 70% of the learners mentioned that they were only members of the church and 25% had active roles within their congregations, including as Sunday school teachers, musicians and technicians. 5% did not answer this question.

The following tables compare the learners pre-test and post-test scores on sections A and B.

Table 1: Comparison between pre-test and post-test on religious questions of Section A

Test score	Pre-test (%)	Post-test (%)	Difference (%)
0%	2	0	-2
< 50%	86	79	-7
50% - 70%	12	21	+9
70% - 95%	0	0	0
95% - 100%	0	0	0

That the learners' knowledge on biblical concepts increased during the almost six weeks between the pre- and post-tests could be attributable to their having been asked the same questions in the pre- and post-tests. However, that does not explain why no one scored more than 70% in the post-test. If they remembered the questions from the pre-test they still had to research the answers in order to score higher during the post-test. A more likely reason is that they consulted with their parents or church leaders during their tuition on evolution.

Table 2: Comparison between pre-test and post-test questions on Section B regarding evolution

Test score	Pre-test (%)	Post-test (%)	Difference (%)
0%	4	3	-1
< 50%	70	56	-14
50% - 70%	22	32	+10
70% - 95%	1	5	+4
95% - 100%	3	3	0

It is clear from this table that there had been a transfer of knowledge during the learners' tuition on evolution, regardless of their religious convictions.

The following table compares the learners' opinion on studying evolution.

Table 3: Comparison of learner's opinions on Section C regarding the studying of evolution

	Pre-test (%)	Post-test (%)	Difference (%)
Negative (%)	22	35	+13
Neutral (%)	44	26	-18
Positive (%)	34	35	+1

The change in attitude from a more neutral stance to a negative stance reflects a general trend throughout this study for learners who had a neutral stance to begin to move to one of the two poles. This polarisation from neutral to a more negative or more positive stance shows that the learners were naïve and ignorant at the beginning of the module on evolution but that through the knowledge transfer that took place they started to form their own opinions.

The learners were asked to describe their parents' attitudes towards the studying of evolution in the Life Sciences classroom. The following table shows the change in attitudes of the parents.

Table 4: Comparison of parents' opinions regarding the studying of evolution as reported by the learners

	Pre-test (%)	Post-test (%)	Difference (%)
Negative (%)	25	27	+2
Neutral (%)	21	19	-2
Positive (%)	18	29	+11
Unsure (%)	34	15	-19

One would assume that the learners' opinions would mirror the opinions of the parents, but these results seem to contradict this assumption. I stress that no questionnaires were given to parents to complete, and these figures are solely the view of the learners of the opinion of their parents. Of significance is that the number of learners who were unsure of their parents' opinion decreased by a substantial number, indicating that there had been dialogue between learners and parents during the tuition time of this module.

The learners were placed into five categories, according to their answers to the questionnaires. Table 5 shows these results.

Table 5: Table indicating the changes between categories

Attitude/Register	Pre-Test (%)	Post-Test (%)	Difference (%)
Religious	26	34	+8
Religious Neutral	23	10	-13
Neutral	16	21	+5
Evolution Neutral	19	11	-8
Evolution	13	21	+8

Once again, there is polarisation of the learners away from neutrality. While many learners who were previously placed in the evolution neutral group moved to the evolution group, it is interesting to see the split of the religious neutral group between the neutral and religious groups, showing that some learners kept an open mind when learning about evolution. It is evident that with transfer of knowledge the learners start to form their own opinions.

Qualitative data generated from questionnaire

The open-ended questions were coded in order to find themes that emerged from the learners' answers. The table that follows compare the pre- and post-test themes.

Table 6: Summary of emerged themes and sub-themes

Theme	Concept of evolution	Personal feelings	Desired classroom approach and learning
Sub-theme	Definition Religious reference Contextual reference Misconceptions	Against evolution Neutral In favour of evolution	Objections Current learning strategy Desired learning strategy Open minded approach Argumentative approach

Comparison of the learners' concept of evolution

The religious and religious-neutral groups showed an increase in concepts on how to define evolution, whilst the neutral and evolution-neutral groups have many different ways to define evolution at the beginning, but after tuition it seems that the learners have a more concrete description of it. This shows that knowledge transfer did indeed take place. The evolution group showed an in-depth understanding of evolution at the beginning but as with the neutral and evolution neutral groups they seemed to have a more concrete and set definition of evolution.

The religious responses of the learners in the religious group did not seem to change, and perhaps their responses became a little more antagonistic towards evolution. However, in the case of the religious neutral group there was a radical change, which could partly be due to so many in this group having moved into either the religious group or the neutral group. The learners remaining within this group now showed a more open-minded approach. In the neutral group there was a change from a neutral view towards a slightly religious view, perhaps because of the learners who came from the religious neutral group still holding on to some of their more fundamentalist opinions. The evolution neutral group recognised the two possibilities of science and faith but it does not seem that they were willing to take a pre-test stance. From a post-test position it seems this group adopted an intelligent design stance. The evolution group seemed confused at the beginning and recognised that religion and science seemed to be in conflict. However, they also realised that evolution did not contradict religion after the evolution section had been taught.

It seemed that the religious group started off very antagonistic towards evolution, even comparing it to fairy tales and fables. This antagonism did not seem to change. The religious neutral group started off in a similar way to the religious group but had no contextual responses, which once again could be due to the result of polarisation within this group. The neutral group had no contextual responses initially but expressed an interesting opinion, namely that the opinion of the learners would depend on the teacher. They did not elaborate on this opinion but one can assume that they referred to either the opinion or enthusiasm of the teacher during tuition on this module. The evolution neutral group had no responses at the start but mentioned that the learning of evolution was acceptable to them. The only contextual comment the evolution group made was that evolution was a continuous process, albeit they had not mentioned this in the post-test.

All the groups, apart from the evolution group, started off with many misconceptions but almost all disappeared during tuition, except for the one that humans developed from the great apes instead of humans and apes having common ancestry. This could be due to a miscommunication between the teacher and the learners, or possibly this concept was so widely used to describe evolution that it takes more time to clarify it. All groups decreased in misconceptions, except the religious group who seemed to gain in them. The learners' preconceived ideas on evolution could be the reason for this. They listen to the tuition on these concepts but seem not to internalise these concepts and stick to their misconceptions. They could also adopt more misconceptions as they engaged in dialogue with parents or church leaders.

Comparison of the learners' feelings about evolution

It is clear that the learners in the two religious groups became more opinionated towards the learning of evolution during their tuition. They added many negative remarks. With the exception of one learner in the neutral group, the other three groups did not change.

At the beginning, the learners in all groups showed a more neutral attitude towards the learning of evolution. It is interesting to note that both religious groups and the evolution group had no neutral opinions afterwards, showing that the learners formed definite opinions during tuition. The neutral and evolution neutral groups showed little difference.

There were no positive remarks made by the religious group at the start, and they showed little change except for one learner who mentioned that the content was interesting. The rest of this learners questionnaire still showed a greater religious response overall. It is important to note the positive attitude of the learners in the evolution neutral group and the little degree of change in it. As new members were added to the evolution group there was an even more positive attitude displayed towards the learning of evolution.

Comparison of the learners' desired classroom approach to the learning of evolution

None of the learners in the neutral or evolution groups had any objections to the learning of evolution and no objections came from this group during tuition. However, the two religious groups had many objections to start with and added a few objections during tuition. These learners felt that they were being forced to study something that went against their religious convictions, and stated that learning about evolution held no advantage to them going forward.

From the data it was evident that learners throughout the different groups only studied the content in order to pass. The evolution groups showed the most change as no learners in them made this comment after tuition. However, the remaining three groups still held onto this.

During the pre-test there were many learners stating that the learning of evolution should be optional, some even saying that they also wanted to learn about creationism. This notion was dropped by all groups, except from the religious group.

During the pre-test we found many open minded remarks in all groups, but during the post-test no open-minded remarks were found for the two religious groups. This could be because during tuition the learners were offended by what was being taught, perhaps they were influenced by the views of their teacher, or the open minded-learners in the religious groups moved to the neutral or evolution groups. The former is the most likely reason.

There were a few learners who saw the potential debate and/or arguments that can arise from the conflict between creationism and evolution. A few comments that the learners in the various groups made indicated that they believed that they needed to know something about evolution in order to partake in discussions on this topic.

FINDINGS

The following findings precipitated from the analysed data.

Knowledge transfer occurs whether a learner has religious objections or not

When comparing the pre- and post-test questionnaires we see an improvement in the answers that the learners gave with regards to the questions pertaining to evolution. Their definitions seem to be coherent and from the textbook, therefore we notice a transfer of knowledge regardless of religious conviction. Learners tend to show a more concrete understanding of the content, but many noted that they only studied the content in order to pass the examination. This indicates that deep learning does not occur in this case.

Goodyear and Zenois (2007) regard deep learning as a desire to comprehend, but we argue that most learners do not have this, preferring to pass the examination and do only what is necessary to achieve their goal. For many learners there is no real conceptual change, since they do not accept the theory of evolution. Part of the problem might be that they have two parallel sets of truths, their religious convictions and evolution, –and that assimilation of opposing views into their worldview does not take place.

Learners formulate a definite opinion about evolution

We noticed a clear polarisation from a neutral stance towards either a more religious or scientific stance. Learners start forming definite opinions on evolution during tuition and the opinions of the majority of the learners during the pre-test had a neutral tone. It seems that the majority of the learners had not given the topic of evolution much thought, and the few individuals who did have strong opinions about it had religious objections to learning about it. This group grew substantially during tuition and precipitated in the post-test. The neutral group became much smaller because learners migrated towards one of the two poles.

Evolution teaching increases dialogue between learners and their parents

The majority of learners conversed more with their parents about evolution during tuition on this section.

The attitude of the teacher influences the attitude of the learner

The opinion and attitude of the teacher had an influence on those of the learners. If the teacher, as authority figure in the eyes of the learners, is biased in any way and degrades evolution to a mere theory, in the unsubstantiated and opinion-based sense of the word, the learners will be influenced and view evolution in a similar fashion. This finding is supported by similar studies, such as that of Yalvac (2011) amongst Muslim teachers and learners.

Many misconceptions are dispelled during tuition on evolution

Most learners have many misconceptions regarding evolution before tuition on evolution starts, but most groups (excluding the religious group) showed a decrease in the number of misconceptions after tuition, except for the misconception that humans evolved from the great apes instead of having common ancestry.

Some of the misconceptions that were mentioned on the questionnaires were:

- The theory of evolution and the Big Bang theory are used as synonyms.
- The theory of evolution describes the origin of the Earth.
- Evolution describes geographical changes to the planet, such as plate tectonics and environmental change.
- Evolution is only a theory. It is not proven and is only speculation.

In the pre-test these misconceptions occurred in all groups, but were absent from all groups in the post-test, except for the group consisting of learners with strong religious objections.

Learners' religious objections toward evolution tend to increase during tuition

The religious groups showed many objections in the pre-test and gained a few more objections during tuition. When asked to describe how they felt about learning about evolution the learners with religious objections used an array of descriptions of which all were negative, showing strong overall dissatisfaction. Many of the learners also stated that the learning of evolution should be optional, perhaps triggered by negative viewpoints of their teachers regarding the topic.

COMPARING THE FINDINGS TO THOSE OF SIMILAR MUSLIM AND HINDU STUDIES

Yalvac (2011) conducted a similar qualitative study focusing on teachers and learners from the Islamic faith, based on interviews with teachers and learners in four Muslim schools in the Gauteng province. The interviews with learners were conducted before and after being taught the section on evolution, and it was found that, as with many Christian teachers and learners, the Muslim teachers and learners had great objections to evolution as they believed it to be in conflict with their religion. They taught and studied evolution for the sole purpose of passing exams. Many of the teachers interviewed were creationists and believed that all life on Earth was created by Allah. This correlates with many Christian teachers who are creationists and believe that God created life in seven days, as stated in Genesis 1.

The Muslim teachers observed that most of their learners held negative views on evolution and describe it as "boring" and "uninteresting", once again correlating with the findings of this study. Yalvac (2011) found that the teachers in his study actively discouraged the learners to accept evolution.

In stark contrast to the Muslim and Christian teachers and learners, Reddy (2012) found in her study on Hindu teachers and learners that they found little or no conflict with their religion and evolution. This is mainly due the theory of evolution and the Hindu faith sharing many themes. For instance, Hinduism subscribes to the notions of reincarnation and avatars that can both be linked to evolution. Most Hindus believe in reincarnation of the soul, and this soul is every time re-born into a new physical body. Since they believe in "spiritual evolution", where the soul every time that it is reborn shows higher levels of "Karma", most Hindus have little problem in believing in physical evolution. The teachers and learners could easily assimilate the new information into their worldviews, whereas their Muslim and Christian counterparts had to accommodate the new information into their worldview, thus creating tension and conflict.

However, this is only part of Reddy's findings. Another interesting trend emanating from her study was that many Hindus have very little knowledge of the Hindu scriptures or doctrines. It would be interesting to see whether there is more resistance towards the theory of evolution when Hindu people are more knowledgeable about the Hindu scriptures and doctrines.

Evident from all three studies is that teachers and learners have many misconceptions with regards to the theory of evolution. These studies also indicate that there should be sensitivity when teaching evolution, since where there are strong (fundamentalist) religious viewpoints, radical conceptual change is needed, and "hot" factors (such as religious objections) undermine true conceptual change.

RECOMMENDATIONS

Address the misconception that evolution is only a theory by placing a greater focus on the nature of science

The misconception that the theory of evolution is only an opinion of the scientific community and that it is only speculation without proof should be addressed by placing more focus on the nature of science.

Dagher and Boujaoude (2005) state in their study with Lebanese students that the NoS should be taught before evolutionary theory can be understood. We recommend that the nature of science should be an essential part of all the learning areas that pertain to science. If the tenets of science are introduced to learners at a young age they would have a greater appreciation of the large body of evidence used to construct the theory of evolution. More commonly accepted theories, such as that of gravity as discovered by Newton or the work of Galileo, need to be taught as part of the Natural Sciences curriculum in the younger grades, with the underlying theme of the NoS. If learners are familiar with an array of theories by the time they are exposed to the theory of evolution they would probably accept evolution as a viable theory to explain the abundance of diverse organisms on the Earth.

This misconception and others like it should be addressed before tuition on this section begins.

Unfortunately, many science teachers do not understand the tenets of the NoS (De Beer & Ramnarain, 2012), therefore these aspects should receive more attention in teacher education curricula.

Improved understanding and explanation of the concept of common ancestry

Another misconception that surfaced in the questionnaires was that the theory of evolution implies that humans developed from other contemporary primates, whilst the theory of evolution actually implies that humans and other contemporary primates had a common ancestor. This misconception drives the notion that brings evolution into conflict with religion. According to *Genesis* 1, humans are created in the image of God. Fundamentalists argue that if one accepts that humans evolved from apes one therefore accepts that God himself is an ape. Christians experience this as a personal attack on their religion and it inhibits a thorough understanding of evolutionary theory.

We once again recommend that all misconceptions be dispelled before tuition on the section about evolution starts. If all the misconceptions are dispelled at an early stage it will remove some of the barriers to the affective learning of evolution. This applies to any form of tuition and teacher training.

There is also a call on all leaders in the field of evolution to be more visible in the public eye to assist in dispelling the many misconceptions that exist about evolution. Blackwell *et al.* (2003:60) is of the opinion that university professors have a significant role to play in promoting the value of evolution.

Teachers also need to think deeply about their own dispositions towards knowledge.

CONCLUSION

This study has strived to determine the lived experiences of Christian Life Sciences learners on the incorporation of evolution into the curriculum. It was noted that a large number of similar studies had been conducted in other countries, but that a study from a South African perspective was lacking. The findings show that many learners experience conflict between their religion and evolution and that learners have a relative naïve understanding of evolution before tuition and have many misconceptions. A polarisation can be seen after tuition. Learners move from a neutral stance into either a more creationistic or scientific point of view.

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FIRST YEAR PHYSICS STUDENTS' ABILITIES AND DIFFICULTIES IN SOLVING KINEMATICS PROBLEMS IN VARIOUS CONTEXTS

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Abstract–The topic of students' application of conceptual knowledge in physics is constantly being researched. It is a common occurrence that students are able to solve numerical problems without understanding the concepts involved. This study investigates the extent to which a group of first year physics students were able to identify and use the correct physics concepts when solving problems set in different contexts. Furthermore, this study aimed to identify underlying factors giving way to students not applying appropriate physics concepts. A questionnaire was designed in test-format, in which all the problems dealt with two objects whose movement had to be compared to each other. The physical quantities describing or influencing the objects' movement differed in each consecutive problem; whilst the nature of the concept under consideration remained the same. The problems were designed to include:

- Formal conceptual questions, some with numeric values;
- Conceptual questions, comprising of contextual questions with no numeric values, and contextual questions with numerical values to be calculated;
- Questions on vertical upward and downward motion.

The questionnaire was distributed to 481 students in the first-year physics course at the NWU Potchefstroom Campus. It was the authors' expectation that problems with numeric values would yield the highest percentage correct answers, and that the percentage of correct answers would reveal discrepancies in the responses to contextual, numeric and formal conceptual questions. The outcome of the statistical analysis confirmed this expectation. In addition, it seemed that only a few students were able to correctly identify the appropriate variables when considering vertical upward and vertical downward motion. It seemed that the context in which the question was posed determined whether the problem was seen as an item that would require "physics reasoning" or as a setting where physics reasoning did not apply. This observation was further investigated in the qualitative component of this study. In light of these findings, some suggestions were made to sufficiently rectify these misunderstandings of students in solving physics problems. It is envisaged that this study would contribute reasonably in suggesting ways of identifying and addressing the concepts which could aid students to solve physics problems by applying the appropriate knowledge.

Keywords: Conceptual knowledge, conceptual understanding, pre-existing knowledge, context of problem.

MOTIVATION FOR STUDY AND RESEARCH PROBLEM

When students understand the physics concept, not only can they solve the problem, they can transfer what they know to unique situations (Concannon, 2012:14). According to Singh (2007:196) learning physics requires the unpacking of the few principles and concepts that are condensed into a mathematical form – physics equations – and understanding their application in various contexts where the same law of physics applies. This study aimed to clarify what students regarded as "various contexts", to determine what the context in which problems were set tell us about student understanding of the underlying physics concepts and to obtain insight in students' use of equations to assist their conceptual reasoning.

LITERATURE STUDY

Pre-existing knowledge

Mechanics is an important topic taught mainly in the first course of physics and passing the topic is generally a prerequisite for admission to advanced topics (Halloun & Hestenes, 1985:1044). Knowledge of mechanics is therefore essential to students' performance in their physics courses. This study focused on kinematics which deals with the relationships between forces acting on objects and the effect of those forces on their movement.

Every student that enters introductory physics has a system of beliefs and intuitions about physics as a result from their personal experience and observations (Van Heuvelen, 1991:891; Halloun & Hestenes, 1985: 1043; Piburn, Baker & Treagust, 1988:3; Singh, 2007:196; Sherin, 2005:535; Gönen, 2008:70; Kavanagh, 2007:21). Halloun and Hestenes (1991:891) maintain that students interpret physical phenomena according to those intuitive beliefs to make sense of everyday occurrences. Inconsistencies in students' beliefs about physics in the world around them prove to be a major obstacle in students' ability to draw conclusions from everyday observations of the physical world (Hedge & Meera, 2012:1). One misconception, an intuition that is incorrect, is Aristotle's assertion that the speed of a falling body is proportional to its weight (Kavanagh, 2007:24, Halloun & Hestenes, 1985:1057). According to Halloun and Hestenes (1985:1057) students' intuitive beliefs about motion are mostly incompatible with Newtonian theory and as a result, students tend to misinterpret elementary concepts taught in introductory physics courses.

Students are expected to learn concepts formulated by Galileo, namely that gravity is a non-contact force that acts at a distance, that free falling objects with different masses hit the ground at the same time and how objects in free fall accelerate (Kavanagh, 2007:26). Kavanagh, (2007:25) reported that parallels between historical Aristotelian ideas and student thinking exist; such as that heavier objects fall faster. Although Galileo formulated his concepts after quantitatively investigation of the movement of a ball along an inclined plane, he did not explain why objects with unequal masses would fall with the same acceleration. Newton's three laws provided an explanation for this and related phenomena. According to Halloun and Hestenes (1985:1057) discrepancies between students' common sense concepts and Newtonian concepts describe what students need to learn.

A primary objective in teaching introductory physics is to help students obtain effective understanding of physics concepts, while a secondary objective is to enable students to effectively use their knowledge to analyse new physics situations (Leonard, Dufresne and Mestre, 1996:1495). Hedge and Meera (2012:1) maintained that problem solving plays a very important role in building cognitive knowledge but it is a common occurrence that students are able to solve numerical problems without understanding the concepts involved (Cracolice et. al., 2008:873; Kim & Park, 2002:759; Concannon, 2012:14). Findings suggest that students' conceptual understanding after completing a traditionally taught physics course is much weaker than anticipated (Leonard et al.,1996:1496). Conceptual understanding and problem solving are constantly being researched with much time devoted to the instruction and assessment thereof. (Schuster & Undreiu, 2009:265; Piburn, M., Baker, D. R. and Treagust, D. F. 1988 Gönen, 2008:70; Hedge & Meera, 2012). Heyworth (1991:195) maintained that the main approach of research investigating problem solving stems from the information-processing theory. According to the information-processing theory, construction of representations of the problem based on a conceptual understanding of information given in the problem statement is the first of two mental processes involved in problem solving. The second process involves the use of a strategy to guide the procedure of searching for a solution from the information and data given to the required answer (Heyworth, 1991:195-196).

Bransford (as cited in Jonassen, 1997:66) maintains that information processing theories regard learning as a skill that can be generalized and applied to any content domain but Jonassen (1997:66) argued that according to constructivism and situated cognition theories, problem solving is dependent on the domain and context and that different skills are involved in solving problems in different contexts and domains. According to Singh (2007:196) cognitive theory suggests that knowledge is encoded in memory in the context it was acquired and that transfer can be difficult if the contexts of the encoded and intended knowledge do not share the same features. Hedge and Meera (2012: 2) motivated that the usage of different representational formats is also a factor that guides student ability in problem solving.

Conceptual understanding and equations

Students often look for equations to manipulate in order to isolate the unknown that must be determined (Van Heuvelen,1991:892) and are unable to identify the major law or principle that describes the specific situation (Leonard 1996:1496). Writing down an equation that represents the problem is a useful way to summarize the information (Singh, 2007:196) but this can add to students' inability to identify the underlying concept, especially if the law or concept which is represented by the equation is only stated verbally (Leonard et al.,1996:1496). Students think that the principle objective is to solve problems by manipulating equations that leads to the solution and that the underlying physics principles are conclusions that has little relevance to obtaining (i.e. calculating) the answers to problems (Leonard et al.,1996:1496). Equation hunting (Hedge & Meera, 2012:2)) promotes rote learning that affects problem solving ability and causes students to disregard the concept features of a problem.

According to Leonard et al., (1996:1498) beginner students often do not understand the conditions under which equations are applicable and what their restrictions are. Experienced physicists start to solve novel problems by qualitatively analysing the underlying concepts and principles and then identify possible mathematical representations of the concepts that can be implemented in solving the problem (Leonard et al.,1996:1498; Schuster & Undreiu, 2009:265; Van Heuvelen, 1991:891; Sherin, 2007:535). Both Singh (2007:196) and Leonard (1996:1499) maintain that there are but a few principles and concepts in physics that are condensed into compact mathematical equations which represents the relationships of the applicable variables. According to Van Heuvelen (1991:893) students do not understand the meaning of basic quantities and concepts represented in all representational formats. Hedge and Meera (2012:2) found that the weak association of students' conceptual framework to the physical principles is a major deterrent in problem solving. Students' tendency to view equations merely as mathematical representations instead of relations between physical quantities attributes to their inability to connect the symbols to the physical quantities. According to Concannon, (2012:22) students should be able to understand and transfer simple concepts to more complex problems but Singh (2007:196) argued that unpacking these mathematical forms and understanding how to apply them in various contexts makes transfer in physics quite challenging

Application of physics principles

Schuster and Undreiu, (2009:266) described principle-based reasoning (PBR) as solving problems by systematically applying fundamental physics concepts and principles. According to Cracolice et. al. (2008:873) students with poor reasoning skills find it very hard to solve conceptual problems. Although it is logical to identify the physical principle applicable to the situation, students' weak ability to associate a conceptual framework to the physical principles acts as a major obstacle in problem solving (Hedge & Meera, 2012:2).

Research by Elby (2001:S54) indicates that some students believe learning consists of just absorbing information and they view physics as pieces of information that are not really connected and should be learned separately. Other students equate physics with a coherent web of ideas to be tied together (Elby,2001:S54). Students with the latter view understand the importance of deeper understanding and that learning physics involves refining your everyday thinking.

Teachers often create situated learning instead of facilitating students' understanding of physics concepts. As a result students' knowledge of physics concepts is relative to how familiar the problem they are trying to solve is to them (Concannon, 2012:14).

RESEARCH DESIGN

The term *Research Design* refers to the decisions a researcher makes regarding the way the research will be approached. It describes how the researcher plans to proceed to answer the research questions (de Vos, Strydom, Fouche, & Delport 2011:73). The research design of this study is represented in Figure 1.

Figure 1:Schematic representation of the research design of the empirical study

This study consisted of a quantitative as well as a qualitative part which were conducted consecutively. The sequential explanatory design was especially useful since unexpected results were acquired in the first phase which could be clarified during the qualitative phase (Hedge & Meera, 2012:3). The data for the quantitative part of the research was acquired in a survey by means of a questionnaire and was followed by semi-structured interviews of participants in an attempt to clarify results obtained from the first phase.

In the quantitative part of the study the extent to which students were able to apply conceptual knowledge in formal and in everyday contexts was investigated. Items that allowed comparison of students' conceptual knowledge versus conceptual understanding and items that investigated students' ability to apply physics conceptual knowledge in various contexts were included in the quantitative study. The questionnaire consisted of multiple choice items with four options for each item. The options provided were carefully constructed to include options that would reveal misconceptions students may have in order to determine the extent of its' influence on students' competence in solving kinematic problems.

The questionnaire (attached as appendix) contained formal conceptual items, items set in everyday context and some conceptual items with numerical values. To investigate the effect of direction of motion on students' responses, two items were set in vertical upward and four in vertical downward direction. In each question the movement of two balls of unequal mass had to be compared.

One or more of the physical quantities were changed and the effect of the change had to be predicted. The physics principle in all questions was: objects in *free fall* have equal acceleration regardless of their mass; i.e. gravity exerts a force on any object with a magnitude that results in all objects having equal acceleration. Free fall meant that the force of gravity was the only force acting on the object, thus no friction or air resistance. With no opposing force acting on the objects their motion was not influenced by their mass, hence when released from or projected to the same height, the time needed to cover the distance would be the same and they would travel at the same speed at any given time.

The questionnaire consisted of six items of which the first four were set in vertical downward motion and two were set in vertical upward motion (items 5 and 6). Three of the questions were presented in a formal physics setting while the others were set in everyday context (- referred to as contextual questions). In two of the contextual questions values were given which the students could use to help them solve the problem although the options were still given as “the heavier ball, the lighter ball; both simultaneously or the same”. Item 1 was used as a base question to which the other questions were compared.

The use of these isomorphic problems allowed comparison of students’ responses to items with different contexts (Singh 2007:197). The problems are called isomorphic because students had to apply the same physics principle to solve the problems (in the absence of air resistance, all objects experience the acceleration of gravity, irrespective of their mass). Students’ responses served as guidelines to determine which setting would be the more reliable indication of their conceptual understanding of the relationship between of gravitational force, mass and acceleration. We expected that students who attained and understood this conceptual knowledge would use physics thinking frameworks in contexts that might otherwise have triggered their intuitive knowledge (heavier objects fall faster). In each item two balls with unequal mass covered the same distance with the force of gravity the only force acting on the balls (i.e. absence of friction and air resistance). Either the initial or the final speed was given or could be deducted. In none of the items diagrams were given to assist the students, i.e. all the items were verbal representations of the settings. In items 1 and 4 the students had to compare the travelling time of two falling objects, in items 2, 3 and 5 either the initial or final speed had to be compared and in item 6 the height that the objects reached had to be compared. Items 1 and 5 were identical except that the balls were projected upward to reach a certain height in question 5 whereas in item 1 they were dropped from the same height.

The questionnaire was completed by 481 students enrolled for first year physics at the Potchefstroom campus of the North-West University.

The data for the qualitative part were obtained by means of unstructured individual interviews with three students. Student A obtained an A symbol for physical science in grade 12, student B is a very high achieving student who averages between 93 and 98% for physical science and student C maintains an average of 70% for physical science. The semi-structured interview approach was aimed at determining reasons for students’ choice of options and identifying elementary principles which lacked in students’ thinking framework that prevented development of conceptual understanding and application of physics concepts. The students were asked to explain why they chose the specific options in the questionnaire items. If the explanation were incorrect or when they struggled to choose an option, they were encouraged to identify the variables that were applicable and later also to use equations that described the problem to aid their reasoning. The responses were written down and analysed. The results of these interviews were used as guidelines for the semi-structured interviews we planned to conduct with a representative sample of the research group that still needs to be done.

HYPOTHESIS

We expected that the numerical items would be answered more correct than the other items, in accordance with previous research (Cracolice et. al., 2008:873; Kim & Park, 2002:759). We did not expect that the direction of vertical movement and the items set in everyday context would influence the students’ responses much. If students understood the concept of free fall and gravitational acceleration the direction of movement shouldn’t influence their answers and they should be able to answer items in everyday contexts as well as in any other contexts (Concannon, 2007:14).

RESULT OF THE QUESTIONNAIRE

The frequency table for students responses to the questionnaire items is presented as Table 1.. We described the context in which the items were set by means of the following abbreviations: F =

formal conceptual setting; C = everyday context; N = numerical context; ↓ = vertical downward movement; ↑= vertical upward movement; t= falling time had to be compared; v= initial or final speed had to be compared.

Table 1: Percentages of students' responses to questionnaire

	Percentages of students' answers to items %					
Item	I 1	I 2	I 3	I 4	I 5	I 6
Context	F ↓ t	F ↓ v	C ↓ v	C N ↓ t	F ↑v	F ↑N
% correct	83.99	69.02	29.11	63.62	34.93	43.87
Heavy object moves faster	14.76	24.53	48.44	34.59	51.98	32.56

From the high percentage of correct answers for item 1 we would assume that students knew the principle of objects in free fall having the same acceleration and hitting the ground at the same time. The setup for items 1 and 2 were the same, both were formal conceptual questions in the vertical downward direction. The only difference between the two items was the physical quantity (time or speed) that had to be compared. Although the correct percentage for item 2 is still high, it is noticeably lower than that of item 1. The low percentage of correct answers for item 3 was most surprising. Although items 3 and 4 were both set as contextual questions the percentage correct answers for item 4 was more than 30% higher than that of item 3. Items 5 and 6 were formal conceptual questions in an upward direction but were answered much poorer than in corresponding items 1 and 2 for downward motion.

From the incorrect options that were chosen, students mostly chose one that implied that the heavier object would fall faster implying that either the travelling time would be less or the speed would be more. Approximately half of the students (~50 %) revealed this misconception in items 3 and 5.

DISCUSSION OF QUANTITATIVE RESULTS

Items 1,2 and 4 were answered most correctly. Setups similar to that of items 1 and 4 are often encountered in textbooks and exam papers. It is often used to teach and explain that objects, regardless of their mass, fall at the same rate in the absence of air resistance. From the result of item 1 it seemed that most of the students "knew" this. We expected that item 4 would be answered similar to item 1 but the difference of 20 % in the percentage correct answers indicated that the benefit of an option that allowed for a calculation was cancelled by the everyday context in which item 4 was set. The difference of 15 % between the results of items 1 and 2 was unexpected and it seemed that the students knew *of* the principle but did not know what the implications of the same falling rate had on the final speed.

The large difference in the percentages of items 3 and 5 compared to that of item 1 indicated that the knowledge the students apparent had, was constricted to the familiar setting of item 1. The contextual setting of item 3 was apparently not linked to the setting of item 1. The quantitative results of item 3 as well as the results from the interviews suggest that the students had difficulty in transferring their formal physics reasoning to a problem not involving friction. The fact that students did not take advantage of the problem not involving friction suggests a lack of understanding of the concept of friction. This is in accordance to research done by Singh (2007:197). We ascribe the increase in the percentage of correct answers of item 6 compare to item 5 to the numerical values in item 6 that allowed for a calculation to be done. We deduce that problems with numerical values were indeed answered more correctly than those without numbers but that the influence of everyday contexts was a much more impedance than the benefit of numerical values. As is maintained by Singh (2007:197) it seemed that students were aware of the relevant variables and the relationships but did not use them to help solving problems.

The results also indicate that students have the perception that problems set in everyday context, has no connection to the physics concepts and principles applicable in a formal context. When the familiar formal conceptual context was altered many students did not apply the basic principles to the new situation. A formal “impersonal” problem statement apparently indicated that formal physics reasoning should be applied but informal or everyday contextual settings cause them to apply their pre-existing knowledge. Even having access to the relevant equations did not help most students to proceed in solving the problems. Students were aware of the relevant variables and the relationships but did not use them as thinking tools to transfer the knowledge they presumably had to the new context (Singh, 2007:197). Students also had difficulty in applying physics concepts if the direction of movement changed.

The large percentage of students that chose the option of the heavier object falling faster or reaching the higher speed in this questionnaire, confirmed that this misconception is still very much prevalent amongst our students. This is in accordance with reports from studies on fourth year university physics students who were asked to answer questions about objects in free fall indicate that more than 50 % of the students stated that the heaviest object would take the shortest time to fall (Kavanagh 2007:33).

INTERVIEW RESULTS

After interpretation of the statistical analysis of the questionnaire three students who were not included in the research group, were individually interviewed. Two of the students are in grade 12 and one is a physics student at a different university than the one where the research was conducted. The purpose of these interviews was to use the results as guidelines to construct questions for use in the semi-structured interviews in the qualitative section of the research project.

Item 1:

Student A : “Air friction is ignored so it is an isolated system. Only gravitation is applicable.... The balls will reach the ground at the same time because they have equal gravitational *force*.” (She is unsure under which circumstances mass will have an influence on the movement).

Student B: immediately wrote down the equation $y = v_i t + \frac{1}{2} at^2$ and identified y, v_i and a for both. She said: “From the equation $y = v_i t + \frac{1}{2} at^2$ I infer that for ball 1 (*m*) and ball 2 (*2m*) the following vectors are the same; *y*: because they fall the same distance; $v_i = 0$ for both; a =the same (always =*-9.8* m.s^{-2} for free falling objects). Mass doesn’t appear in equation <u>therefore it plays no role</u> and both balls will hit ground at same time”.

Student C: “I think that mass doesn’t play a role because there is no air resistance so the balls will hit the ground at same time, but I am not sure”.

When asked to identify and compare variables that were applicable Student C drew a neat table; and proceeded to write the variables in two columns using words instead of the physics symbols. He asked: “Is the acceleration gravitational acceleration?” He decided that it was because “at school we always took -9.8”. He wrote down the equation $v_f = vi + at$. He wanted to substitute values for the variables but ends up comparing the variables qualitatively and managed to solve the problem.

Item 2:

Student A “The balls will have the same speed if they reach ground at the same time; because the item is related to the previous one and all variables are the same”.

Student B: She wrote down equation: $v = u + at$ and said: “From item 1 the time is equal and if they fall from rest then all variables are the same therefore the final speed will be the same”. She commented:“ no kinematic equation contains mass”

Student C “I think that because there is no air resistance, mass doesn’t play a role and the balls will have the same speed”.

Item 3

Student A: “A larger mass causes larger acceleration therefor the larger mass will reach the higher speed”. Then she asked: “What exactly does it mean if it says frictionless?”.

Student B: She started to draw a diagram of an inclined plane and indicated the component of gravity parallel to the plane and reasoned: "On larger mass the force will be larger". She wrote down: "$3\ F_{net} = 3\ ma$" then cancels out the 3 on both sides of the equation. "So the heavier person will have the same acceleration and therefore same speed as the lighter person".

Student C: "In my experience with a super tube, heavier persons go faster, but this not the same here because it says frictionless". He chose the option stating that the greater weight caused greater acceleration and drew a diagram of an inclined plane and wondered "-- is it a bigger force or bigger acceleration?" He reconsidered and wanted to give the correct answer but needed to convince himself because of his intuitive feeling that heavier objects move faster. When probed to expand on the nature of the resultant force and on acceleration, he decided that the objects would have the same speed.

Item 4

Student A: "They will hit the ground at the same time, I remember the examples we did in class - objects will hit ground simultaneously".

Student B: "This question is the same as some of the previous questions and the same equation applies here. Because mass doesn't appear in the equation it has no influence on the acceleration of free falling objects, therefore both will hit the ground at the same time". .

Student C: This student was very unsure but when the interviewer suggested the he should identify and compare the variables, he managed to solve the problem.

Item 5

Student A: "The heavier ball must have larger initial velocity to reach the same height as the lighter ball".

Student B: Started with $F = ma$; crossed it out and wrote $x= v_i t + \frac{1}{2} at^2$. "The time they are in the air is the same and their final speed at the top is zero. And they reach the same height...." - Refers to the equation. "....therefore the initial speed must also be the same".

Student C: Considers using an equation: "Mass has no effect because it is not included in the equation. I remember a demonstration of a tennis ball and a cricket ball ....no, mass has no influence so I think they will have the same speed". He asked what the difference between the influence of same force and the same acceleration was, then realised that equal forces could not cause the same acceleration for objects of unequal mass. He relaxed visibly and chose the correct option.

Item 6:

Student A: When the student was asked to identify the variables, she drew a schematic representation of the problem. She identified the variables and chose an appropriate equation. She then realised that if air resistance and friction were ignored the acceleration of both of the objects equalled gravitational acceleration and that the objects would reach the same height. She then corrected the answer of item 5 as well.

Student B: Wrote the equation: $v = u + at$. The student compared the variables and decided that the balls would reach the same height.

Student C: The student appeared confident. He identified the variables, chose an appropriate equation and used the equation in his explanation to prove that the balls will reach the same height.

DISCUSSION OF INTERVIEW RESULTS

Student A discriminated between formal physics setting and contextual settings. In her opinion formal conceptual settings indicate that physics equations should be used to solve the problem. Problems in everyday context seemed unrelated to physics principles and the student relied on her intuitive knowledge instead of trying to apply his/her conceptual knowledge. Student A wrote the following comments on the questionnaire and interview: "Drawing a diagram and using equations definitely helped me to realize that if air friction is ignored free falling objects will hit the ground at the same time regardless of their *weight* because gravitational acceleration is the same for both. It (the principle) also applies to practical objects (everyday contexts) although it doesn't feel logical.

Student B wrote the following comment on the questionnaire "Conceptual questions appear more difficult than contextual questions, which seems friendlier, but is not interpreted in terms of physics concepts. When values are given, the problem looks easier. Students often search for familiar questions to use as blueprints or templates to solve new problems". Student B's last comment that students look for similar problems to serve as examples or guidelines to solve unfamiliar problems is a perfect example of what Schuster and Undreiu, (2009:266) call case-based reasoning (CBR). In CBR students retrieve formerly compiled knowledge of similar cases and instead of constructing a new principled solution try to adapt the features of the former cases to the current one. This inability to apply knowledge pointed to a lack of conceptual understanding.

Student C's remarks on the questionnaire were "I struggled to make the connection between mass, acceleration and friction but now I realised that the *net* force isn't the same as the *applied* force and that makes a difference. Now I know to compare variables in questions without values and use equations to explain my reasoning".

CONCLUSION

While the result of item 1 would lead one to believe that students knew the principle of gravitational acceleration of free falling objects being constant the results of the other items clearly indicate that there is a major lack of understanding of the principle and ability to apply even this elementary physics concept.

As the two higher performing students stated in the interviews it seemed that students generally find it hard to adapt their intuitive reasoning to a physics thinking framework when they are confronted with problems set in everyday contexts. It was very interesting to observe that the result of items 5 and 6 corresponded with the results of the contextual items and therefore we deduce that the direction of motion can be regarded as a different context along with everyday context. Using an item set in another context than formal conceptual i.e. in opposite direction or in everyday context, would be a much more accurate way to determine not only whether students know but also whether they understand the principle of objects in free fall experiencing gravitational acceleration.

The students, who initially did not use equations to aid their reasoning, benefitted from guidance in this regard and were ultimately more confidant in using the physics equations not only to solve the problems but also to adapt their thinking framework to a physical conceptual thinking framework. There may be room for developing the skill of using symbolic forms to assist transfer of intuitive knowledge to formal knowledge by means of equations and we suggest that the role of qualitative reasoning in this regard should be investigated and expanded.

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APPENDIX: QUESTIONNAIRE ITEMS

Item 1: F ↓ t Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. Air resistance can be neglected. Which ball will reach the ground first? 1. The heavier ball. 2. The lighter ball. 3. Both will reach the ground simultaneously. 4. Not enough information is provided.	Item 2: F ↓ v Which ball in item 1 will reach the ground with the largest speed? 1. The heavier ball. 2. The lighter ball. 3. Both will reach the ground with the same speed. 4. Not enough information is provided.
Item 3: C ↓ v While in a playground you and your little niece slide down two frictionless slides of similar height. Your mass is three times the mass of your niece. Assuming that both of you begin sliding from rest, which one of the following statements best describes who has a larger speed at the bottom of the slide? 1. Your niece because she is not pressing down against the slide as strongly so her motion is closer to free fall than yours. 2. You because your greater weight causes a greater downward acceleration. 3. Your niece because lighter objects are easier to accelerate. 4. Both of you will have the same speed at the bottom.	Item 4: C N ↓ v During a family outing to the amusement park, a mother decides to take her little son on a rollercoaster ride. At the highest point of the ride, 30 m above ground level, the mother's heavy handbag (2 kg) as well as the little boy's small stuffed teddy bear (0.5 kg), accidently falls out of the car at the same time. The father, watching from the ground, decides to try and catch the two objects. Which statement is true for the time it takes for them to reach the ground? (Air resistance can be neglected). 1. The handbag will reach the ground first. 2. The teddy bear takes 4 times as long as the handbag. 3. Both will reach the ground simultaneously. 4. Not enough information is provided.
Item 5: F ↑v Two metal balls are the same size but one weighs twice as much as the other. The balls are projected upwards from the ground to reach the roof of a single story building at the same time. Air resistance can be neglected. Which statement is true about their initial velocities? 1. The heavier ball must have the larger initial velocity. 2. The lighter ball must have the larger initial velocity. 3. Both are projected with the same initial velocity. 4. Not enough information is provided.	Item 6: F ↑ N A 1-kg ball and a 5 kg ball are thrown into the air both with an initial vertical velocity of 30 m/s. Ignore the effect of air resistance. Which statement is true for the heights they reach? 1. the 1 kg ball reaches a height of 45 m. 2. the 5 kg ball reaches a height of 9 m. 3. they will reach the same height. 4. not enough information is provided.

INVESTIGATING RESISTANCE TO ACTIVE LEARNING IN A HIGH SCHOOL PHYSICS CLASSROOM

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Abstract–This paper investigates the impact that resistance to active learning has on high school students' ability to learn physics. This case study investigates the impact that resistance to active learning has on high school students' ability to learn physics. Action research was implemented, evaluated, and modified over two cycles as a strategy to reduce resistance to active learning. Data was collected using surveys, questionnaires, informal interactions with students during class time and results from the Force Concept Inventory. The study found that a combination of these interventions had an effect size of d=0.26 for the domains of student views of active learning and views of learning science, and an effect size of d=0.13 for student views of collaboration. While the students in the second cycle demonstrated a measureable improvement in conceptual understanding compared to those in the first cycle, the extent to which the interventions investigated were the primary cause is unclear. It can be concluded that the methods employed in cycle 2, to decrease student resistance to active learning methodologies and improve the attainment of the objectives of the course, were successful.

Key words: Active learning, action research, Force Concept Inventory, diffusion theories, epistemology.

INTRODUCTION

Traditional methods of instruction are relatively ineffective in bringing about deep conceptual understanding in the introductory physics classroom (Crouch, C, Watkins, J, Fagen, A & Mazur, E. 2007:5). If students are to learn physics in such a way that they understand the concepts as opposed to simply knowing how to apply algorithms in solving problems, they must be actively engaged with the material. Various instructional methods have been developed and proven effective in these regards as demonstrated through the use of pre- and post-tests such as the force concept inventory (FCI) (Hestenes, Wells and Swackhammer 1992:141-158) and the force and motion conceptual evaluation (FMCE) (Thornton & Sokoloff 1998:338). These methods include *Just-in-Time Teaching* (Formica, Easley, & Spraker 2010:1-7), *Interactive Lecture Demonstration* (Bernhard, Lindwall, Engkvist, Zhu & Degerman 2007:2), *Peer Instruction (*Crouch & Mazur 2001:970) and *Modeling* (Hestenes 1996:8) to name just a few.

However, there is generally a high degree of resistance to active learning instructional methods (Felder & Brent 1996:43). For the most part, students are accustomed to traditional methods of instruction in which the teacher presents information lecture-style while the students passively receive it. This type of instruction often translates into an expectation by students that an effective physics education is one in which they receive information but are not required to work at applying it in the classroom. While the efforts of physics education research (PER) and other educational reforms have resulted in positive changes in the classroom, very little work has been done to document the nature of student resistance to active learning, the effect that it has on students' ability to learn, and what can be done to assist students in overcoming this resistance.

One way to examine this issue is to consider student epistemologies. Surveys such as the *Maryland Physics Expectation Survey* (MPEX) (Redish, Saul & Steinberg 1998), the *Colorado Learning Attitudes about Science Survey* (CLASS) (Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman 2006), the *Epistemological Beliefs Assessment for Physical Science* (EBAPS) (White, Elby, Frederiksen and Schwarz 1999) and the *Views About Science Survey* (VASS) (Halloun 2001) were developed and administered to determine what attitudes, beliefs, and expectations students hold regarding the nature of science and the nature of learning science. Researchers are using these tools effectively to determine how attitudes, beliefs and expectations affect what and how much students learn in a science classroom.

This paper reports on strategies that a high school physics educator implemented to reduce student resistance to active learning, the results of the action-research study that was undertaken, and conclusions drawn from the data. The study was guided by the following questions: Can student performance be investigated by Forced Concept Inventory (FCI)? Will regularly describing and discussing with students the benefits of active learning result in an improvement in student achievement in a high school physics class?

THEORETICAL FRAMEWORK

A variety of theories of learning have been postulated in relation to individual learning including constructivism and cognitive load theory. Each of these has the potential of enhancing the physics classroom, though constructivist approaches appear to have more utility due to the nature of the discipline. Active learning pedagogies have been established on this foundation, and physics education researchers have documented evidence showing convincingly that these instructional methods are effective. However, it has also become evident that student epistemology plays an equally significant role in how well students are able to learn. Student perceptions of the nature of the material that they are studying, how learning should take place, the purpose of learning, and conceptions of what their role in the learning process should be all heavily impact the learning process. For this reason, epistemological surveys should continue to be developed, administered, and the results studied in order to inform researchers how to integrate curricular and epistemological elements of instruction.

To date, comprehensive and well-informed epistemological surveys have been developed. However, there has been a lack of work done in the area of collaboration and student's views of it. Collaborative approaches in education are necessary, not only to address the changing nature of science and the increased dependence on it in modern culture, but also because educational research has shown that it works. At the same time, research has revealed that many students are resistant to active-learning and collaborative approaches. There are a variety of possible reasons for this, but having an understanding of why this is the case as well as knowing the factors that may favorably shift this resistance would benefit educationists. Diffusion theory is an avenue that could provide additional insights regarding how to effectively move active learning from an innovation to main-stream pedagogy.

CLASSROOM SETTING

The study took place at an independent school in a suburb of Vancouver, British Columbia (BC). The curriculum in BC is such that students in grade 11 have had very little prior instruction in physics. This results from the spiral model upon which it is based, in which biology, chemistry, earth science, and physics are taught as units within a general science program from primary school to the end of grade 10. Science in grade 10 is a survey course which allocates 20% of the curriculum to physics instruction. The physics content of this course is minimal and is generally taught by teachers who are more likely to have training and experience in biology or chemistry. For this reason, most students entering physics courses in grade 11 have received very little formal training in physics. The school in which the research took place is an independent school which offers grades nine through 12 and the school population of approximately 480 students is divided equally amongst the grades. The students attending the school generally come from families with a slightly higher socio-economic status than the average of the students attending public schools in the surrounding area, and greater than 90% of the graduates attend post-secondary institutions within two years of completing grade 12.

Both of the classes involved in the study (one for each cycle) were typical for physics classes in the school. The demographics were consistent with those of the past several years, and the pre-test results on the FCI were consistent with data that had been collected for the previous two years. The two groups of students in the study had common backgrounds in the sciences, and both the classroom, resources available, teacher, and classroom setting were consistent in each case.

MOTIVATION AND METHODS

In this study, action research was used to probe the efficacy of various instructional methods in reducing student resistance to active learning pedagogies. The researcher was interested in exploring the possibility of a correlation between resistance and understanding of course content. Two cycles were completed over the span of two years. The instruction of the classes under study in both cycles could be described as non-traditional; the classroom setup consisted of round tables large enough to accommodate groups of five students and lessons typically included ConcepTests (Crouch C & Mazur E 2001: 970), interactive lecture demonstrations (Bernhard, Lindwall, Engkvist, Zhu and Stadig Degerman, 2007:2), peer instruction (Crouch & Mazur, 2001:970) and guided-inquiry labwork. The amount of time spent lecturing rarely exceeded 20% of class time. It was noted in various classes prior to the beginning of the first cycle that students were not always keen to be actively engaged during class time; this phenomenon was corroborated in published PER articles, thus giving rise to this study.

To provide a baseline of data, students in cycle one were given the FCI both pre- and post-instruction. While the topics assessed by the FCI represent only a small portion of the outcomes of the physics course under study, it was deemed a valuable assessment tool because of the significant prior work undertaken to ensure its validity and reliability. A survey was also developed and given to all grade 11 and 12 students taking a science course in the school at the time. It was administered approximately 80% of the way through the semester and consisted of three domains: student views of active learning, student views of learning science, and student views of collaboration. An emphasis was placed on the domain of active learning as this was the area deemed most pertinent to the goals of this study. The *Colorado Learning Attitudes about Science Survey* (Adams, Perkins, Podolefsky, Subson, Finkelstein, and Weiman, 2006) and the *Views About Science Survey* (Halloun, 2001) were referred to in the development of this survey. To increase the validity of the survey it was given to two other educators to complete, after which a session was held to discuss the test and determine how the questions were being interpreted. Changes were made to potentially ambiguous or vague questions. This same process was repeated with three students. A course evaluation survey was also developed and given to students at the completion of the course. It was comprised of thirty Likert statements and four open-ended questions and was aimed at gathering data regarding student views of how efficacious the structure of the course was in their minds.

After completing cycle one, the data was analyzed and significant changes to instruction and assessment were implemented in the second cycle as a result. For the second cycle, the same data collection tools were used at approximately the same point in the course as was done in cycle one. At the completion of the second cycle the data was analyzed and conclusions drawn.

COURSE MODIFICATIONS

Students in cycle one exhibited a significant resistance to many of the active learning methodologies that had been implemented. This resistance was detected through dialoguing with individual students, interacting with them during whole-group discussions, and examining data they provided on course evaluation forms. Reducing this resistance was the overall aim of cycle two, and data collected suggests that student resistance to active learning was decreased considerably during the second cycle.

As a result of the data collected in cycle one, it became evident that students did not understand why it was important for them to be active participants and collaborators in the physics classroom. Up to that point in the researcher's teaching career the main focus had been to educate students in the concepts of physics. With the recognition that students had much to learn regarding epistemology, there was a realisation that instruction needed to be multi-faceted in this respect, so instructional modifications were made and implemented in cycle two. Students were guided through a process to help them understand why they may have held some of their faulty notions, and were informed of the processes involved in learning something new. In all situations the discussions with the students were related to the learning of physics so that students had the opportunity to apply and see the effects of what was being discussed.

The data collected throughout cycle two revealed that students became less resistant to active learning pedagogies and were also more willing to work collaboratively with their peers than they had been previously. Triangulation of data sources confirmed that this change applied to the majority of students. This change may be attributed to the introduction of collaborative activities that had a high degree of structure and which guided students through the process of learning challenging material. Enough input was given that students were not required to rely solely on a common constructed understanding of the phenomena they were discussing. This change was based largely on data from cycle one that suggested students were often frustrated when expected to apply logic and reason to new scenarios in a largely unguided process. While it had been demonstrated that they were able to make positive gains in understanding through such activities, from the developmental stage these students were at, it was apparent that they were not ready for such a high degree of responsibility. When building in the additional structure, the development of student epistemology was purposefully considered and meshed with the activities. This addition essentially provided a map for students to follow as they learned to apply logic, reason, and past knowledge through the learning of new concepts. In the development of these activities, the researcher was also mindful that process was equally as important as the end product, and this resulted in a shift that encouraged students to take chances. Sometimes these modifications were successful, and when they were not it provided an opportunity to assess the learning process and encourage students to identify what went wrong and how to avoid the same mistakes in the future.

In cycle two, a regular pattern was implemented in which students were taken through a sequence of learning new content, considering the implications of the ideas presented in light of what they already knew along with the application of logic, discussing their ideas in a number of different contexts, and then having the process debriefed. Discussions focusing on the importance of each of these stages accompanied the activities, with the frequency of discussion being higher at the beginning of the course and diminishing as the students became more familiar with the process. The performance of the students in cycle two indicated that learning was significantly enhanced. And because the chief variables in this study were the learning activities used, along with a focus on enhancing student epistemologies, it would appear that regularly describing and discussing with students the benefits of active learning resulted in an improvement in student achievement.

A key factor that determines how successfully an innovation will be adopted is the extent to which it is attractive and has attributes that the target population finds compelling (Gladwell 2002:196-201). In addressing the importance of active learning, along with shifting the emphasis from the final product (an examination at the end of the course) to the process of learning, students were able to identify attributes that were important to them and as a result were more inclined to adopt the new approaches. It appears that this took place throughout the course as students became more willing to participate collaboratively in the learning process, as well as to appreciate the fact that their learning could be enhanced through interacting with their peers. However, it should be noted that the social environment also plays an important role in this process, and the particular class under study in cycle two had several influential individuals who could most aptly be described as laggards—those who tend to hold the status quo, viewing the adoption of an innovation as risky and waiting until the innovation has become mainstream before adopting it themselves (Oldenburg and Glanz 2008:317). These students were passive during class activities and their sphere of influence was large enough that it impacted those who may have followed the more adventurous early adopters given a different environment. The identification of the effect these passive learners had on the other students is notable inasmuch as it impacted the results of this study; however, it is possible that the proportion of laggards in the class under study was not an anomaly and that other classes would have similar groupings of students. If this were the case, then it would be prudent to investigate methods to reduce the negative tendencies of this group on the rest of the class in adopting active learning methodologies.

RESULTS AND CONSIDERATIONS

Previous work done in the area of physics education research has noted that students are particularly resistant to active learning instructional methods (Armarego 2005:4, Boud 1981:13). This is concerning, yet surprisingly there has been minimal research done to identify the effects this resistance has on learning and how it can be overcome. This paper summarizes an attempt to investigate this issue within the domain of the researcher's classroom, to improve the quality of learning happening there, and to draw out possible avenues for further inquiry. The chief aim was to explore how resistance to student-centered instruction could be reduced in order to improve achievement.

The refinements introduced in cycle two to educate students regarding the necessity and benefits of active learning had positive results. Conceptual learning, as measured by the FCI, was much higher than expected. Changes made during cycle two were limited to two main areas: purposefully addressing epistemologies and modifying instructional activities to guide students through the learning process. While it is difficult to separate the effects of each of these changes, it can be concluded that in combination student learning improved as a result.

Cycle two activities that were controlled and which contained more structure than the activities in cycle one resulted in students feeling confident that they could learn through collaboration with their peers. This result was encouraging and was corroborated through multiple sources of data. Focusing on the importance of the process of learning physics, as well as its collaborative nature, highlighted for students the benefits of engaging the curriculum in an active way. At the same time, changes to the assessment model emphasized the importance of the process of learning physics as well as the ability to simply solve problems. This was necessary to overcome the belief held by students that they should be instructed through lecture-style interactions and the copying down of notes in the physics classroom. This sense is often reinforced by the ubiquitous use of traditional teaching methods in which information is transmitted to students who play a passive role in the learning process.

While it was encouraging to see that students became more willing to collaborate as a result of the changes made during cycle two, it is important to note that this gain did not come without a cost. The increased structure of the activities required the teacher to be ever present and always close at hand to answer questions and help direct student learning. The classroom environment was student-centered but required the teacher to direct the learning. This resulted in a situation where students became dependent on the teacher; they would collaborate together and actively engage in the learning process, but it appears as though they conflated teacher presence with their ability to learn. The aim of this study was to determine how resistance to student-centered instruction could be overcome, and while there was a large measure of success in this respect, it appears that to some extent the process resulted in the development of an epistemology where the learning of physics requires the presence of an *expert*. Because of the high value placed on creating students who are life-long learners with the ability to learn on their own as their interests or needs dictate, this possible development needs further investigation to ensure that a gain in one area is not negated by a significant loss, though of a different nature, in another.

The development of students' epistemologies became a large focus throughout cycle two, as a desired outcome was to help students become more adept at improving the processes involved in learning challenging concepts. Various habits of mind, such as discussing, summarising, strategising, justifying, and reflecting are equally as important (if not more so in many situations) as the final results that students are able to do produce the end of the course. A study done at the Massachusetts Institute of Technology showed that after four years, students who took an introductory physics course in their first year of study had forgotten over half of the physics they had learned (Barrantes, Pawl and Pritchard 2012:9). This highlights the fact that much of what is done in the classroom will be forgotten, making it incumbent upon educators to pay at least some attention to developing thought processes that will last throughout the life of the student and enhance their ability to learn.

The evidence collected throughout the study suggests that focusing on the development of student epistemologies had a moderate effect in transforming students' views of active learning and the necessity of collaboration in both learning science and for learning in general. The effect size, which Hattie (Hattie 2012) defines as "a useful method for comparing results on different measures…on a scale that allows multiple comparisons independent of the original test scoring…across content, and over time", was calculated for three domains to measure the effect that the interventions adopted in cycle two had. The effect size for the domain of student views of active learning was $d = 0.26$; for student views of learning science it was $d = 0.26$, and for student views of collaboration, $d = 0.13$. It is commonly accepted that an effect size of $d = 0.26$ is considered only to have a medium impact, but it is important to note that in this study, data was collected for each of the classes at approximately the same point in the course. Consequently improvements can be correlated to instruction and not the result of a linear progression as a group of students moved through the course.

In addition to focusing on student epistemologies, this study aimed to determine the extent to which a link exists between students' resistance to active learning and their ability to achieve the outcomes of the course. The Force Concept Inventory (FCI), which measures students' conceptual understanding of mechanics concepts, was used to provide data in this respect. Results showed a dramatic improvement from cycle one to cycle two. Students in cycle one achieved average normalised gains 36% $\pm$ 20% sd. The average normalised gain of the class taught during cycle two was 65% $\pm$ 9% sd. The FCI has undergone rigorous testing and analysis to ensure its validity and reliability, so it is possible to place a high level of significance on the results that it gives. Additionally, it should be noted that the teacher did not 'teach to the test' during the second cycle. As per the instructions provided to teachers by the writers of the FCI, students were not told the name of the test they were writing, nor were any of the questions discussed with the students either before or after the test. Consequently, it is safe to conclude that any improvements seen were the direct result of student learning and no other extraneous factors.

Student resistance to active learning was seen to decrease between cycle one and two, and results on the FCI increased significantly. While it may be tempting to correlate the two, there was not sufficient data collected to suggest that this is necessarily the case. Throughout cycle two there were many activities that were done to address epistemology and to help students appreciate the necessity and benefit of collaborating and learning in an active learning classroom. But there were also significant modifications to instructional methods which were based on external research and which likely played a large part in increasing cognitive gain. In order to demonstrate that changes to resistance directly impacted student achievement and grades throughout the course, it would be necessary to perform multiple cycles in which no changes to instructional methodologies were made.

As the focus on the development of student epistemologies was shifted to include an emphasis on the process of learning, along with the related habits of mind, learning was impacted positively; this demonstrable improvement was noted and shared with the students as a way to encourage the continued development of learning processes. However, it appears as though many of the students were still focused inordinately on being able to solve problems and that this was their chief focus, especially near the end of the school year. Perhaps this is not surprising given the nature of the course, in which a significant portion of their mark was determined through final exams imposed by an outside authority. By all accounts, it appears that summative assessment proved to be a powerful undercurrent. Students appreciated what was happening in class throughout the course and learned effectively through the methods and activities used, yet they were continuously cognisant of the fact that they would also be required to 'perform' on a final exam.

CONCLUSION

The use of activities that were controlled and which contained more structure than in cycle 1 resulted in students feeling confident that they could learn through collaboration with their peers. This was an encouraging result which was corroborated through multiple sources of data. Focusing on the importance of the process of learning physics, as well as the collaborative nature of physics, highlighted for students the benefits of engaging with the curriculum in an active way. At the same time, changes to the assessment model reinforced for students the importance of this approach as it shifted the emphasis away from the ability to simply solve problems to including the processes involved in learning new material. These emphases were necessary in order to overcome the belief held by students that they should be instructed through lecture-style interactions and the copying down of notes in the physics classroom. This sense has been informed by the ubiquitous use of traditional teaching methods in which information is transmitted to the students who play a passive role in the learning process.

In summary, it can be concluded that the methods employed in cycle two to decrease student resistance to active learning methodologies and improve the attainment of the objectives of the course were successful. Spending time discussing the learning process with students, as it related to the development of a cohesive understanding of physics, along with providing a structured environment which modeled this process, resulted in a group of students who were more willing to work collaboratively and actively than had been seen in previous groups. The significant gain in learning that was measured may be related to these efforts, though it is possible that they are a product of the development and implementation of the structured learning activities that were employed alongside the above-mentioned focus on epistemology. While it is not possible at this time to state conclusively what caused the learning gains, it can be concluded that the methods employed during cycle two had a positive impact on student learning.

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CONCEPTUAL IMPLICATIONS OF SUB-MICROSCOPIC REPRESENTATIONS OF BASIC CHEMICAL CONCEPTS: NOVICE PHYSICAL SCIENCE LEARNERS' VIEWS

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Abstract–The study investigated South African Grade 10 Physical science learners' reasoning about basic chemical phenomena at sub-microscopic level. The study adopted a non-experimental, exploratory and descriptive method and was principally guided by the ex-post facto research design using a concurrent embedded strategy of mixed quantitative and qualitative approach. A total of 280 grade 10 physical science South African learners in their intact classes and six of their teachers participated in the study. A two-tier multiple-choice paper and pencil Test of Basic Chemistry Knowledge (TBCK) based on the three levels of chemical representation of matter was administered to the 280 physical science learners in their Grade 10 last term to collect both quantitative and qualitative data. In addition to the TBCK, focus group discussions (FGDs) with learners, teacher interview responses and document analysis were used to triangulate data.

The results revealed that most Grade 10 learners find it easy to identify pure elements and the solid state but find it difficult to negotiate between the three levels (macroscopic, sub-microscopic and symbolic) of chemical representation of matter. It became clear that learners experienced more difficulties in the concepts of basic solutions, acidic solutions, concentration and ionic compounds in solution. It was also found that some learners could not tell differences between a diatomic element and a compound indicating conceptual problems when they reason at particle level. The results also indicated that learners found reasoning at particle level difficult. It is, therefore, concluded that learners find it difficult negotiating the three levels of chemical representation of matter. Furthermore, justifications to the multiple-choice tasks revealed lack of understanding of basic chemical concepts as well as language problems amongst learners as they could not clearly express their reasoning. Based on the results, some recommendations to educators, chemistry curriculum planners, teacher education and the chemistry education research field are suggested.

Keywords: chemical concepts, chemical language, chemical phenomena, chemical triangle thinking model, macroscopic level, particulate nature of matter, sub-microscopic level, sub-microscopic representations, symbolic level.

1. INTRODUCTION

The Grade 12 National Senior Certificate is an entry qualification into universities and other tertiary institutions as well as for general employment in South Africa. The preparation for the NSC examination takes three years of further education and training (FET), comprising Grades 10, 11 and 12. The recent South African Department of Education National School Certificate examinations have revealed poor performance in physical sciences (chemistry component) by Grade 12 learners (National Examinations and Assessment, 2008, 2009). The November 2009 physical science examination results recorded a record failure rate of 63.1% (36.9% pass rate) in South Africa. According to National Examinations and Assessment, (2008 and 2009), there has been a downward trend in the grade 12 physical science examinations. It should also be noted that 2008 saw the introduction of the new National Curriculum Statement (NCS). Unlike the old curriculum, the NCS was not wholly assessed through public examinations. Whether poor performance could be attributed to this or not, it is very clear that teachers were probably not trained in the new methods of assessment that were required in the new NCS curriculum. In addition, it should be noted that the choice of the 2008 and 2009 grade 12 matric (physical science) results lies in the fact that these results showed a clear departure from those of the previous years (2005 to 2007).

Poor performance by candidates in physical science has been attributed to a number of factors, one of which is the new Outcome Based Education (OBE) assessment procedure that teachers are still not yet familiar with (National Examinations and Assessment Report, 2009). OBE is the procedure followed when assessing students under the new National Curriculum Statement (NCS). Under the new NCS, students are assessed in two parts, namely, School Based Assessment (SBA) which is continuous and constitutes 25% of the National School Certificate (NSC) assessment, and the national examinations which make up the remaining 75% (Gauteng Department of Education Abridged Report, 2008). This assessment is unlike the previous Senior Certificate Examinations (SCE) prior to 2008 where assessment was wholly (100%) based on public examinations. This assessment entails that teachers do not adequately prepare learners for public examinations. As already pointed out, teachers were still not familiar with this new assessment procedure (National Examinations and Assessment Report, 2009).

Poor performance is also attributable to the teacher factor. Many science teachers are unqualified to teach physical science in terms of subject content training or lack of professional qualifications (Mji and Makgato, 2006). For example, many life sciences trained teachers find themselves teaching physical science, a subject with specialized content (Gauteng Department of Education Internal Moderators' Report, 2008).

According to National Examinations Assessment (2009), the candidates are said to have had difficulties specifically with concepts such as collision theory, differences between atoms, ions and molecules, balancing of equations and topics concerning organic chemistry and oxidation-reduction reactions. All the topics cited by the Department of Education (DoE) as problem areas involve the three levels of chemical thinking (macro, sub-microscopic and symbolic levels) and this is in line with numerous research findings that support the notion that the interplay between macroscopic and microscopic worlds is a source of difficulty for many chemistry learners (Sirhan, 2007). This last factor (complexity of chemistry due to the way in which it is portrayed) prompted the study.

1.1 Background

Research studies have revealed that learners experience difficulties in basic chemical concepts. Examples include atomic structure (Zoller, 1990; Harrison & Treagust, 1996), and chemical concepts concerning solutions, acids and bases (Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar, 2004). Recently, Umesh and Aleyamma (2012) in their study about learning difficulties experienced by grade 12 South African students in chemical representation of phenomena, further substantiated the view by Devetak, Urbancic , Wissiak Grm, Krnel , & Glazer (2004) and Sirhan (2007) when they noted that students find it more difficult to answer questions demanding transformation (connecting the three levels of chemical representation).This crucial finding prompted the authors to undertake an armchair analysis of the November 2009 National Senior Certificate chemistry (examination) test items in terms of conceptual level demand as a possible source of difficulties which were experienced by candidates. Indeed, the armchair analysis revealed that some questions required learners to make connections between the three levels in which chemistry is conceptualized, namely, macroscopic, sub-microscopic and symbolic.

According to Johnstone, (1993); Treagust, Chittleborough, and Mamiala (2003); Nahum, Hofstein, Mamlok-Naaman and Bar-dov, (2004); and Sirhan, (2007), the macroscopic level is real and may take the form of experiments which are visible and/or observable; the sub-microscopic level is invisible but real and deals with atoms, molecules and ions; and the symbolic level is the chemical language expressed as formulae, symbols, chemical equations, pictorial representations, graphs and mathematical representations. These levels of chemical representation are in line with what researchers (Devetak, Urbancic, Wissiak Grm, Krnel D, & Glazar, 2004; Devetak, Vogrinc, and Glazar, 2009) envisage to constitute chemistry thinking. Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar, (2004) attribute the complexity of chemistry teaching and learning to the relationship between the three levels and the abstract nature of chemistry itself. It is against this conceptual framework that an attempt was made to analyze the November 2009 chemistry paper. This analysis was done in order to gain insight into the nature and type of questions that were predominantly set and to establish whether it was or was not a possible source of difficulty.

There is increasing awareness that first year post-matriculation learners who gain admission into chemistry courses or science teacher education courses at higher institutions' (Further Education and Training) level, still hold misconceptions or overly simplistic conceptions of the particulate nature of matter (Harrison, 2000; Harrison and Treagust, 2002; de Jong, Van Driel, & Verloop, 2005; Onwu and Randall, 2006). Studies (Onwu and Randall, 2006; Potgieter, Davidowitz, & Venter, 2008) have pointed out the need for research into school chemistry teaching and learning in the South African context. It can be concluded that in some South African universities many first-year students have inadequate understanding of basic chemistry concepts that ought to have been understood at secondary school level. While students show some evidence of learning and understanding in their performance in public examinations, researchers also found evidence of misconceptions and rote learning (learning without conceptual understanding) in certain areas of basic chemistry even at degree-level (Johnstone, 1984; Bodner, 1991; Harrison and Treagust, 2002; de Jong, Van Driel, & Verloop , 2005; Onwu and Randall, 2006; Sirhan, 2007).

Research (Harrison and Treagust, 2002) further points out that there is tension between teaching macroscopic chemistry and the difficulties of explaining macroscopic changes in terms of the behavior of sub-microscopic particles. This tension has been ascribed to how and when to deal with the three levels in which chemistry is portrayed. Teachers are not sure as to how and when to make the connections. Teachers lack pedagogical content knowledge (PCK) of teaching chemistry involving all three levels of chemical thinking (Cohen, L., Manion, L., & Morrison, K., 2000; de Jong, Van Driel, & Verloop, 2005). Johnstone (1991) and Gabel, et al (1992) attribute part of the tension to whether or not the particulate model is best-explained at the macroscopic, sub-microscopic, and/or symbolic level. The conceptual demands of switching between models and phenomena can be daunting (Anderson, 1990) and this becomes an impediment to the learning of chemical concepts.

It then became interesting to investigate how Grade 10 physical science learners reason about the particle nature of matter due to the fact that they try to make connections between macroscopic, sub-microscopic and symbolic levels of chemical thinking since they are novice problem solvers. The South African grade 10 physical science (chemistry) curriculum introduces learners to the particulate nature of matter more rigorously in grade 10 than in grades 8 and 9 and this lays foundation to the matric examinations in grade 12. At grade 8 and 9 (the first year of secondary school) learners are introduced mainly to symbolic representations, in the form of learned rules (chemical symbols, formulae and equations), and have limited exposure to macroscopic and sub-microscopic representations (Umesh and Aleyamma, 2012) and this persists through grade 10, where physical science is by choice (not compulsory) right up to grade 12, the final year of secondary education. Due to this, learners resort to rote learning of symbols, chemical formulae and equations (Umesh and Aleyamma, 2012) and there is no proper understanding of the concepts involved. As a result the novice learners do not appear consciously to internalize the chemical meaning of the task (Onwu and Randall, 2006) instead, they resort to strategies that are tied to the salient or surface features of the chemical task at the expense of the task goal (Onwu, 2002). It is also our observation that many grade 8 and 9 teachers are not trained in physical sciences and as a result they tend to pay more attention to the life sciences topics of the natural sciences, the foundation of physical sciences. This observation, therefore, implies that chemical concepts are not properly introduced (poor foundation) at that early stage; hence the reasons why novice grade 10 physical science learners find chemical concepts difficult to comprehend.

Onwu & Randall (2006) suggest that "the experienced chemist is comfortable on all three levels of communicating chemical concepts and can easily move from one level to the other, while the novice learner is not comfortable in any of these levels and has difficulty connecting one level to the other". Furthermore, other studies (Johnstone, 1991; Johnson, 1998; Gabel, 1999) also show that learners find it easier and more fun to deal with observable chemical activities (macroscopic chemistry) rather than handling theoretical concepts (concepts by definition) which require conceptual understanding, and the language facility to express the latter. The physical science educator's instructional approach ought to be presented in ways that seek to emphasize and incorporate in a balanced way all three levels of representational thinking for conceptual understanding and performance by learners.

Chemistry learners generally have difficulty transferring from one level of representational thinking to another (Onwu and Randall, 2006; Treagust et al, 2010; Umesh and Aleyamma, 2012) although the particle theory serves to explain some chemical phenomena. In addition, 'chemistry is often regarded as a difficult subject, an observation which sometimes intimidates and repels learners from continuing with studies in chemistry' (Sirhan, 2007). Many South African learners find particle concepts difficult to conceptualize, and there is limited instruction about particles in Grades 8 and 9 (Umesh and Aleyamma, 2012). It was then useful to direct research attention at finding out what Grade 10 chemistry learners do not know about concepts like particle theory and how they reason about the particulate model, with the hope of making appropriate teaching and learning recommendations.

The use of the particle theory of matter to relate macroscopic phenomena is not always apparent to learners. In a study by Harrison (2000), secondary school teachers also hold some of the alternative conceptions held by their students, indicating that the topic is highly conceptual. This is in line with de Jong, Van Driel, and Verloop (2005) when they suggest the need to teach the particulate nature of matter to pre-service postgraduate chemistry teachers so as to enable them to develop the pedagogical content knowledge (PCK) necessary for them to use when using particle models in teaching. Very few studies have investigated students' ability to relate observable phenomena to sub-microscopic entities using pictorial representations of the particle model (Onwu and Randall, 2006) and yet particle ideas are fundamental to all physical and chemical explanations.

This observation calls for more research in this field, 'students' understandings about the particulate nature of matter' as it has become evident that students find it difficult to relate the macroscopic world to the sub-microscopic one. This is in line with Onwu and Randall (2006) when they suggest that such research has become necessary in the South African context due to the fact that there is a growing recognition or awareness that post-matriculation students, who gain entry into chemistry courses and science teacher education programmes, still hold incorrect (over simplistic) conceptions of the particulate nature of matter. The fact that post-matriculation students still hold over simplistic conceptions of the particulate nature of matter (Onwu and Randall, 2006) informed and motivated the authors to investigate novice (Grade 10 physical science) learners' reasoning about basic chemical phenomena using particle model representations. It therefore, became necessary to investigate how grade 10 physical science learners (novice learners) reason at particle level as they try to make connections between levels of chemical thinking, as the particulate nature of matter appears to be a difficult and abstract concept. The misconceptions about the particulate nature of matter persist through grade 10 up to postgraduate level, thus, suggesting that the topic is a difficult and/or an abstract concept for learners. Again, this interesting observation calls for more research in this field, particularly in the early years of secondary chemistry education.

Here are some of the commonly known students' conceptions of the particulate nature of matter: students from junior high school to senior high school to university held concepts that were consonant with perception of matter; novice learners believe that copper atoms are red-brown because copper is red and/or that chlorine atoms are green because chlorine gas is yellowish green in colour (Ingham and Gilbert, 1991); matter is a continuous medium, rather than an aggregation of particles, Nakhleh (1992); students use the macroscopic properties of a substance to infer its particle properties (Krnel, Watson & Glazar, 1998); students consistently and erroneously have the view that matter is continuous and attribute macroscopic properties of matter to its sub-microscopic particles (Johnson, 1998; Harrison and Treagust, 2002); students hold common conceptions that molecules are in substances, rather than that substances are made up of molecules (Onwu and Randall (2006);

and students hold notions that molecules in ice are heavier than those in liquid, with molecules of water in the gaseous phase being the lightest (Krnel, Watson & Glazar, 1998).

Research (Harrison and Treagust, 1996, 2002) attributes misconceptions held by students to their inexperience in the use of scientific models, lack of intellectual maturity and lack of adequate and appropriate mental representation or mental model. Treagust et al., (2010) suggest careful and explicit use of representational models, in order for chemical concepts to make sense. There seems to be some tension between the use of representational models in explaining chemical concepts and chemistry discipline itself, hence the above-mentioned suggestion. Students are unable to solve chemistry tasks since in most cases the chemical concepts on which the tasks are based do not make sense to them (Onwu and Randall, 2006).

Several studies (Harrison and Treagust, 2002; Justi and Gilbert, 2002; Singer, Tal, & Wu, 2003; Emine Adadan, 2006; Onwu and Randall, 2006) of secondary school learners' conceptions about the particulate nature of matter have been undertaken, but it is still not clear how learners reason with regard to the way sub-microscopic particles are presented in representational models. Since representational models are not always understood, it was of interest to investigate novice learners' reasoning and how the use of schematic or pictorial representations of particle models contribute to the cognitive and or communication gap if any, between them and the chemical instruction. The study focused on how learners reason about the particulate nature of matter, to relate macroscopic phenomena to sub-microscopic particles, to achieve the identification of this cognitive or communication gap. In addition, conceptual implications of sub-microscopic representations on novice learners, with the view of making appropriate instructional recommendations were critically examined.

1.2 Statement of the Problem

The problem of the study was to determine how novice physical science learners reason about the particle theory using representational models of sub-microscopic entities to solve tasks in basic chemistry.

1.3 Research Questions

The following research questions have been addressed in this study:

a) What are novice physical science learners' levels of achievement in reasoning about basic chemical phenomena using sub-microscopic representations?
b) What are the conceptual implications of sub-microscopic representations on novice physical science learners?
c) Why do novice physical science learners reason the way they do about basic chemical phenomena using sub-microscopic representations?

1.4 Significance of the Study

The study is considered significant because of the scientific contribution the findings are expected to make to knowledge in the field. It provided insight into beginner chemistry learners' ways of reasoning when they attempt to solve chemical problems that require the use of macroscopic, sub-microscopic or symbolic levels of representation, as well as the nature of the difficulties they experience, in trying to solve such problems. Indeed, grade 10 physical science learners showed many problems as they tried to make connections between the three levels of chemical conceptualization. Beginner learners' understanding of particle theory has important epistemological implications for teaching and learning chemistry at school level, and it was important to reassess what, how, and why learners are educated in this important concept.

It is hoped that the study will add to the solutions currently being offered to solve learner learning difficulties. Insights into learners' conceptions (alternative ways of reasoning) and learning difficulties which were revealed will hopefully make chemical concepts more meaningful and accessible to more and more learners (Onwu & Randall, 2006) thereby allowing conceptual change (understanding) to take place and improve performance. Because the particle theory is fundamental to topics such as atomic and molecular structure, bonding, solution chemistry and chemical reactions, the way in which, learners' reasoning is crucial if comprehension is to take place, especially since most of these topics are encountered at introductory level chemistry. These topics are important building blocks for understanding both quantitative and qualitative aspects of chemistry. In addition, understanding the nature of learners' conceptual misunderstandings and learning difficulties should be helpful when planning lessons (improve instruction) and is, therefore, a significant starting point if chemistry is to be made sensible. Lastly, the study should help to identify cognitive gaps for more research in chemistry education.

1.5 Conceptual Framework

Chemistry is conceptualized in three levels (Johnstone, 1993; Chittleborough, Treagust, & Macerino, 2002; Treagust, Chittleborough, & Mamiala, 2003; Nahum, Hofstein, Mamlok-Naaman and Bar-dov, (2004); Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar, 2004; Sirhan, 2007; Devetak, Vogrinc, & Glažar, 2009), namely, macroscopic, sub-microscopic and symbolic. Figure 1: The Modified Chemistry Triangle Thinking Model shows the three levels in which chemistry is conceptualized. This model, on which this paper is based, was chosen as the conceptual framework of the study as it is a tool that is used in teaching, learning and assessment of chemical concepts. The three elements (macroscopic, sub-microscopic and symbolic thinking levels) of the model formed the conceptual pillars of this conceptual framework. The conceptual framework puts emphasis on two aspects; the constant interplay (connectedness of the levels) between levels and their interdependence. The three levels can be compared to three points on a turning wheel that are equidistant to each other in the sense that, there is constant interplay as they touch the ground and they depend on each since they are found on the same wheel. These two characteristics of a moving wheel will enable smooth movement of the wheel. Similarly, the constant interplay and the interdependence of the three elements of the modified Chemistry Triangle Thinking Model should facilitate chemical thinking (mental representational model of the learner), concept development and conceptual change in beginner students. The conceptual framework was used as a guiding tool to select appropriate instruments for the study. This selection was done in line with the nature in which the chemistry questions were designed in the grade 12 November 2009 Physical Science chemistry paper. According to the authors' and Umesh and Aleyamma (2012)'s analysis, the November 2009 Physical Science chemistry paper had questions that required learners to make transitions across the three levels in which chemistry is portrayed.

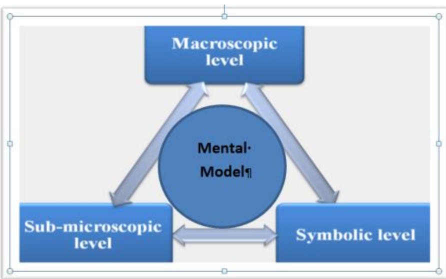

Figure 1: The Modified Chemistry Triangle Thinking Model

(Johnstone, 1993; Chittleborough, Treagust, & Macerino, 2002; Treagust, Chittleborough, & Mamiala, 2003; Nahum, Hofstein, Mamlok-Naaman and Bar-dov, (2004); Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar, 2004; Sirhan, 2007; Devetak, Vogrinc, & Glažar, 2009)

2. METHODOLOGY

The study adopted an ex-post facto research design embedded a in mixed methods research approach to collect and analyze both quantitative and qualitative data from Grade 10 physical science learners with regard to reasoning about basic chemical concepts using sub-microscopic representations.

2.1 Research Method and Design

The ex-post facto research design in this paper implies that the independent (formal teaching) and dependent (formal learning) variables have already occurred. Ex-post facto research is a systematic empirical inquiry in which the scientist does not have direct control of independent variables because their manifestations have already occurred, and they are inherently not manipulated. Inferences about relationships among variables are made, without direct intervention, and this kind of research design is based on a scientific and analytical examination of dependent and independent variables. Independent variables are studied in retrospect for seeking possible and plausible relations and the likely effects that the changes in independent variables produce on a single or a set of dependent variables. The investigation started after the fact had occurred without interference from the authors.

2.2 Population and Sample

The population for this study was Grade 10 beginner physical science learners (1215 learners in total) in (D3) Tshwane North District's township secondary schools (27) in 2013. Grade 10 physical science marks the entry point into a three-year physical science preparation for the National Senior Certificate examinations, hence the choice of learners that had completed grade 10. The sample was made up of a total of 280 learners (23% of the total learner population) in their intact classes. Stratified and purposive sampling procedures were used. Stratified sampling would ensure equal representations of all abilities. Purposive sampling (Tshwane North District Schools), was used as the schools were the majority of the under-resourced schools in Tshwane as a whole, and also partly because the researcher was working in the same district. The sample comprised high, (70% to 100% or levels 6 and 7), average (50% to 69% or levels 4 and 5) and low (0% to 49% or levels 1, 2 and 3) performing schools that had been offering National Senior Certificate examinations for the period 2005-2009.

Firstly, the 27 schools were identified and categorized in terms of whether they had been offering Grade 12 National Senior Certificate Examinations in physical science in the last five years (2005-2009) and then secondly using Grade 12 physical science results (performance) in 2009. Five (5) schools were categorized as high performing, seven (7) schools as average performing and fifteen (15) schools as low performing schools. The first criterion used (offering grade 12 National Senior Examinations for at least past 5 years) was to ensure consistency regarding grade 12 physical science results. Performance was chosen as the second criterion as the study was prompted by poor performance by grade 12 candidates in physical science, especially in 2009. Three strata (high, average and low-performing schools) were determined, and random sampling was then used to select two schools from each stratum. Each school selected had either at least 45 (one class) physical science learners or at most 135 (three classes). The number of learners taking physical science per school was not crucial as the research is based on reasoning by individual learners. It is the policy in South Africa that no learner should be discriminated against taking physical science and therefore no streaming is practiced in Tshwane North District schools. All classes selected were mixed ability classes.

Stratified random sampling was carried out in two stages to ensure representation of all abilities: firstly, based on performance and secondly, based on whether the schools had been offering National Senior Certificate examinations since 2005. Grade 12 candidates are the end product of a three year matric course comprising of grades 10, 11 and 12. Random sampling usually referred to as epsem sampling or the 'equal probability of selection method' (Ross, 2005) http://www.sacmeq.org and http://www.unesco.org/iiep retrieved 29/04/2011 was then used to select six (two from each stratum) schools, so as to ensure equal probability of selection for all elements in the population. The sample comprised 280 students and six teachers from the six selected schools.

2.3 Research Instruments

To determine conceptual implications of sub-microscopic representations of basic chemical concepts to novice learners, four instruments, namely; (1) a two-tier Test of Basic Chemical Knowledge (TBCK),

(2) Focus group discussion guide, (3) Teacher interview schedule and (4) Document analysis were used to gather data. The Test of Basic Chemical Knowledge was used to collect data on the learners' levels of achievement when solving basic chemical concepts using sub-microscopic representations to explain macroscopic properties of processes. Focus group discussions were carried out in order to determine some of the ways learners reasoned and why they reasoned the way they did. Teacher interviews were used to establish some of the ways teachers went about communicating chemical concepts using the three levels of chemical representation while document analysis was used to triangulate data.

To ensure reliability Kuder and Richardson formula 20 (KR20) was used to determine the internal consistency of the instruments (TBCK) of this study. The choice of KR20 reliability coefficient formula was based on the dichotomous nature of the items which also measured the cognitive levels of the respondents and this established how closely related the test items were since they were designed in accordance with the conceptual framework (macroscopic, sub-microscopic and symbolic levels of thinking). The three elements of the conceptual framework are interrelated, hence the need to measure their internal consistency. The value ($\rho KR20 = 0.83$) from the statistical evaluation shows that the instrument used was, therefore, reliable.

The validation process of the TBCK was carried out by a chemistry expert from the university and a seasoned chemistry teacher of reputable standing, for content and curriculum validity. The chemistry expert from university was requested to validate the content of the test items in the instrument while the chemistry teacher of reputable standing would ensure both content validation and whether it was in line with the curriculum planners' expectations (Department of Education Grade 10 physical science work schedule). Experts in the field scrutinized test in order to check if the test instrument was in line with current research issues about the use of sub-microscopic representations in the teaching, learning and assessment of chemical concepts. The results are now presented.

3 DATA PRESENTATION AND DISCUSSIONS

Data for each school were firstly presented in tabular form and secondly in graph form. The tables showed every participant's score and how he or she fared in each of the tasks given in the test (TBCK), the school average score and percentage pass and failure rates per each task. The graph presented here shows percentage pass rate per task for each school's respondents. The tasks presented and analysed were the multiple choice questions and the justifications thereof. For insights into how and why learners reasoned the way they did an in-depth analysis of the results was carried out with 55 (20%) randomly selected respondents' scripts; some extracts of which are shown in this section.

Table 1: Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK

Level of School Performance	Respondents	Q 1.1	Justification	Q 1.2	Justification	Q 1.3	Justification	Q 1.4	Jusification	Q 1.5	Justification	Q 2	Justification	Q 3	Justification	Q 4	Justification	Q 5	Justification	School TBCK Averages
	√=pass	87	48	51	21	49	15	50	18	86	77	65	10	36	2	16	5	14	8	37
	X=fail	13	52	49	79	51	85	50	82	14	23	35	90	64	98	84	95	86	92	63
	N=response	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	4	4	1
	% pass	87	48	51	21	49	15	50	18	86	77	65	10	36	2	16	5	14	8	37
	% fail	13	52	49	79	51	85	50	82	14	23	35	90	64	98	84	95	86	92	63
Low perfoming schools (2) (N=32+68)	% total pass	87	48	51	21	49	15	50	18	86	77	65	10	36	2	16	5	14	8	37
	√=pass	72	34	34	20	56	14	37	9	75	60	59	8	41	2	13	6	7	4	31
	X=fail	16	54	54	68	32	74	51	79	13	28	27	77	43	83	73	77	78	81	56
	N=response	0	0	0	0	0	0	0	0	0	0	2	3	4	3	2	5	3	3	1
	% pass	82	39	39	23	64	16	42	10	85	68	67	9	47	2	15	7	8	5	35
	% fail	18	61	61	77	36	84	58	90	15	32	33	91	53	98	85	93	92	95	65
Average perfoming schools (2) (N=43+45)	% total pass	82	39	39	23	64	16	42	10	85	68	67	9	47	2	15	7	8	5	35
	√=pass	77	55	52	33	57	21	61	29	78	70	46	11	23	3	26	12	9	5	37
	X=fail	15	37	40	58	34	67	30	61	13	20	43	72	65	75	65	75	80	79	52
	N=response	0	0	0	1	1	4	1	2	1	2	3	9	4	14	1	5	3	8	3
	% pass	84	60	57	36	62	23	66	32	85	76	50	12	25	3	28	13	10	5	40
	% fail	16	40	43	64	38	77	34	68	15	24	50	88	75	97	72	87	90	95	60
High perfoming schools (2) (N=47+45)	% total pass	84	60	57	36	62	23	66	32	85	76	50	12	25	3	28	13	10	5	40
	√=pass	253	147	147	80	175	54	158	60	256	221	182	31	108	7	59	25	32	18	
	X=fail	27	133	133	200	105	226	122	220	24	59	98	249	172	273	221	255	248	262	
	N=response	0	0	0	1	1	4	1	2	1	2	5	13	9	18	3	10	10	15	100
	% pass	90	53	53	29	63	19	56	21	91	79	65	11	39	3	21	9	11	6	40
	% fail	10	47	47	71	37	81	44	79	9	21	35	89	61	97	79	91	89	94	60
Total (all schools) (n=280)	% total pass	90	53	53	29	63	19	56	21	91	79	65	11	39	3	21	9	11	6	40
Total (all schools) group averages(n=280)	% total pass	84	49	49	27	58	18	53	20	85	74	61	10	36	2	20	8	11	6	37

"Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK" (table 1) shows group averages (low, average and high performing) in the TBCK individual tasks. The TBCK is presented showing the groupings of schools in terms of high performing, average performing and low performing. Each category was analysed in terms of the actual number of learners who took part in the study and their average pass and failure rates per every task. The graph (figure 2) "Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK (low, average and high performing averages)" is a clearer picture of the results analysis.

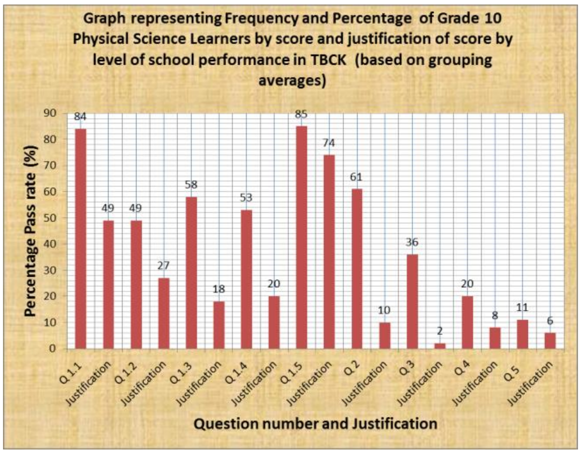

Figure 2: Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK (low, average and high performing averages)

The above frequency and percentage graph Figure 1: Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK is based on the 'Total (all schools' respondents) group averages (n=280)' figures as indicated in Table1: Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK.

"Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK" (table 1) and graph (figure 2) "Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK" for all schools clearly show that participants scored extremely well in questions Q 1.1 (84%) and Q 1.5 (85%). Justification scores for the same questions although lower than the multiple choice scores were fairly high as well. Q 1.5 had the higher justification score of the two questions. Question Q 1.1 required participants to identify the pictorial diagram (schema) that depicted a pure element whilst question Q 1.5 required them to identify the pictorial diagram that depicted a substance in its solid form. It, therefore, appears that the concepts of pure elements and the kinetic molecular theory of solid matter were easily conceptualised by the participants during instruction.

However, the case was different with the rest of the tasks with the majority of the participants scoring lowest (11%) in Q 5 with a justification score of only 6%. Generally, all justification scores were lower than the multiple choice scores for all tasks and in the case of Q 3, the correct justification constituted only 2% and this was the lowest justification score. Thus, respondents appear to have relied on guessing the correct response. Notably, it appears as if participants were not used to questions that required them to give explanations to multiple choice questions. Task Q 3 required participants to identify the schema that represented an aqueous solution of a base whereas Q 5 required them to identify the schema that depicted an aqueous solution of sodium chloride. Participants scored higher (61%) in task 2 than tasks (Q 3, Q 4 and Q 5) which demanded similar levels of conceptualization, thinking at particle level about solutions and chemical reactions. Hence, it appears that those who got correct responses to Q 2, Q 3, Q 4 and Q 5 had put their trust in luck (guess work). For example, analyses of some of the unpalatable justifications indicated that some participants resorted to guessing, with no conceptual understanding at all. Notably, in some cases in Q5 no justifications were given for both correct and wrong responses. It, therefore, can be concluded that chemical concepts that represent particles in solutions and chemical reactions are not always apparent to learners.

Tasks Q 1.2, Q 1.3 and Q 1.4 were more difficult than Q 1.1 and Q 1.5 although they were all in the same category. These tasks required participants to identify atoms, elements in general, molecular elements, molecular compounds and the states of matter. These tasks had similar conceptual-level-demands, differentiating between atoms, elements, molecules and states of matter. It can, therefore, be concluded that learners find it is easier to understand pure elements, but it becomes increasingly difficult as one develops the concept to higher-order-thinking-levels when it involves molecular elements and molecular compounds. This difficulty is probably because molecular elements and molecular compounds require the understanding of chemical bonding. Thus, these concepts become difficult to comprehend. Overall, all schools' respondents scored an average of 37% (Table1: Frequency and Percentage of Grade 10 Physical Science Learners by score and justification of score by level of school performance in TBCK). This score is a worrisome observation as it means that the majority of the respondents did not score above 50%. Only 62 respondents (22%) got scores above 50%. Examples of how some learners responded to more difficult tasks (excluding Q 1.1 and Q 1.5) are given below. Notably, although justification scores were lower than corresponding multiple-choice scores, respondents did exceptionally well in Q 1.1 and Q 1.5 indicating learners' understanding and mastery of the concept of the kinetic theory of matter.

Task Q 1.2 which required learners to identify a diagram that represented a pure compound had a 44.6% (26 out of 55 respondents) failure rate. These respondents were unable to solve the problem. For example, (figure 3) "Response to question Q 1.2 of the TBCK" shows how more difficult the concepts became. The respondent chose option C instead of option D. This is a clear indication that many respondents did not know the difference between simple molecular elements (diatomic molecules) and compounds. They confused a diatomic molecule with a compound.

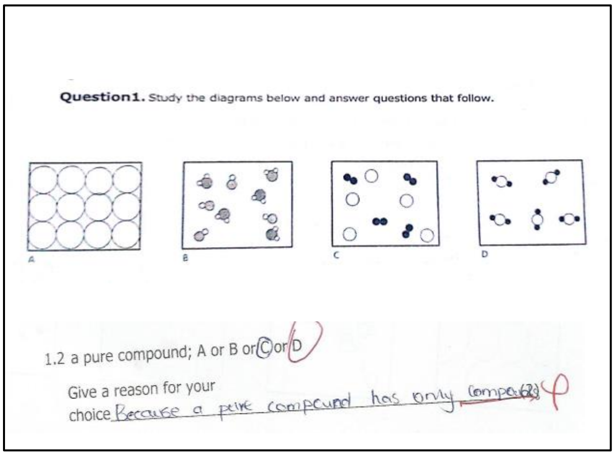

Figure 3: Response to question Q 1.2 of the TBCK

Figure 3 (Response to question Q 1, 2 of the TBCK) illustrates the point that the respondent did not have the correct understanding of the concept of elements; hence he/she was unable to make transitions across the three levels, namely, macroscopic (purity), sub-microscopic (same particles of compound) and the symbolic (chemical diagram). A similar observation was made by Onwu and Randall (2006) when 40% of their student teachers were unable to distinguish elements from compounds.

Another example, showing how basic chemical concepts became more difficult to understand, is shown in Figure 4 (Response to question Q 1.3 of the TBCK). Forty percent (40% as 22 out of 55) of the respondents were unable to identify a diagram that depicted a mixture of elements. This inability to identify entails that they were unable to make connections between the macroscopic (mixture), sub-microscopic (particles of the elements) and the symbolic (chemical diagrams) levels.

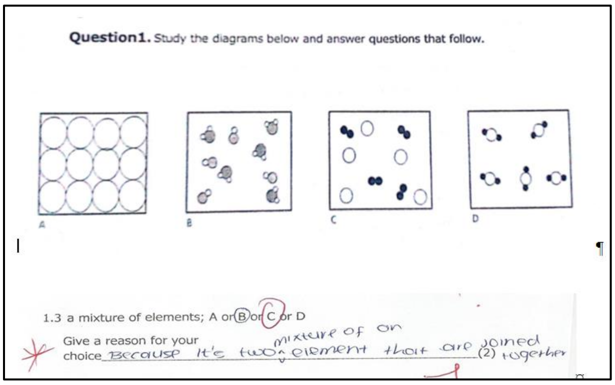

Figure 4: Response to question Q 1.3 of the TBCK

Figure 4 (Response to question Q 1.3 of the TBCK) illustrates that the respondent did not know the difference between elements and compounds. In this example, one can assume that the respondent noticed the difference in sizes of the atoms that made up the compound, but was not knowledgeable about chemical bonding that existed between them. Unlike in Onwu and Randall (2006), the respondents (40%) to Q 1.3 of the TBCK were not able to identify a mixture of elements. This observation may have been due to the fact that the TBCK used a mixture of mono-atomic and diatomic elements, and this tended to confuse the respondents. It therefore, can be concluded that making connections between the three levels of chemical conceptualisation that is, macroscopic (mixture of elements), sub-microscopic (chemical bonds between particles) and symbolic (chemical diagram) was problematic.

Furthermore, question Q 1.4 revealed that 49.1% (27 out of 55) of the respondents had no clear understanding of differences between elements and compounds as they chose either option C or D instead of option B. Figure 5 (Response to question Q 1.4 of the TBCK) shows that the respondent did not understand the difference between elements and compounds as elements in a compound were still taken as separate entities, chemical bonding not taken into consideration. This notion is strongly illustrated in the reasoning the respondent gave (*the different compounds are combined even when they're not the same*). Onwu and Randall (2006), in their study about some aspects of students' understanding of representational model of the particulate nature of matter in chemistry in three different countries also revealed that some (66-88%) of their respondents could not distinguish atoms from compounds. Their respondents (66-88%) thought that only atoms can be pure, seeing two different atoms chemically combined meant impurity.

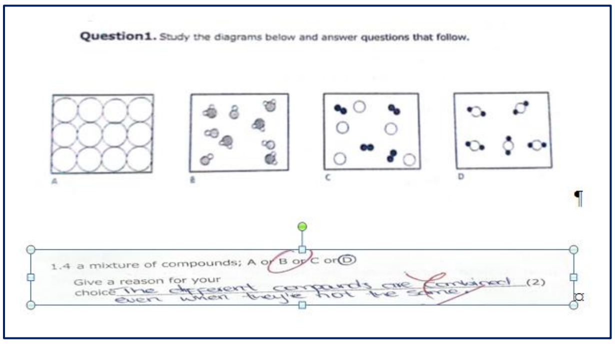

Figure 5: Response to question Q 1.4 of the TBCK

It, therefore, can be concluded from Figure 5 (Response to question Q 1.4 of the TBCK) that many learners were not able to make transitions across the three levels, in which chemistry is conceptualised, namely, macroscopic (mixture of compounds), sub-microscopic (chemical bonding between particles) and symbolic (chemical diagrams); hence they were unable to solve the problem.

The majority of the 45.5% (21.8%) learners who did not get the correct response to Q2 chose option D and had similar reasoning about the interaction of water and hydrochloric acid. Figure 6 (Response to question 2 of the TBCK) shows the manner that some of the learners were using to get to the solution of the task. Learners failed to move across the macroscopic level (water and the acid) and microscopic level (interaction of water and the acid).

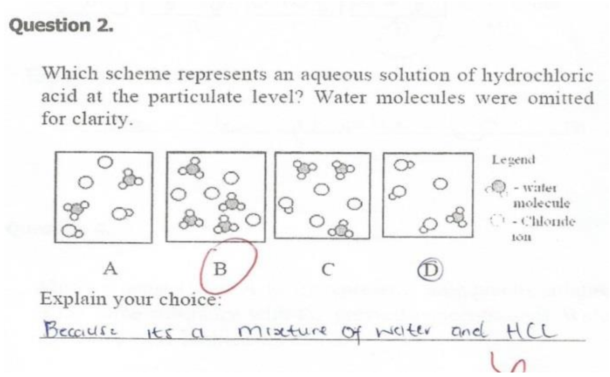

Figure 6: Response to question 2 of the TBCK

Furthermore, students do not seem fully to understand the difference between dissolution and chemical reactions that involve water. For example, learners did not realise that HCl reacts with water to give rise to hydronium (H_3O^+) and chloride (Cl^-) ions. Learners had to be familiar with the reaction that takes place between HCl and water to give rise to H_3O^+ and Cl^- ions ($HCl + H_2O \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$) and not just simply the H^+ and Cl^- ions. In many responses the hydronium ion (H_3O^+) was thought to represent the water (H_2O) molecule. Unlike in Devetak I., Vogrinc, J., and Glazar, S. A. (2009), respondents were not familiar with the hydronium ion; instead they took it for water. Majority of the 54.5% (30 out of 55 respondents) who managed to get the correct response had incomplete reasoning.

Nevertheless, the proportion of respondents who chose the incorrect option D sub-microscopic representation is still big (21.8%). These respondents did not know that hydrochloric acid is a strong acid that completely ionises to form hydronium ions and chloride ions in water. This is in line with Devetak, Lorber, Jurisevic and Glazar (2009), whose 20-26% of their pupils also chose the incorrect option D.

Although learners scored an average of 36% in task 3 (Q 3 in Figure 7: Response to question 3 of the TBCK), only 2% were able to give correct justifications and this means they could not move easily from concepts represented in diagrams to written and verbal descriptions of the sub-microscopic representation. Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar, (2004) made similar observations when they studied secondary school students' chemical conceptions using sub-microscopic representations as a tool for evaluation. This observation is also supported by Nakhleh (1992) in her study about high school students' understanding of acid-base chemistry at particle level. It was clear that learners were not familiar with what determines the basicity of a solution. 64% of the respondents were unfamiliar with the fact that it is the hydroxide ion (OH^-) that gives rise to basic solutions. Majority of learners could not connect the macroscopic level (visible solution) to the sub-microscopic level (invisible OH^- ions).

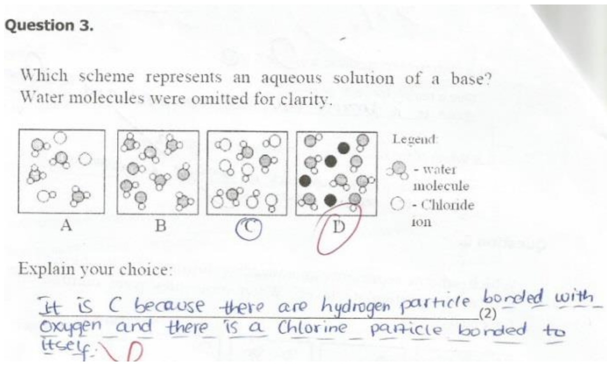

Figure 7: Response to question 3 of the TBCK

Figure 8 (Response to question 4 of the TBCK) illustrates how difficult it was for respondents to get to the solution of the problem. The respondents (49.1%) making up 27 of the 55 chose option D. It can, therefore, be concluded that the common reasoning among the 49.1% is that they did not understand the distribution of solute particles in solution; hence they could not solve the problem.

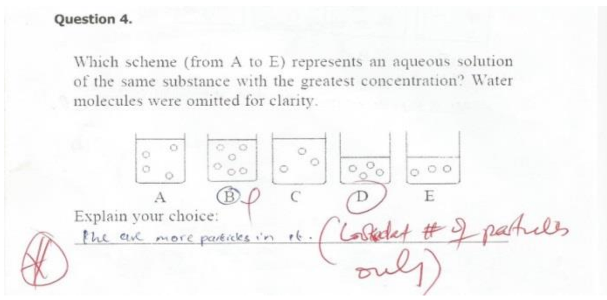

Figure 8: Response to question 4 of the TBCK

As can be seen, in Figure 8 (Response to question 4 of the TBCK) it appears that, from the way they responded, learners did not take account of the volume in which the particles existed. Thus, they were unable to make transitions across the three levels of chemical thinking; namely, the macroscopic (volume of water), sub-microscopic level (particles in solution) and symbolic level (manipulation of the mathematical aspect involved, $C = n/V$, where C = concentration, n = number of particles and V = volume of solution).

In some cases, learners failed to express themselves precisely. Learners struggled to come up with meaningful justifications at times. This struggle may be due to the fact that most multiple choice tests do not require them to explain their choices. It is also true that some learners relied on guessing to get multiple choice responses right. This guessing was very evident in cases where unpalatable explanations were given for the correct responses in this study.

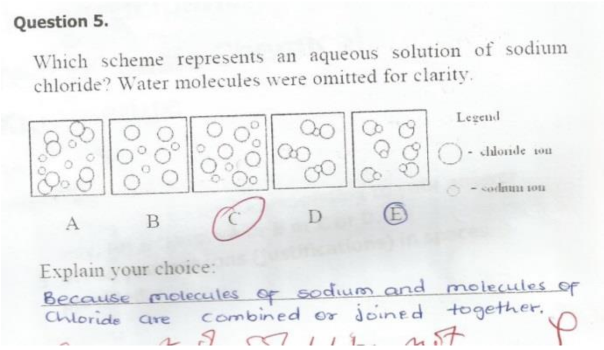

Figure 9: Response to question 5 of the TBCK

It can also be concluded from Figure 9 (Response to question 5 of the TBCK), that grade 10 physical science learners do not clearly understand the behaviour of ionic compounds in water. For example, learners do not understand that when sodium chloride dissolves in water, ions (Na^+ and Cl^-) are simply separated into the ratio (1:1) they were in before the dissolution process and are surrounded by the water molecules. It can be concluded that learners found it extremely difficult to make transitions across the three levels into which chemical concepts are conceptualised. They think that the aqueous solution of sodium chloride contains molecules of undissolved sodium chloride. Devetak, Vogrinc, and Glazar, (2009) observed the same in their study of grade 8 and 9 pupils' knowledge of electrolyte chemistry and their intrinsic motivation. This implies that learners could not connect the macroscopic (dissolution) level to sub-microscopic (separate ions in solution) and then to the symbolic ($NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$) level. Most learners remained trapped in the macroscopic (undissolved sodium chloride) and the symbolic levels as they could not picture the separation of ions in water but could give the correct formula of sodium chloride.

Figure 9 (Response to question 5 of the TBCK) shows a typical response where the respondent could not move between the macroscopic level (sodium chloride formula units referred to by the respondent as molecules) and the sub-microscopic level (Na^+ and Cl^+ ions in solution); hence the respondent could not identify the correct sub-microscopic diagram. The respondent did not realise that sodium chloride is an ionic compound and not a covalent compound. Hence, the dissolution process became difficult to imagine. Figure 9 (Response to question 5 of the TBCK) shows the general reasoning among the 47.3% (26 out of 55 respondents) who chose option E (of question 5 of the TBCK).

Because they could not connect the three levels, they were unable to solve the problem. This finding also lead to the conclusion that learners did not understand the concept of chemical bonding in ionic compounds as some of them thought that sodium metal had a valency of two, assigning two chloride ions to one sodium ion. This misconception was the understanding exhibited by those who chose option D (sodium atom joined to two chloride atoms) of the task. This is also supported by

Devetak (2005), when he noted that similar misconceptions are also common among the secondary school students and university students alike (Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar, 2004; Onwu and Randall, 2006; Potgieter, Davidowitz, & Venter, 2008).

5 CONCLUSIONS

The results revealed that most Grade 10 learners find it easy to identify pure elements and states of matter but find it difficult to negotiate between the three levels of chemical representation of matter when dealing with concepts of molecular elements, compounds, concentration and solution chemistry. It became clear that these concepts are not always apparent to learners. For example, majority of learners had very low achievement scores in tasks that involved these concepts. Analysis of justifications to multiple choice tasks revealed language problems as most learners could not express themselves in English and this brought down the level of achievement in the TBCK test by most learners. Justification scores were generally lower than scores in the multiple choice responses indicating that learners were not used to this type of questioning (two-tier). In addition, majority of the learners who got correct responses did not have correct justifications indicating the way they reasoned, thus they relied mostly on guessing. This could be a pointer that many teachers teach learners for examinations rather than understanding of the concepts. However, majority of the learners pointed out that this was their first time to have been assessed in this way (asking for justifications), thus suggesting that methods of instruction are not incorporating the use of sub-microscopic representations and the reasoning thereof.

It is therefore concluded that learners find it difficult negotiating the three levels of chemical representation of matter. However, it is not clear whether the misconceptions the learners showed could be completely attributable to the concepts involved or the nature of the sub-microscopic models that were used in the test as it was also revealed that many teachers were not using similar sub-microscopic representations during instruction to enable learners to think at particle level. Finally, these findings seem to suggest that this way of teaching and evaluating basic chemical concepts using sub-microscopic representational models is a fairly new approach to many teachers in South Africa. This therefore calls for more research of this nature in South Africa. Teachers are unfamiliar with this new way of teaching and assessing concepts. This way of learning and teaching is rarely practised in our secondary schools Devetak, Urbancic, Wissiak Grm, Krnel, & Glazar (2004).

6 RECOMMENDATIONS IMPLICATIONS FOR CHEMISTRY EDUCATION

It is against the above mentioned background in the discussions section that the following suggestions or recommendations are made:

Teachers and Educators should try to include the use of sub-microscopic representations in order to simplify the abstract chemical ideas about the particle theory of matter. Teachers should be diligent about the use of sub-microscopic representations as these are models of an already abstract model (atomic model). Teachers should try and help learners make connections between the three levels of chemical thinking when teaching chemical concepts (thus scaffolding the learner) in order to develop a mental model in the learner about the particle theory. Teachers should constantly make learners aware on the constant interplay between the three levels in which matter is portrayed (macroscopic, sub-microscopic and symbolic). In addition, teachers should help learners to decide how and when to use these three levels of chemical conceptualization.

Teachers should provide learners with opportunities to carry out experiments (macroscopic level) involving basic concepts about the particulate nature of matter themselves and allow them to discuss their observations in terms of particles. In addition, teachers should carry out demonstration experiments and discuss these in terms of the three levels of chemical conceptualization in class. This will enable learners to realize the connections that exist between the three levels of matter and will probably enhance their chemical understanding.

Teachers are also encouraged to use two-tier multiple-choice activities when teaching and assessing basic chemical concepts. Thus, the use of multiple-choice questions that require learners to justify their responses reveals learners' levels of understanding in a more sensitive way. Justifying choice of responses will help both learners and teachers to identify conceptions that are not compatible with science community knowledge. Knowing learners conceptions about a particular concept, helps the teacher to guide learners toward meaningful conceptual change and prepare future lessons for the next classes. Learner activities must be organized in a way that takes into consideration learners' conceptions like the ones that have been revealed in this study.

In the view of the authors, sub-microscopic representations are models of models (atomic or particle theory models) and this aspect is a problem in itself and teachers should pay particular attention to this during teaching and learning of chemical concepts. In other words sub-microscopic representations are models of an already abstract model based on the atomic theory and this seems to be the most confusing part of sub-microscopic representations as chemical explanations rely on the atomic theory of matter upon which the particle level is based. This is in line with Davidowitz and Chittleborough (2009) when they point out that it is not yet possible to see how atoms interact, thus the chemist relies on the atomic theory of matter on which the sub-microscopic level is based.

South African Chemistry Education System should provide relevant teacher support materials which include training in the use of sub-microscopic representations. Teacher education programmes should lay emphasis on the constant interplay between chemical phenomena (macroscopic events), sub-microscopic and symbolic representations as most teachers are not confident in the usage of such representations. The South African chemistry curriculum should consider including a hands-on practical examination (macroscopic level) on chemical concepts from grade 10 to12 as this would probably enhance learners' understandings (at present, only symbolic representations are predominantly used in South African schools) about the macroscopic world. In addition, considerations to streamline the chemistry curriculum should be made as the current one (CAPS) seems to overload the novice learner.

Teacher Education (Universities) should include in their chemistry programmes, courses that prepare pre-service teachers for using multi-representational views (use of sub-microscopic representations in the form of pictorial diagrams, computer simulations and animations) approach. This will ensure the starting point for the development of teachers' pedagogical content knowledge in the teaching of chemical concepts. Furthermore, universities and other teacher education institutions should take part in chemistry curriculum planning and development, as this would ensure alignment of chemistry teacher training with chemistry curriculum planning and development.

Chemistry Education Research Field: more research about use of sub-microscopic representations, as a tool for teaching and evaluating chemical concepts is needed as these representations are *models of models* (atomic models) based on a very abstract atomic theory. However it is not clear about why the learners found it difficult. It could be that learners did not understand the concepts or they were not used to assessment approaches that made use of sub-microscopic representations. The inability of students could also be arguably attributed to problems associated with use of a model (chemical representation) to explain another model (based on atomic theory) as this could actually complicate chemical understanding. For, example, some learners in this study saw the pictorial diagram entities as the actual and moving atoms (indication of confusion). .

Furthermore, research on how novice learners view matter before instruction is needed. This probably will help the field to identify learners' phenomenological and epistemological beliefs about the structure of matter. This will also help teachers to develop strategies that will narrow the cognitive gap that exists between students' prior chemical knowledge and that chemical knowledge which is accepted by the chemistry community. Research about students' epistemological views towards theories, models and sub-microscopic entities is strongly advised.

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EFFECTS OF STUDENTS' CHEMICAL CONCEPT UNDERSTANDING LEVEL ON THEIR ACHIEVEMENT ON BIOCHEMICAL TOPICS

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Abstract–This study investigated the effects of students' chemical concept understanding level on their achievement in biochemical topics (photosynthesis, respiration, diffusion, osmosis, carbohydrates, proteins, fats and enzymes) and Krebs cycle in some selected secondary schools in Delta State of Nigeria. It is a part of a doctoral research report. The design of the study was quasi experimental which involved the non-randomized control-group Pre-Test and Post-Test. Kuder Richardson formula 20 (K-R20) was used to calculate the reliability coefficient of the test. The internal consistency of reliability co-efficient was calculated to be 0.76. This shows evidence of internal consistency of the instrument. The population of this study consist of all senior secondary (II) students in the twenty (25) local government areas of Delta State. Six secondary schools randomly selected from the three senatorial districts were used for the study, with three (3) schools for experiments and the other three (3) for control groups. Intact classes were used for both groups. The sample was made up of five hundred and ninety two (592) students. Four (4) research questions were raised and answered and three (3) null hypotheses were formulated and tested at 0.05 level of significance. The research instruments used were the Test of Students Understanding of Chemical Concepts (TOSUCC) and Biology Achievement Test (BAT) which measured achievement in bio-chemical topics. The data collected is being analysed using Analysis of Covariance (ANCOVA) for the hypotheses and Mean Rating for the research questions to have the findings and recommendations.

Keywords: Achievement, Biochemistry, Biochemical topics, Biology, Chemical Concepts, Concept Understanding, Prior Knowledge

1. INTRODUCTION

Biology, a branch of natural sciences, which occupies a unique position in the school curriculum, is central to many science related courses like biochemistry, medicine, pharmacy, nursing and agriculture. In spite of the importance and popularity of biology among Nigerian students, performance at senior secondary school level has been poor (Ahmed, 2008). Poor academic performance of students has been a great concern to many educators, parents, psychologist, psychometrics', government, curriculum planners and researchers (Aremu, 2004).

Biochemistry is a branch of chemistry or biology that deals with the study of chemical compounds found in living systems and the reactions they take part in. Robert (2006) defined biochemistry as the science concerned with the chemical basis of life and that the cell is the structural unit of living systems. Thus biochemistry can also be described as the science concerned with the chemical constituents of living cells and the reactions and processes they undergo. It is therefore the science concerned with studying the various molecules that occur in living cells and organisms and with their chemical reactions.

The aim of biochemistry is to generate the understanding at the molecular level of all the chemical processes associated with living cells. To achieve this aim biochemist isolate the numerous molecules found in cells, determine their structures and analyze how they function (Robert 2006). The knowledge of biochemistry is essential to all life sciences. It is important for the study of genetics, physiology, immunology, pharmacology, toxicology, pathology, microbiology, zoology, botany and medicine. Some of the biochemical topics in the Federal Ministry of Education Senior Secondary Core Curriculum for biology in Nigeria are: Cellular respiration, Photosynthesis, Carbohydrate, Protein, and Kreb's cycle.

2. CONCEPTUAL FRAMEWORK

According to the Webster Dictionary (2010), a concept is a general notion or ideas of conception; an idea of something formed by mentally combining all its characteristics or particulars. Also concept enables us to organize learned responses which enable us to organize and interpreted data. Concepts enable us to respond effectively to the complexity of the world. The chemist is able to plan and control chemical process of great complexity to produce new plastics or man-made fibers because he has mastered the concepts of his discipline. The key to understanding a subject is to understand its concepts. These concepts are identified with words. To know a subject is to know the meanings attached to the words which represent its concepts. Once concepts have been learned we can apply or generalized them in new instances that share the same essential attributes

Some chemical concepts in the curriculum of Junior Secondary School are: physical and chemical changes, elements, compounds and mixtures, chemical symbols, chemical formula, chemical equation and atomic structure.

The understanding of bio-chemical topics requires the knowledge of some chemical concepts. Beskeni, Yusuf, Awang, Ranjha (2011) investigated how effective prior knowledge can help in the understanding of difficult chemistry concepts at secondary school level teaching, and found that students' prior knowledge has tremendous implications in the teaching of chemistry; and that prior knowledge must be considered in any classroom situation for effective teaching and learning of chemistry

Villafane, Bailey, Locrtscher, Minderhout, Lewis (2011), observed that biochemistry is a challenging subject because students` learning depends on the application of previously learned concepts from general chemistry and biology to new biological context. For meaningful learning to take place, the learning must have relevant concepts available within the existing cognitive structure which can be linked with the new material.

Muwanga (2007) stated that one of the challenges of teaching biochemistry is that learning involves comprehension of objects and processes that cannot be seen or experienced. From experience, a lot of biochemistry topics that would lay foundation to the understanding of photosynthesis, respiration, organic compounds- carbohydrate, protein and fats, enzymes and Krebs' cycle pose challenges to teachers and they avoid them. The object and processes has to be presented in such a way that understanding and excitement are generated when teaching and misconceptions are avoided.

The uniqueness of Biology and the central role that it stands to play in the development of any nation, are however not evident in the performance of students. It is sad to note that student's performance in Biology has continuously been poor and unimpressive. Many researchers have been done and are still being done to enhance the performance of students in Biology with a view to proffering solutions to low performance and the way forward. Hence the present study is to find out the effects of student's chemical concept understanding level on their achievement on biochemical topics, with the hope that conceptual understanding instructions or procedure will be used by teachers to teach bio-chemical topics for better understanding.

2.1 STATEMENT OF PROBLEM

The problem of this study was to determine the effects of students' chemical concept understanding level on their achievement in biochemical topics of topics and also to find out the chemical concept understanding level of students. To address the problem the following research questions are raised.

1. What is the level of students` understanding of chemical concepts (physical and chemical change, elements, compounds, mixtures, valency, chemical symbol, chemical formula, simple equation, atomic structure)?
2. What is the effect of students' chemical concept understanding level on their achievement in biochemical topics (photosynthesis; respiration; diffusion and osmosis; carbohydrates, proteins, fats and enzymes?

3. Is there any interaction effect of students` level of chemical concept understanding on their achievement scores in bio-chemical topics?

2.2 HYPOTHESES

The following null hypotheses were tested at $P \leq .05$ for the study:

1. The students' level of chemical concepts understanding is low.
2. There is no significant difference between students who have understanding of chemical concepts and those who do not have, in their achievement in bio-chemical topics of photosynthesis, respiration, diffusion, and osmosis, carbohydrate, protein, fats and enzymes.

2.3 SIGNIFICANCE OF THE STUDY

The findings of this study would be of benefit to teachers, researchers, curriculum planners as well as the Behavior Changing Agents to develop a greater awareness and understanding of the various interaction involving variables that predict the academic performance of students.

1. The student will eventually benefit greatly from this study as it is a fact that students with academic success will eventually contribute to the social industrial and technological advancement of the nation.
2. The study will make it possible to develop experimental researches in future in order to contain the variables investigated herein.
3. The study will help in serving as basis for designing intervention programs for improving the academic performance of students who could be described as low achievers.

2.4 SCOPE AND LIMITATION OF THE STUDY

The sample for this study was made up of the senior secondary two (SS 2) students in Delta State public schools. The study was limited strictly to senior secondary two biology content (scheme of work). Areas to be covered in chemical concepts are matter, physical and chemical changes, elements, compounds and mixtures, chemical symbols, formula and equation, atomic structure. The biochemical topics are photosynthesis, respiration, diffusion and osmosis, carbohydrate, fat, enzymes and Krebs's cycle.

3. METHODOLOGY

3.1 Research Design

This is a quasi-experimental Non –Randomized pre-test, post-test control group design. In quasi experimental design intact groups or classes are used and members are not assigned to the groups and classes randomly (Ary, Jacobs, Sorensen (2010).The design takes this form;

	Pretest	Treatment	Posttest
Experimental group	O_1	X	O_1
Control group	O_1	-	O_1

3.2 Experimental Group

This group consisted of three hundred and three (303) students from three (3) senior secondary schools randomly drawn from the 3 (three) senatorial zones of Delta State. This group was pre tested on chemical concepts and taught chemical concepts for four (4) weeks and post-tested in chemical concepts. They were pre-tested on Bio-Chemical topics and then taught bio-chemical topics for four weeks and Biology Achievement Test administered.

3.3 Control Group

This consists of two hundred and eighty nine (289) students from three (3) senior secondary schools randomly drawn from the three senatorial zones of Delta State This group was pre-tested on chemical concepts but were not taught chemical concepts. They were pre-tested on Bio-Chemical topics and were taught bio-chemical topics for four (4) weeks and Biology Achievement Test administered.

3.4 Population of the Study

The population of this study consist of all senior secondary II (SS II) students in the 25 (twenty five) local government areas of Delta State The population is made up of males and females students with a total population of 72,876 students with an average of 4,896 in each senatorial zone.

3.5 Sample and Sample Technique

The research sample consist of 592 (five and ninety two hundred) SS II students from six secondary schools drawn by simple random technique. Two schools drawn from each of the three (3) senatorial zones would be centered on public schools. The schools are distributed as follow: Three (3) schools for Experimental group and (3) schools for control group. The classes would be used as they are (intact classes).

3.6 Research Instrument

1. Test of students understanding of chemical concepts. The chemical concepts to be tested are physical and chemical changes, elements, compounds and mixtures, chemical symbols, formula, equation and atomic structure.
   Five (5) essay and twenty (20) short structured test items were used.
2. Biology Achievement Test (BAT). Test items on Biochemical topics are photosynthesis, respiration, diffusion and osmosis, carbohydrate, protein, fats, enzymes and kreb's cycle.
   Five (5) essay and twenty (20) short structured test items were used.

3.7 Reliability of the Instrument

The test items were administered to SS2 (Senior Secondary Two) students of College of Education Model Secondary School, Agbor in Ika Local Government Area of Delta State; to pilot-test the instrument and generate data for reliability test.

Kuder Richardson formula 20 (K-R20) was used to calculate the reliability coefficient of the tests. Ary, Jacobs and Sorensen (2010), said that the best probably known index of homogeneity (internal consistency) is the Kuder Richardson formula 20 (K-R20), which is based on the proportion of correct or incorrect responses to each of the items on a test and variance of the total scores. The internal consistency reliability coefficient was calculated to be 0.76.

4. ANALYSIS OF DATA

T-test and Analysis of covariance (ANCOVA) statistics were used to analyze the data generated to provide answers the research questions and test the stated hypothesis of the study. The results of the analyses have been shown in the tables discussed as follows:

4.1 RESULTS AND DISCUSSIONS

Hypothesis One

1. This is an Alternative hypothesis which states that the students' level of chemical concepts understanding is low.

Table 1: Distribution of Respondents by Group

		Frequency	Percent
Valid	Control	289	48.8
	Experimental	303	51.2
	Total	592	100.0

Table 1 shows the frequency of control group as 239 (48.80%) and experimental group 303 (51.2%). This gave a total of 592 respondents that took part in the study.

Table 2: t-test of Independent Samples in Pre-test Scores on Test of Students Understanding of Chemical Concepts (TOSUCC)

	Group	N	Mean	Std. Deviation	t	Sig (2-tailed)
PRE-TEST	Control	289	20.94	3.09	-2.25	0.822
	Experimental	303	20.54	3.08		

α = 0.05

Table 2 shows a t-test calculated value of -0.225 and a P value of 0.822 at an alpha level of 0.05. Since the P value is greater than the alpha level, it shows that there is no significant difference between the two groups in the Pre-tests. Percentage of the mean scores of the respondents was used to indicate their level of understanding. Thus, the mean score of less than 50% and more than 50% is considered as indicative of low and high level of understanding of chemical concepts respectively. The mean scores for the control group 20.94 (46.5%) and experimental group 20.54 (45.60%) are low. Therefore the students' chemical concept understanding level is generally low which is in agreement with the first hypothesis of the study before the special and remedial teaching of the selected chemical concepts.

Table 3: t-test of Independent Samples in Post-test Scores on Test of Students Understanding of Chemical Concepts (TOSUCC)

	Group	N	Mean	Std. Deviation	T	Sig (2-tailed)
POST-TEST (TOSUCC)	Control	289	25.94	3.60	-6.838	0.000
	Experimental	303	27.93	3.49		

α = 0.05

Table 3.3 shows a calculated t-test value of -0.6.838 and a P value of 0.000. Testing at an alpha level of 0.05, the P value is less than the alpha level. It shows that the null hypothesis which states that 'There is no significant difference in the level of understanding of chemical concepts by those exposed to instructions on chemical concepts and those who are not could not be accepted. Consequently, there is a significant difference in the level of chemical concepts understanding of those exposed to the instructions on chemical concepts and those who were not. Since the mean of the Experimental Group 27.93 is greater than the mean of Control Group which is 25.94, it shows, therefore that those exposed to chemical concepts instructions had better level of understanding of chemical concepts than who were not.

Hypothesis Two

This states that there is no significant difference between students who have understanding of chemical concepts and those who do not have in their achievement in bio-chemical topics of photosynthesis, respiration, diffusion, and osmosis, carbohydrate, protein, fats and enzymes.

Table 4: Description of students' post-test achievement in bio-chemical topics

Group	Mean	Std. Deviation	N
Control	17.1246	3.28270	289
Experimental	20.2277	2.93488	303
Total	18.7128	3.47317	592

Table 4 shows a post-test mean of control group as 17.12 and post mean for the experimental group as 20.23. Therefore the experimental group performed better than the control group. The standard deviation of 2.93488 for the experimental group is significantly lower than the 3.28270 for the control group. This means students in the experimental group showed higher and better achievement than those in the control group.

Table 5: ANCOVA Summary Table for Achievements on Bio-chemical Topics

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3996.685[a]	2	1998.343	375.746	.000
Intercept	323.054	1	323.054	60.743	.000
Pre Bio-Chem	2572.306	1	2572.306	483.668	.000
Group	883.887	1	883.887	166.196	.000
Error	3132.497	589	5.318		
Total	214430.000	592			
Corrected Total	7129.182	591			

a. R Squared = .561 (Adjusted R Squared = .559)

Table 5 shows an F value of 166.196 and a P value of .000 which is less than

α = 0.05 level. Hence, the null hypothesis which states that 'There is no significant difference between students who have understanding of chemical concepts and those who do not have in their achievement in bio-chemical topics of photosynthesis, respiration, diffusion and osmosis, carbohydrates, protein, fats and enzymes' could not be accepted. In other words, there is significant difference between students' chemical concept understanding level and their achievement in bio-chemical topics of photosynthesis, respiration, diffusion and osmosis, carbohydrate, protein, fats and oil, and enzymes.

Table 6: Pair wise Comparison of Students achievements in Bio-chemical

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Control	Experimental	-2.472*	.192	.000	-2.849	-2.096
Experimental	Control	2.472*	.192	.000	2.096	2.849

Based on estimated marginal means
**. The mean difference is significant at the .05 level.*
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 6 shows a mean difference of experimental and control as 2.472 and a P value of .000. Since the P value is less than .05 (P<0.05), it shows that students who have understanding of chemical concepts achieved more in bio-chemical topics than those who do not have chemical concept understanding.

Table 7: Description of Post-test Achievements on BAT

Group	Mean	Std. Deviation	N
Control	16.1246	3.28270	289
Experimental	21.9406	2.42294	303
Total	19.1014	4.08868	592

Table 7 shows a post-test mean of the control group as 16.12 and a post-test mean for experimental group as 21.94.The mean for the experimental group is greater than the mean for the control group, therefore the experimental group achieved more than the control group in biochemical topics. This observation is further interpreted by the fact that the standard deviation of 2.42294 for the experimental group is significantly lower than the 3.28270 for the control group.

Table 8: ANCOVA of students' achievement in BAT

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	8048.093[a]	2	4024.047	1.294E3	.000
Intercept	1549.613	1	1549.613	498.258	.000
Pre Krebs's Cycle	3044.621	1	3044.621	978.959	.000
Group	4298.493	1	4298.493	1.382E3	.000
Error	1831.826	589	3.110		
Total	225878.000	592			
Corrected Total	9879.919	591			

R Squared = .815 (Adjusted R Squared = .814)

Table 8 shows F value of 1.382E3 (i.e. 1.382×10^3) and a P value of .000 at an alpha level of 0.05, the P value is less than the alpha level, so the null hypothesis which states that 'There is no significant difference between students who have understanding of chemical concepts and those who do not have in their achievement in biochemical topics is not accepted. Therefore, there is a significant difference between students who have understanding of chemical concepts and those who do not have in their achievement in biochemical topics.

Table 9: Pair wise Comparisons of Students Achievement on BAT

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Control	Experimental	-5.412*	.146	.000	-5.698	-5.126
Experimental	Control	5.412*	.146	.000	5.126	5.698

Based on estimated marginal means

**. The mean difference is significant at the .05 level.*

Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 9 shows a mean difference of experimental against control as 5.41 and a P value 0.000. With the P value is less than 0.05 ($P<0.05$), that students who had understanding of chemical concepts achieved more in biochemical topics.

4.2 SUMMARY OF THE RESEARCH FINDINGS

1. The level of students' chemical concept understanding is generally low without special interventions. There is no significant difference between the experimental and control groups in their level of chemical concept understanding before being exposed to instructions on chemical concepts.
2. There is a significant difference in the level of chemical concepts understanding of those exposed to the instructions on chemical concepts in preparation for instructions in biochemical topics and those who were not.
3. There is a significant difference between students' chemical concept understanding level and their achievement in bio-chemical topics of photosynthesis, respiration, diffusion and osmosis, carbohydrate, protein, fats and oil, and enzymes. This is because students who have understanding of basic and appropriate chemical concepts perform better than their peers without such level of understanding, and so they achieved more in bio-chemical topics than those who do not have chemical concept understanding.

This result is in line with the result of Beskeni, Yousuf, Awang, Ranjhal (2011), who said that the knowledge of biochemistry concepts requires the knowledge of chemical concepts. They investigated how effective prior knowledge can help in the understanding of difficult chemistry concepts at secondary school level teaching and found out that prior knowledge has tremendous implication in the teaching and learning of chemistry. It is also in line with the work of Villafane, Sachel, Bailey, Cheryl, Loertscher, Jennifer; Minderhout, Vicky; Lewis, Jennifer (2011) who in their work stated that learning depends on the application of previously learned concepts from general chemistry and biology to new biological context. They said also that for meaningful learning to take place there must be relevant concepts available within the cognitive structure which can be linked with the new material. Khan (2011) in his article said that existing level of understanding of concepts to the subject of chemistry among class IX students was not high.

5. CONCLUSION

Findings of the study and others cited in the literature reveal that

1. The result of the study shows that the chemical concept understanding of students is low. This explains one of the reasons why many students perform poorly at the Senior Secondary School Examinations (SSCE).
2. The treatment approach of this study was very effective in enhancing achievement of the participants in bio – chemical topics. This shows that chemical concept understanding aids the understanding of biochemical topics or that if students understand chemical concepts, they will have better achievement in biochemical topics.
3. Prior knowledge of chemical concepts is important for the teaching for understanding of biochemical topics in biology and that chemical concept understanding is a pre – requisite for the understanding of biochemical topics. It also shows that learning biochemical topics depends on the application of previously learnt chemical concepts.

5.1 IMPLICATIONS

1. Biology students in the sampled schools in Delta State have low level of chemical concepts. Students who had chemical concepts understanding performed better than those without in biochemical topics. The low level of chemical concept understanding of biochemical topics by students has implication in their learning of the topics. There is the probability that secondary school biology and chemistry teachers do not teach for concepts understanding. This study will therefore enhance better teaching and learning.
2. The treatment strategy used in this study will provide educational psychologists, policy makers, curriculum planners, teachers and principals of secondary schools with guidelines for future educational diagnosis aimed at improving educational system in Nigeria.

5.2 RECOMMENDATIONS

1. Secondary school biology and chemistry teachers need to teach or revise certain topics related to the new topics for concept understanding before teaching such new topics.
2. Curriculum planners and school administrators should run workshops on concepts understanding especially for difficult topics like biochemical topics to update their knowledge in the effective process of enhancing students' achievement in biology.
3. Federal Government should:
    - I. Fund, train and retraining workshops and seminars for biology and chemistry teachers on – job.
    - II. Send inspectors of education especially those of science department for awareness training, and workshops for teaching for conceptual understanding. This would enable them to be competent to recommend books and other materials that are required for teaching for conceptual understanding.
    - III. The various examination bodies like WAEC and NECO should include appropriate models in their syllabuses and make sure the course can be covered within the stipulated time. Enough time should be given for the topics to be covered
4. To ensure high performance, competent adequate and qualified teachers with defined areas of specialization and with teaching experience should be engaged to teach the students from JSS1. Such teachers should be involved in examining, supervising and marking of the internal and external examinations; by this, they will be professionally enhanced.

5. Schools and Government should provide for teachers all the necessary requirements and good environment for teaching for concepts understanding.

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THE IMPACT OF BALL AND STICK MODELS AND COOPERATIVE LEARNING STYLE IN STEREOCHEMISTRY LESSONS ON STUDENTS' VISUALIZATION AND ACHIEVEMENT

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Abstract–The purpose of this research was to investigate the impact of cooperatively using ball and stick models in stereochemistry lessons on students' visualization and achievements; and to assess students' attitude toward using ball and stick models and understanding stereochemistry lessons. This study was conducted with three years with 294 students that participated in it. The research design used for the study was the pre-test- posttest quasi-experimental control design, using intact sample students. The study unit of the research covered stereochemistry topics. For the experimental groups the contents of the unit were taught with ball and stick models, while the control group was taught following the usual teaching-learning approach. The result indicates that there was no significant difference in the pre-test achievement scores of students between the experimental and control groups at the beginning. Whereas, on the post-test there was statistically significant difference observed between experimental and control groups with the t-tests (at $p<0.05$). The experimental group students were found to perform and achieve better in stereochemistry lessons than those in the control group. The responses to the questionnaires gathered from participants of this study have indicated that ball and stick models is effective in advancing students` comprehension of stereochemistry concepts. This is also supported by students' positive attitude observed on some interviews made regarding the use of ball and stick model in stereochemistry lessons.

Keywords: Attitude, Achievement, stereochemistry, ball and stick model, cooperative learning style, two-dimensional form, three-dimension, visualization.

INTRODUCTION

Chemistry is an essential basis for our everyday lives, and has many unforeseen potential benefits for our future. An understanding of chemistry allows us the opportunity to explain the world around us; and to make informed decisions concerning our actions as individuals. Generally, understanding of chemistry is necessary for working in almost all the other sciences such as material sciences, engineering, environmental sciences, and medicine. Students opting for any of these career fields need good knowledge in chemistry and about current trends in chemistry (Ingo Eilks and Avi Hofstein; 2013).

Many scholars addressed organic chemistry as a hard course and many college students who wish to pursue a career in Chemistry and medicine must have a solid understanding of organic chemistry and, perhaps more importantly to the students, a good grade in organic chemistry. However, the difficulty of the Organic Chemistry materials prevents many students from continuing with this career path. One of the major difficulties for students in organic chemistry is that of understanding the three-dimensional nature of molecules. Students usually have no good background in three-dimensional visualization and have great difficulty in converting between the two dimensional drawings used in text books and on classroom chalkboards to represent molecules and their three-dimensional structures (Gilbert 2008; Uttal and Doherty 2008; Michael Corrin, *et al.,* 2013). Without this understanding, students memorize a large vocabulary of molecules and rules to fake an understanding of the three-dimensional structures in order to survive the course.

Stereochemistry is one of the most important lessons in undergraduate organic chemistry course and students are expected to develop an understanding of this topic and to interpret a variety of representations of chemical bonds (using chemical formulae, ball-and-stick models, etc.). Yet, students commonly find it problematic and eventually develop a wide range of alternative conceptions (Stieff, 2007). Apparently, stereochemistry requires the use of Visio-spatial strategies because scientific problems often require explicit consideration of spatial relationships (Gilbert, 2005), and chemists might mentally rotate visualized molecules when designing new pharmaceuticals (Habraken, 1996). It is a challenge for undergraduate chemistry students in linking 2-D and 3-D representational levels (Gilbert 2008; Michael Corrin, *et al.,* 2013). Stereochemistry is frequently a source of confusion when students are first exposed to it, and unfortunately, this feeling may linger even after repeated exposures (Bowen and Bodner, 1991; Bodner, 2003; Izzet Kurbanoglu, *et al.*, 2006). Visualizing the three-dimensional aspects of molecules and their relationships to other molecules is difficult (Brand, 1987). When dealing with principles that are particularly difficult to visualize or conceptualize, such as stereochemistry, instructional materials and mnemonic devices become invaluable in the learning process. Often, these devices help individual students make a connection between the new material and their own experiences and prior knowledge base. These methods vary from mathematical approaches to two-dimensional Fischer projection techniques to the three-dimensional models (Barta and Stille, 1994).

A model is understood as a representation of a target. The targets represented by models can be of various entities, including objects, phenomena, processes, ideas and their systems. A model is also considered a bridge or mediator connecting a theory and a phenomenon, it helps in developing a theory from data and mapping a theory onto the natural world (Seok and Jin 2011). Analogical models are widely used in science to describe and explain non-observable objects and processes. Models are *thinking* tools that encourage students to build meaningful mental representations of abstract ideas; indeed, modeling is often called the essence of inquiry science. Models are not fixed, but are thinking tools (Grosslight, Unger, Jay & Smith, 1991), students use models to predict molecular shapes, explain reactions in terms of collision theory and visualize the states of matter.

In the Chemistry department at Haramaya University, it has been observed that many students work hard with course materials in stereochemistry. However, their examination results in stereochemistry show that a great many of them often seem not to be achieving well (they scored less than mean: analysis of past three years results in stereochemistry topic) relative to the other topics. Though they seem to be working hard, they do not acquire the necessary knowledge and cannot express their answers clearly and logically. In order to facilitate students learning, many lecturers put their effort in making them actively engaged in the construction of their own knowledge, when they give lectures on stereochemistry. But, no more significance change is observed in this regard. Generally, we observed that students have difficulty in visualizing structures of streoisomers in three-dimensional forms; in relating three-dimensional with two-dimensional shapes; in giving nomenclature of Enantiomers (R-S) system; and in explaining stability of different configuration of molecules. A number of researches provide empirical evidence that ball and stick model is a useful learning strategy in many content areas such as Biology and Physics,(Mathewson, 1999; Jones, Jordan and Stillings, 2001, 2005; Jose and Wiliamson, 2005). Boulter and Gilbert (2000) considered the importance of using models for students to gain a better understanding of the subject and of how scientific knowledge is achieved. However, a number of researches provide evidence of using ball and stick models in improving students visualizing ability as a teaching learning strategy, no systematic study could be located in Ethiopian context to solve undergraduate students' learning difficulties in stereochemistry while the dominance of the lecture method was still being used in stereochemistry lessons. Therefore, this study attempted to investigate the impact of cooperative learning style using ball and stick models in stereochemistry on the students' visualization ability, attitude and achievement. 1.3. Objective of the Study

Objectives of the study:

- To determine whether or not cooperative learning using ball and stick model improves students' achievement in stereochemistry lesson.
- To assess students' attitude and level of visualization as may be influenced by cooperatively learning using ball and stick models in stereochemistrylesson.

RESEARCH METHODOLOGY

Participants of the Study

A total of 294 (54 in the experimental group) and 240 in the control group) first year chemistry students in 2011/2012, 2012/2013 and 2013/2014 academic years in their intact classes participated in this study. The researchers took participants from different academic years to reduce contamination between group participants and compared their results on the same lesson performance test (stereochemistry). The researchers also considered organic chemistry teachers during his research time at examining his actual classroom practice with the experimental groups.

Description of Sampling Procedure

The design of this study was quasi experiment design**.** Quasi experimental designs are commonly employed in the evaluation of educational programs when random assignment is not possible or practicable. If they are from the same academic year, they may share their idea to each other about the newly implemented cooperative learning style using ball and stick model in stereochemistry, which may cause contamination between experimental and control group students. However, the course lecturer, course contents, pre-and posttests and the time taken to cover the contents were the same to all the groups excepting the treatment condition given to the experimental group in the 2013/2014 academic year.

The group design in cooperative learning environment

In this study cooperative learning style was used. For convenience, one preliminary session were assigned in the beginning of the first week to introduce cooperative learning approach to experimental group students to minimize difficulties toward the method. According to Ai Bin (2009), for cooperative strategies to work, careful planning, inconspicuous observation and evaluation and preplanned adjustments (alternative activities) are essential to help learners move consistently forward. As an application of this principle in this research, students in the experimental group were on the use and management of cooperative learning style based on Johnson & Johnson, (1998) model. Cooperative learning is an instructional strategy that involves students working in teams to accomplish a common goal, under conditions that include the following elements: Positive interdependence, Face-to-face interaction; Individual accountability (Personal responsibility); Interpersonal and small-group skills (Teamwork skills); and Group processing.

Students in the experimental class were assigned to nine different groups of 6 students per group by the researchers. From the group members one is assigned as the leader/manager to manage the group and ensure that members fulfill their roles and work cooperatively in a timely manner; one as recorder to records the group's answers and discussion outcomes; and the rest members as reflectors to ensures that all possibilities have been explored by posing questions such as `What's another idea? ` or `How can we look at this problem in another way?`. The students were then continuously encouraged in their groups for two hours twice a week during the training period. After the training, the researchers gave the actual questions and assignment which assessed students' conceptual understanding of stereochemistry and general visualization lessons. I, problems were chosen out of the real world order to achieve this aim thereby enabling the individuals develope by possible integration of accumulated information about any learning material presented to them. They were made to deal with scenarios involving several problems and to find appropriate answers to these problems. Then, one of the researchers played a tutoring role rather than that of an instructor. He guided the students on the use of ball and sticks model and helped to give explanations and extra help to the students as the need araose. In this way, all the students were kept active, and they were involved in the learning process. To maintain uniformity, the treatment time (three times per week of one hour each) for both groups was the same. At the end of the treatment period, the same post-test was administered to both groups of students.

Data Gathering Instruments

Relevant data from the subjects of study were collected through the use of multiple instruments listed below:

Chemistry achievement tests

A Stereochemistry achievement test (StAT) developed by the researchers (pre-test and post-test) was used in this study in order to gather relevant data from the subjects of the study. The test was evaluated by four experienced organic chemistry lecturers from two different Universities not used for the main study. The reason for evaluating the tests was to make sure that the questions were aligned with the course content and level and thereby the instrument's reliability and validity were positively determined. Indeed, their comments on the validity of tests led to some rearrangement of the items to ensure a high level of validity. The measure of content validity index of the test was 0.82.

The test contained 16 workout and 4 multiple choice in Organic Chemistry (Stereochemistry).. The posttest measured students' achievement generally on the lesson they learned (stereochemistry) at the end of the study period.

Questionnaire

Questionnaire was also used as tools to gather relevant information from the subjects of the study. Therefore, two sets of questionnaires (open ended and closed ended) were prepared to for experimental group students to collect data on: Whether cooperative learning using ball and stick model in stereochemistry lessons is impacted on their visualization and achievement or not; and the effectiveness of the approach in improving students understanding of three dimensional structure and in acquiring stereochemistry concepts.

Prior to distributing the instruments, which were prepared in the English language, the researcher collected data by taking totally 15 randomly selected student and distributed the researcher constructed test that were not included in the sample, as a pilot test. Then its reliability was checked with Cronbach's Alpha. The Cronbach's Alpha value was 0.80 on the tests. Cronbach Alpha is an important tool to determine the reliability of instruments by calculating a reliability estimate (Brown, 2001; Cronbach, 1970; Tesfaye demise 2012).

Interviews

Interviews were also used as data collecting instruments to get the views and opinions of students generally in cooperatively using ball and stick models in stereochemistry lessons (the effectiveness of learning stereochemistry lesson with ball and stick models, and the effect of the method in enhancing their understanding of stereochemistry lesson and achievement. 11 students were randomly selected from experimental group and interviewed.

3.6. Methods of Data Analysis

The data were analyzed by using both quantitative and qualitative analysis methods. The quantitative data were analyzed by using both descriptive and inferential statistics to describe the data in terms of the mean, and percentage. Comparative analysis was also employed to see possible gain - scores in cooperative learning style using ball and stick models on stereochemistry as compared with the traditional lecture method of teaching. The t-test was used to test if there was any statistically significant difference between the two groups.

RESULTS AND DISCUSSION

The Pre-test and Post-test Results of Students

To determine if there was any statistically significant difference or not between experimental and control group students on pre-test two sample independent t-test was used and the results as indicated in Table 1 bellow. the mean score results and the two sample independent t-test at (α =

0.05) from the table confirm that there is no significant differences observed between experimental group and control group students on the pre-test.

Table 1. Comparative analysis on pre-test and Post test result of experimental and control group students using two sample independent t-Test

Tests	Groups	N	Df	Mean	SD	t-value	*p-value
Pretest	Experimental group	54	292	0.16667	0.33646	-0.55122	0.58191
	Control group	240		0.13958	0.3239		
Posttest	Experimental group	54		26.98148	6.91864	-10.387	0.00000
	Control group	240		18.00333	5.44267		

*At the 0.05 level, the difference of the population means is significantly different
N=number of experimental and control group students, P= probability, SD = standard deviation, Df = degree of freedom

To assess any and level of differences observed in performance or not a post-test was administered on students who completed the stereochemistry lesson with cooperative learning style using ball and stick models (experimental group) and those who completed the lesson with traditional lecture method (control group) were investigated by using two sample independent t-test. The t-test at (α = 0.05) confirmed that there is highly significant difference observed between the experimental group students and control group students on the post-test results. The experimental group students gained higher scores in post-test than control group students.

Perception of students on cooperatively using ball and stick models in stereochemistry lessons

The aim of this questionnaire was to gather information on the effectiveness of cooperatively using ball and stick models in enhancing students' visualization ability and achievement in stereochemistry lesson in teaching-learning process. The experimental group students were asked to provide feedback on their experiences in the stereochemistry classes that employed with ball and stick models. Closed ended questionnaires are administered to experimental group students. The items were rescaled into three parts (agree, undecided and disagree) as shown Table 2 below:

Table 2. The students' response to questions related to learning stereochemistry with cooperatively using ball and stick models

No	statements	% of respondents		
		Agree	Undecided	Disagree
1.	Cooperative learning using ball and stick models seems to be a good way to learn stereochemistry concepts	100	-	-
2	The approach (cooperative learning using ball and stick models) helped me to understand the concept of stereochemistry chemistry	96	1.9	1.9
3	Cooperative learning using ball and stick models helped me to visualize and understand structures of stereochemistry molecules	100	-	-
4	I felt that cooperative learning using ball and stick models create an opportunity for us to discuss with my colleague on abstract concepts in stereochemistry lessons	96	1.9	1.9
5	Cooperative learning using ball and stick models helped me to memorize the structure of molecules easily when I study stereochemistry independently	90.7	9.3	-
6	The presentation given by the teacher with ball and stick models is very interesting	87	11.1	1.9
7	Cooperative learning using ball and stick models helped me to visualize and understand the structure of stereochemistry lesson; and to score better result in this lesson	90	7	2

Discussion

Table1 above showed that there was no significance difference between the groups prior to intervention. Therefore, from this result it is possible to say that the groups used in the study exhibited comparable characteristics towards stereochemistry lesson at the beginning of their programmes. The groups were therefore suitable for the study when comparing the effects of cooperative learning using ball and stick models in visualization and understanding stereochemistry lesson with the regular teaching (lecture) method.

Similarly, the two sample independent t-test ($\alpha = 0.05$) confirmed that there is highly significant difference observed between the experimental group students and control group students on the post-test results. Besides, the mean results of 26.98148 and 18.00333 also exhibited significant difference observed between the two groups in favour of the experimental group on post-test. The experimental group students scored better results in post-test than control group students. This result revealed that cooperative learning using ball and stick models is effective in enhancing students' visualization in stereochemistry lessons and achievements than traditional lecture method. The students who took the course without such treatment had a challenge to visualize and mentally rotate molecular structures, and also difficulty in mastery of specific heuristics and algorithms for efficient problem solving in stereochemistry lessons. Their mean score was very low compared to experimental group students. Thus, the propensity of cooperative learning using various ball and stick models in stereochemistry to make explicit the spatial features of molecular structures offers a great opportunity for reasoning and comprehension in stereochemistry problems.

This study has attempted to elucidate the application of cooperative learning using ball and stick models in visualizing three dimensional molecules in stereochemistry and external representations of three-dimensional objects suggesting a need for students to generate and manipulate internal visual representations. In the use of traditional instruction (lecture) method, organic chemistry students learn the concept of stereochemistry, which concerns the three-dimensional arrangement of atoms within a molecule by using two dimensions (Fischer projections or Howarth projections). Specifically, students learn that two molecules which contain the same atoms with identical bond arrangements may have unique three dimensional structures (stereoisomer): such molecules have the same physical make-ups, the same connectivity, yet they are unique spatially. For example, both molecules in Figure 1 bellow contains one atom each of carbon, X, Y, Z, and W; however, the molecules are asymmetrical mirror images, or enantiomers, and no imagined rotation of either molecule will allow them to superimpose (match exactly when one molecule placed over) the other). In stereochemistry, students solve this and other related problems in which they determine whether two molecules are identical as well as propose methods to transform, one spatial configuration into the other.

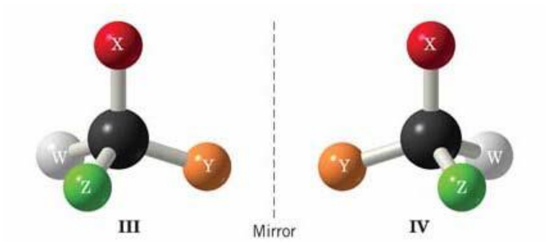
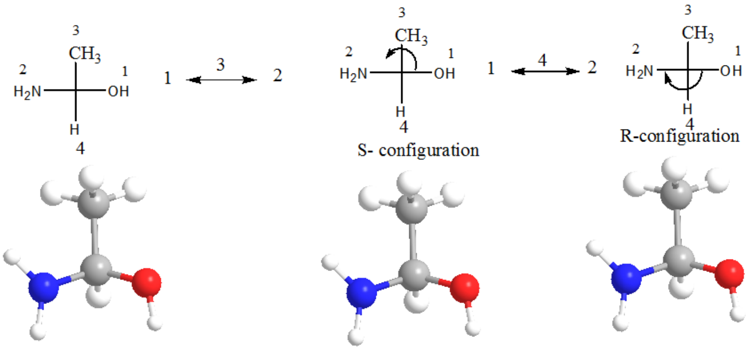


Figure 1. Pictures of ball and stick models for chiral molecules

For example, for question "*assign the R or S configuration to the following molecules in accordance with the sequence rule and interchange rule mentioned so far*": majority of control group students have difficulty in visualizing and in adressing the spatial orientation of the given molecule.



In order to give the configuration for the molecule given above, majority of control group students started from 1 and moved to 2 through 3 rather than started from 1 and move to 2 through 4, while majority of experimental group students addressed this that 4 is between 1 and 2 after cooperatively using ball and stick models. Ball and stick models, explicitly show us 4 is not found between 1 and 2, but, it is a molecule which found at the rear side of the chiral carbon. Therefore using ball and stick model proves a very good approach for students to show whether 4 was found on the rear side of chiral carbon or not. Comparing experimental group students () against control group student's, majority of experimental group students were answered the question correctly after using ball and stick models.

Let us see the following molecules:

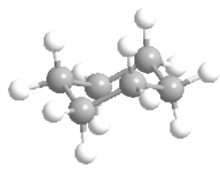


Figure 2a. Chair conformation of three-dimensional structure (six hydrogens are axial and six hydrogens are at equatorial position)

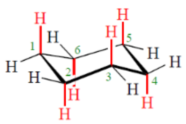


Figure 2b. Chair conformation of two-dimensional structure (six hydrogens are axial and six hydrogens are at equatorial position)

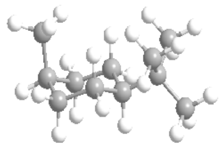


Figure 2c. three-dimensional structure (cis-1-tert-butyl-4-methylcyclohexane)

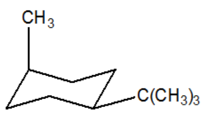


Figure 2d Two dimensional structure (cis-1-tert-butyl-4-methylcyclohexane)

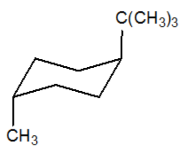


Figure 2f. Two dimensional structure (trans-1-tert-butyl-4-methylcyclohexane)

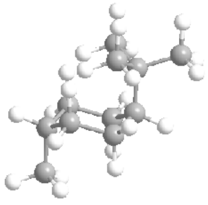


Figure 2e. Chair conformation of three-dimensional structure of trans-1-tert-butyl-4-methylcyclohexane

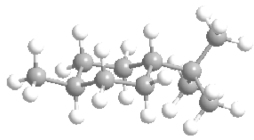


Figure 2g.Three-dimensional structure (trans-1-tert-butyl-4-methylcyclohexane)

Figure 2h.Two dimensional structure (trans-1-tert-butyl-4-methylcyclohexane)

For example; another question posed to the students was: “Write structural formulas for the most stable conformation of each of the following compounds and explain why it is more stable than the other: (a). trans-1-tert-Butyl-4-methylcyclohexane (b). cis-1-tert-Butyl-4-methylcyclohexane”. For this question 68% (majority) of control group students didn’t give appropriate and logical answer while, 83.1% (majority) of experimental group students gave clear and appropriate answers. With ball and stick models it is easy to predict, why one molecule is more stable than the other depending the structure of the molecules and by considering the closeness of the bulkier groups which cause sterric hindrance from its’ crowdedness. On the other hand, the control group students had difficulty in identify the axial and equatorial positions for different conformations of di-substituted cyclohexane such as cis-1-tert-butyl-4-methylcyclohexane or trans-1-tert-butyl-4-methylcyclohexane; in determining and in writing the most stable structure; and in explaining why trans-1-tert-butyl-4-methylcyclohexane (in Figure 2h) is more stable than the other trans-1-tert-butyl-4-methylcyclohexane (Figure 2f).

Generally, in lessons which require students’ visualization, they should be better assisted by applying cooperative learning using ball and stick models to increase students’ ability of visualization and to show the particulate or sub-micro “representational levels” of stereochemistry understanding, instead of simply giving lecture by talkMany scholars similarly addressed that visualizations (graphs, tables, illustrations, animations) are valuable in educational settings because they help make complex information accessible and cognitively tractable, and “help us think in visual rather than abstract, symbolic terms”. It helps students to assess their level of understanding and show them the gap where they need to cover. This is because it provides for a self-paced, logical sequence of small steps, and immediate confirmation or correction, it helps to overcome the wide spread of abilities and interest among university chemistry students (Michael Corrin, et al., 2013).

This is also supported by students’ positive attitude observed from their responses on questionnaires and some interviews made regarding cooperatively using ball and stick model in stereochemistry lessons.

For example, Table 2 above shows students` responses for the statements “Cooperatively using ball and stick models seems to be a good way to learn stereochemistry concepts; the approach (cooperatively using ball and stick models) helped me to understand the concept of stereochemistry chemistry; Cooperatively using ball and stick models helped me to visualize and understand structures of stereochemistry molecules; and Cooperatively using ball and stick models helped me to visualize and understand the structure of stereochemistry lesson; and to score better result in this lesson” one can be see clearly from Table 2 above, majority of respondents agreed with the given statement. This shows that learning stereochemistry by cooperatively using ball and stick models is good for students in clarifying spatial orientation of molecules and could be better to visualize structure of stereochemistry concepts.

The responses of the students for the statement “I felt that cooperatively using ball and stick models create an opportunity for us to discuss with my colleague on abstract concepts in stereochemistry lessons” indicated that, majority of students responded that cooperatively using ball and stick model was preferable in facilitating conditions (example; in highlighting the problematic areas and creating an opportunity for students to help each other), for students to ask questions, and to visualize, grasp and organize important stereochemistry concepts from the lessons. This revealed that the students could have better chances for posing questions, discuss on it and come to consensus during cooperatively using ball and stick models.

Similarly, students response for the statement "Cooperatively using ball and stick models helped me to memorize the structure of molecules easily when I study stereochemistry independently; and the presentation given by the teacher with ball and stick models is very interesting", also showed that majority of the respondents agreed with the given statement. This indicates that the students are interested in using ball and stick models stereochemistry.

Experimental group students were asked to comment on their perception about cooperatively using ball and stick models in stereochemistry classes and majority the of students indicated positive attitudes on the effectiveness of cooperatively using ball and stick models as teaching-learning tool, not only in the laboratory but also in class room. This showed that students` interests are boosted if they learn stereochemistry by cooperatively using ball and stick models. Using ball and stick model is helps them to visualize spatial orientation of molecules; to understand the nature of bonds in organic chemistry (bond difference in length); and to grasp and organize the structure of stereochemistry three dimensionally which further helps them to relate with two dimensional. Based on the students` views on questionnaires and subsequent interview responses on cooperatively using ball and stick model, it was seen to have helped them tremendously to organize and entering information into long memory that is not taped easily on structure of stereochemistry.

Students` responses to open ended questions such as "What experience did you get from you stereochemistry class most?" "Do you think cooperatively using ball and stick models is important for you than individual work in learning stereochemistry concepts? If yes, why? if no, why?" Explain briefly were selectively analysed as follows:

Most (91%) of the students answered that:: "the ability to see and manipulate three-dimensional molecules using ball and stick models, helped us to visualize the difference between enantiomer and diastereomer in stereochemistry; how one molecule differs spatially from its other isomers; working in pairs or groups cooperatively; and hands on experience working with models" This sums up their answers.

One student said (during the interview):

> "I am very happy in my duration in this lesson than the other lesson, because of I have got good experience in visualizing the structures of molecules three-dimensionally (using ball and stick models) than rotating the molecules through two-dimensionally (on black board). Even, this is my first experience to think and assume what the molecules look like spatially (in space) and I believe that using ball and stick model is useful.

Similarly, the other student addressed that,

> "we discussed with our group members on the difficult point of visualization and come to consensus on the discussion and working cooperatively on stereochemistry is appreciated than working independently, in my opinion. This is because of, visualizing one molecule three-dimensionally and relating it with two-dimensionally is difficult to me and this one is more understandable to me after I discussed with my colleague."

Generally, majority of students felt that cooperative learning using ball and stick model helped them to understand the content of stereochemistry more clearly, and this enhanced their visualization which they do not experience before. As confirmed from the interviews, students considered cooperative learning using ball and stick models to be a good way to learn stereochemistry concepts explicitly, and improve their understanding and visualizing ability of stereochemistry molecules three-dimensionally.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

It came out very clear that many first year undergraduate Organic Chemistry students have problems with stereochemistry. Based on the result of the study, the control group students exhibited difficulty in visualizing structure of stereoisomer in three-dimensional; in relating three-dimensional with two-dimensional forms; in giving nomenclature of Enantiomers (R-S) system; in explaining stability for different conformation of molecules and they scored below the mean.

From the comparison analysis, experimental group students were better positioned in visualizing structure of stereoisomer in three-dimensional; in explaining stability for different conformation of molecules; and the mean of post-test also indicates that the experimental group students performed better and achieved more than control group students. In the same vein, experimental group students showed very positive attitude toward the research model for stereochemistry lessons than learning the topic individually.

Finally, from the findings of this study is that, cooperatively using ball and stick models in stereochemistry lessons is highly beneficial; and if it is used teaching stereochemistry lessons which requires students visualization, it improves students achievement and understanding; enhance students self-efficacy in stereochemistry and reduce students difficulty towards visualization. Cooperatively using ball and stick models is important in teaching stereochemistry and it should be used by both teachers (in class in teaching stereochemistry) and the students (outside the class if possible) in order to visualize the structure of molecules.

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BRIDGING THE GAP FOR IT STUDENTS: ACTION RESEARCH AND DESIGN SCIENCE RESEARCH AS RESEARCH APPROACHES FOR LIFE-LONG LEARNERS

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ABSTRACT–Fourth year Information Technology students are confronted with career in industry that requires them to be life-long learners. Some of them are contemplating further academic study; they are in need of good scholarly preparation. This paper reflects on a project-module that is used to achieve both goals of developing life-long learners and provide an introduction to postgraduate research work. The paper promotes the development self-directed learning skills of students through project-based learning. Students are required to take ownership of their own learning, sensitive to their own abilities and interests. They have to create some sort of artefact to demonstrate knowledge of a new field in Information Technology. They are required to demonstrate a suitable research approach. Action Research and Design science research is presented in the paper as suitable approaches. Many students struggle to choose between these approaches. This paper provides guidance in this regard. The paper concludes by demonstrating how different students may approach a single research scenario according to their interests and using different research approaches.

Keywords: action research, design science research, project based learning, self-directed learning, life-long learning.

1. INTRODUCTION

At North-West University Vaal Triangle Campus we use the fourth year (Honours) project to achieve both goals of preparing our students for industry as well as preparing them for further study. Honours students have to complete a 320 credit-hour project that demonstrates project work and research competence. These fourth-year IT students are at crossroads in their careers. On the one hand they are preparing for a life as IT professionals with all the expectations of the IT industry. They are expected to be life-long learners and project managers. On the other hand they may choose to continue their academic training by enrolling for a research degree similar to a Master’s degree. As academic scholars in the IT discipline they need sufficient preparation in research practice. Combining these seemingly conflicting goals into one project is difficult to achieve.

After selecting an appropriate project most students find it difficult to choose a research approach suitable to their chosen project. Often students are confronted with choosing between the two closely related approaches of action research and design science research.

The aim of this paper is to reflect on the project from a research perspective without losing focus of the expectations of the IT industry. This conceptual paper reflects on how action research (AR) and design science research (DSR) can be combined with project-based learning (PBL) and self-directed learning (SDL) to enhance the experience of the student. We applied a four phase method for our reflection. The aim of the first phase is to enhance our understanding of educational approaches (SDL and BPL) and research approaches (AR and DSR). This is achieved by literature studies of the abovementioned fields (summarised in Sections 2 and 3). The second phase of our reflection was to reflect on the current instructional design of the project module (Section 4). The third phase in our reflection process was to establish a clear distinction between AR and DSR and to develop a strategy for ourselves to select between these approaches (presented in Section 5). The final phase and result of our reflection is a demonstration the use of AR and DSR in PBL in terms of example projects.

2. SELF-DIRECTED LEARNING AND PROJECT- BASED LEARNING

Never before had mankind experienced so many changes in technology and the use thereof in such a short time span as today. We are almost daily confronted with new gadgets that is said to improve some aspect of our being. In this explosion of knowledge educators are telling us to move away from "just-in-case" knowledge to "just-in-time" knowledge. Stewart and Ruckdeschel (1998) already highlighted the value of knowledge and the changing demands on education. Educators are focussing on new skills that must be developed for people to cope in this new world of everlasting change. Hanka and Fuka (2000) argue that we have to develop strategies to obtain the correct information when we need it from an overload of available information. Helm and Katz (2011, p. 1) supports Stewart and Ruckdeschel (1998) and Hanka and Fuka (2000) by stating that students "will need to be critical and creative thinkers and be able to work on teams collaborating within organizations with a diverse membership". We propose that the concepts of self-directed learning are used to foster life-long learning in our students.

2.1 Self-directed learning

Self-directed learning (SDL) is not a new discipline in education. Malcolm Knowles introduces the concept in 1975. He advocated a shift away from teacher oriented learning towards learner oriented learning. As highlighted by Collin and Hammond (2013), SDL's central concept is driven by the adaptability to an external reality as permanent transformation toward the purpose of self-development and personality development. Learning should be task orientated rather than subject orientated (Knowles, 1975). He argues that SDL skills are developed by a learner – one grows in ability to take responsibility for own learning. SDL has been identified with life-long learning many times. Candy (1991) give a good scholarly explanation of the relationship between life-long learning and SDL. He promotes personal autonomy of learners, willingness to investigate and master new skills; ability to manage one's overall learning activities, independent pursuit of learning without formal institutional support and learner-control of instruction as key aspects of SDL (Candy, 1991). There exist many models for SDL on factors that must be taken into account by educators when developing SDL skills of learners. One example is that of Oswalt (2003) that identify factors such as opportunity, support and collaboration in the learning environment; learning components such as motivation, context and cognitive critical self-reflection; and student attributes such as willingness to learn, content skills and SDL skills. The SDL skills of students can be improved by using specific teaching strategies. In this paper we focus on project-based learning as a teaching strategy to improve SDL skills of students.

2.2 Project Based Learning

In the ever changing world of IT, it is impossible for universities to adapt academic programmes constantly to give formal instruction on all aspects of the IT industry. The students always seem ahead of the programme in terms of specific interest in IT developments. PBL facilitates the teaching of IT concepts not covered by traditional content-based modules while at the same time improving the SDL skills of the students.

Project-Based Learning (PBL) is a student-driven, teacher-facilitated approach to learning that teaches strategies that is critical for success (Bell, 2010). Knowledge is pursued by leaners by questions asked driven by interest and curiosity and the project is driven by inquiry (Bell, 2010). Learners represent what they've learned through the construction of a personally-meaningful artefact such as play, a multimedia presentation or a poem (Harel & Papert, 1991). Learners are self-directed to what they learn, enabling learners to maintain interest and motivation to take responsibility (Wolk, 1994; Worthy, 2000). Often learners are given the responsibility to develop their projects in such a way that it supports their own interests and abilities (Moursund, 1988). This is supported by Grant (2002) who states that "project-based learning and the construction of artefacts enable the expression of diversity in learners, such as interests, abilities and learning styles". Noteworthy in this statement of Grant (2002) on PBL is the construction of artefacts as it falls under design science research (DSR).

3. DESIGN SCIENCE RESEARCH AND ACTION RESEARCH

DSR is methodology in the IS discipline defined as research that is concerned with the construction of a wide range of socio-technical artefacts such as decision support systems, modelling tools, governance strategies, methods of IS evaluations, and IS change interventions (Gregor & Hevner, 2013, p. 337). However DSR is many a times confused with Action Research (AR). Baskerville (2008, p. 442) clearly states that “design science is not action research” and that “action research is clearly centred on discovery through action”, while “design science is clearly centred on discovery through design”. Action Research (AR) accredited to Lewin (1946) and has been defined by Rapoport (1970, p. 499) as follows:

“Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework”.

The next sections provide an overview on these two research methodologies.

3.1 Action Research

Lewin (1946) first developed action research in the late 1940’s. He focussed his research on the natural setting of the problem situation. Lewin (1946) conceptualised social change as a three-stage method: dismantling former structures (unfreezing) changing the structures (changing) and locking them back to the permanent structure (freezing). This implies a stable state prior and after the intervention or change phase (Greenwood & Levin, 1998). Lewin (1946) argued that one could only understand the inner structure of a social system by trying to change it.

Blum (1955) identified two stages in action research. During the diagnostic stage, the researcher and the subjects of the research study the social situation together. This diagnostic phase is followed by the therapeutic phase that involves collaborative change experiments. Changes are designed and introduced, and the results are studied to introduce more changes to improve the situation.

Baskerville and Pries-Heje (1999) identified five stages in the cyclic IS action research process: (1) diagnosing, (2) action planning, (3) action taking, (4) evaluating, and (5) specifying learning, as depicted in figure 2.3. Baskerville (1999:14) gives an explanation of these components. The client structure, also known as the client-system infrastructure, is the specification and agreement that constitutes the research environment. It provides the conditions under which change may be specified. It also defines the responsibilities of the client and the researcher and is by nature a collaborative undertaking.

Diagnosing refers to a collaborative effort by the researcher and the client to analyse the primary problems of the current situation that form the underlying causes of the desire for change in the organisation.

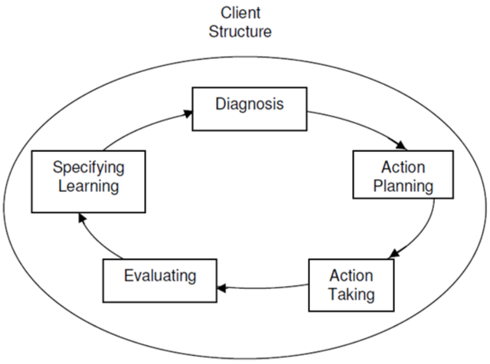

Figure 3.1:Action Research Cycle

Action planning is a collaborative effort to specify actions to relief or to improve the specified problems. The plan should also include a description of the target state or desired future state of the organisation.

Action taking refers to the collaborate effort of intervention in the organisation. Changes can be made directly or indirectly. Lewin (1946) model of unfreezing, changing and freezing can be followed.

A collaborative evaluation of the resulted state of the organisation is done to determine if the changes had the desired effect. This implies that the current state is compared with the desired future state described during action planning. Where the action was successful, the evaluation should determine whether the success could be attributed solely to the planned action. Where the action was unsuccessful, the reasons should be analysed, and the action plan for the next iteration needs to be designed.

The research team needs to specify and document the learning that took place during the specific iteration of the action research cycle. The organisational norms should be changed to reflect the new knowledge gained. Where the change was unsuccessful, the additional knowledge should be added to the original research design, altering the research plan as required. Where the change was positive, the specific situation and the successful action need to be carefully documented to aid future research, not only in the specific situation, but also in similar situations.

3.2 Design Science Research

Design science research (DSR) has been put into practise for some time in the engineering and Information Systems (IS) disciplines (Gregor & Hevner, 2013, p. 338). DSR is defined within the IS discipline as the construction of a wide range of socio-technical artefacts such as decision support systems, modelling tools, governance strategies, methods of IS evaluations and IS change interventions (Gregor & Hevner, 2013, p. 337). DSR also analyses the performance of a designed artefact in order to understand and improve the artefact (Hevner & Chatterjee, 2010, p. 30; Vaishnavi & Kuechler, 2004). DSR is primarily the creation and evaluation of an artefact used to acquire the solution to the identified organisational problem through understanding thereof (Hevner & Chatterjee, 2010, p. 6; Hevner, March, Park, & Ram, 2004, p. 82). The evaluation of these artefacts could be subject to quantitative and/or empirical and qualitative methods (Hevner et al., 2004, p. 77).

The knowledge contribution made by DSR is effective when it is clear and related to the real-world application environment (RAE) from where the research problem or opportunity is drawn (Hevner et al., 2004). The RAE refers to industry and academic fields, but it is not limited to these fields. Research conducted in DSR contributes to knowledge and generalised theory (Gregor, 2006; Gregor & Jones, 2007; Hevner et al., 2004; Vaishnavi & Kuechler, 2004). DSR contributions can be made on three maturity levels that were built on a framework introduced by Purao (2002). Table 2.2 illustrates DSR artefact types and provides an example of each level of maturity.

Table 3.1: DSR Contribution Types (Gregor & Hevner, 2013:342)

	CONTRIBUTION TYPES	EXAMPLE ARTEFACTS
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artefact	Instantiations (software products or implemented processes)

The knowledge of a DSR project should include reference to a kernel theory (Gregor & Hevner, 2013, p. 340). According to Walls, Widmeyer, and El Sawy (1992, p. 48), kernel theory refers to “theories from natural science, social sciences and mathematics”. The reason for the inclusion of kernel theories in DSR knowledge is to explain why the design works (Gregor & Hevner, 2013, p. 340). For the purpose of this study, kernel theory guides the artefact’s creation and refers to prescriptive knowledge.

DSR knowledge can be divided into two distinct types known as descriptive knowledge (denoted Ω or omega) and prescriptive knowledge (denoted λ or lambda). Descriptive knowledge is known as the ‘what’ knowledge about natural phenomena and the laws as regularities among phenomena, while prescriptive knowledge is the ‘how’ knowledge of a human-built artefact (Gregor & Hevner, 2013, p. 343). Figure 2.1 shows the knowledge base for a DSR domain.

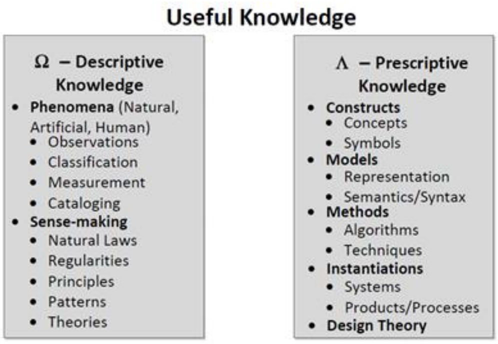

Figure 3.2: DSR knowledge base (Gregor & Hevner, 2013:344)

Hevner and Chatterjee (2010) and Iivari (2007) state that DSR begins in the application environment when an opportunity, challenging problem or insightful vision for something innovative is presented. The success of a DSR project rests on the research skills of the research team, who aim to draw knowledge appropriately from both descriptive and prescriptive sources. The relationships and interactions of descriptive and prescriptive knowledge are key insights into the performance of DSR. Figure 2.2 illustrates these relationships and interactions and the roles DSR plays in the application environment with reference to descriptive and prescriptive knowledge.

A DSR project has the potential to make many different types and levels of research contributions. These contributions depend on the starting points in terms of problem maturity and solution maturity. It should be noted that there is limited advice on how to signal and assess the degree of the contribution made by a DSR project in IS literature to date. The nature of the artefact often presents difficulty in identifying a knowledge contribution (Gregor & Hevner, 2013, p. 340).

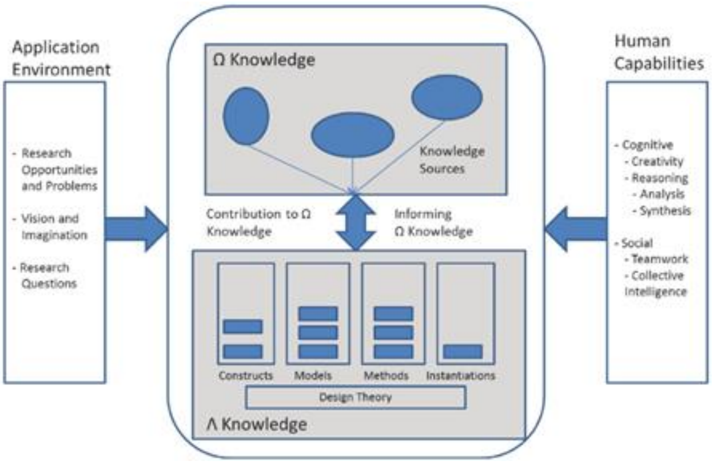

Figure 3.3: DSR knowledge roles (Gregor & Hevner, 2013:344)

3.3. Action research and Design Science Research is similar yet different

The closely related approaches of AR and DSR are debated in many articles including Jarvinen (2007) and Iivari and Venable (2009). Most outline what AR and DSR is, what are the similarities and differences. Jarvinen (2007) provides a summative table (see Table 3.2) for the similarities between the fundamental characteristics of AR and DSR. Iivari and Venable (2009) on the other hand provides a more distinguishable difference between AR and DSR. Iivari and Venable (2009) state that “AR assumes collaboration between researchers and the client within a mutually acceptable ethical framework” and DSR “attempts to construct new and innovative artefacts or solution technologies”. Thereby, it can be concluded that there is a difference between AR and DSR, as supported by Baskerville (2008:442) that clearly states “design science is not action research” and that “action research is clearly centred on discovery through action”, while “design science is clearly centred on discovery through design”. Figure 3.1 shows a simplified view of the differences between AR and DSR.

Table 3.2: Similarities between the fundamental characteristics of AR and DSR (*Jarvinen, 2007*)

Action Research	Design Science Research
Action research emphasizes the utility aspect of the future system from the people’s point of view.	Design science’s products are assessed against criteria of value or utility.
Action research produces knowledge to guide practice in modification.	Design science produces design knowledge (concepts, constructs, models and methods).
Action research means both action taking and evaluating.	Building and evaluation are the two main activities of design science.
Action research is carried out in collaboration between action researcher and the client system.	Design science research is initiated by the researcher(s) interested in developing technological rules for a certain type of issue. Each individual case is primarily oriented at solving the local problem in close collaboration with the local people.
Action research modifies a given reality or develops a new system.	Design science solves construction problems (producing new innovations) and improvement problems (improving the performance of existing entities).
The researcher intervenes in the problem setting.	Design science research is initiated by the researcher(s) interested in developing technological rules for a certain type of issue. Each individual case is primarily oriented at solving the local problem in close collaboration with the local people.
Knowledge is generated, used, tested and modified in the course of the action research project.	Knowledge is generated, used and evaluated through the building action.

The major difference between these two approaches is the focus that they address. AR is focused toward the participant and the interaction with the artefact while DSR is more focussed towards the artefact and only the artefact. Figure 3.1 shows this focus where AR looks at the participant and DSR looks at the artefact.

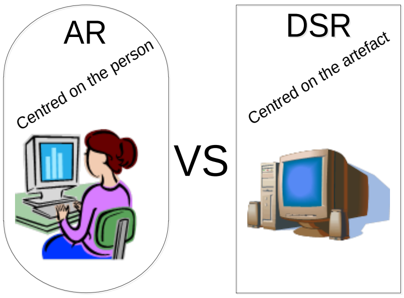

Figure 3.4:AR focus vs. DSR focus

AR and DSR are different and it is therefore crucial to make an informed decision about selecting one of the approaches. Due to the difference in AR and DSR there is a possibility of combining these two approaches to form a more supportive study. The project module's instructional design is presented next and the integration follows after in Section 5.

4. INSTRUCTIONAL DESIGN OF THE PROJECT MODULE

The aim is of this paper is to demonstrate how a project module on a fourth year level of an IT programme can develop life-long learners while at the same time develop the scholarly skills of the students. The instructional design is based on PBL and allows the student to take responsibility for his or her own learning. Typically 30 students enrol annually for the module in projects. Students are allowed to work individually or in groups of two. Faculty members are assigned as supervisors to students. Students are given a list of fields of faculty expertise from which they can make selection. Some students are allowed to work on projects outside this list after the student presented a clear motivation. These ad hoc topics are almost always linked to work experience of students or specific fields of interest of individual students who plan to continue with a Master's degree in the same field.

Before the allocation of projects to specific students is done, students are exposed to basics of project management, academic writing and research methodology. Four facilitated sessions are held where students have to read papers on the relevant topics before having group discussions. A presentation on research paradigms assists the students in selection of an appropriate research methodology.

Clear evaluation rubrics are given to the students as part of the introduction to the module. This allows them to evaluate their own progress and they have clear expectations of the role of their supervisors. Students are also given a channel to report problems encountered with supervision. In order to be successful, SDL approaches need to give some guidance to students of different SDL skills. The university's learning management system is used to make available resources on different levels on key research and academic writing topics. Students are encouraged to evaluate their own progress in terms of these academic resources.

Since the scholarly aim of the project module is to prepare the students for Master's study, they have to write a research proposal for their project in the same format as a Master's dissertation's proposal. They have to identify primary and secondary objectives for their project. The final project documentation is structured similar to a mini dissertation. It should include sections on:

1. Introduction and proposal
2. Literature review on key concepts
3. Literature review on chosen research methodology
4. Literature review on similar research projects

5. Empirical report
6. Findings and conclusion

Although the scope of each section is much smaller than that of Master's dissertations, it is important that all sections are present. The supervisors give feedback to students on their literature reviews. These literature reviews are short but high academic standard is expected from the students. From a life-long learning perspective students develop the skills to integrate knowledge and to evaluate the quality of knowledge found on various electronic sources.

The nature of the project should motivate the choice of research methodology and students are not limited to any research method. Being IT students, many are interested in the development of some IT artefact as part of their project. Over the years interest in surveys and case studies has declined. Students prefer to develop a game or to implement a specific information systems development methodology. Students doing surveys are guided in their selection of qualitative or quantitative or mixed methods. This paper focuses more on the selection between AR and DSR for those students interested in developing artefacts.

5. EMPIRICAL COMPONENT OF PROJECT

Many students struggle to make a selection between AR and DSR when selecting a research methodology for their project after they decided that they want to develop some kind of artefact. This section provides some guidance and it also reflects on the combination of the two methodologies.

5.1 Which to select? AR or DSR

The main goal of AR is to improve a problem situation by diagnosis of oppressing structures and to take action in order to emancipate the participants. The main goal of DSR is to develop and evaluate an artefact. These two statements do not simplify the selection, because it is the goal of the researcher or study that determines the selection. The first question to be answered by the researcher is whether the researcher plans to design and/or evaluate an artefact in order to solve the problem he or she is interested in. If the answer is "No" then this is a possible AR or other study. Assuming that the researcher wants to create an artefact then we need to determine why the researcher wants to create the artefact. If the researcher solely wants to evaluate the artefact alone on its performance then it is a simple DSR study as the main focus. However if the researcher want to create the artefact to emancipate the participants then it becomes an AR study as a main focus with a DSR sub study. This thought process is outlined in Figure 5.1.

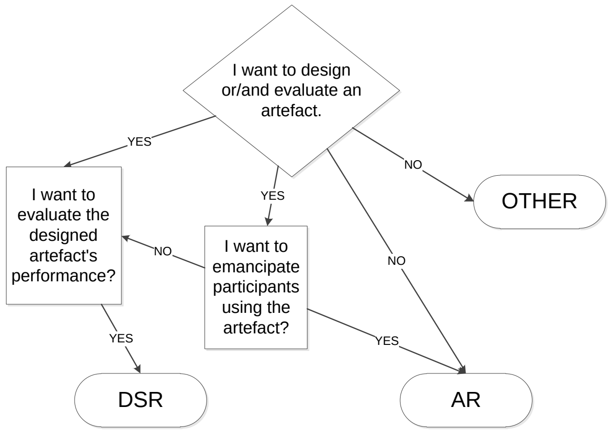

Figure 5.1:Dicision tree to guide towards AR, DSR or OTHER

5.2 What about combining AR and DSR?
Action research and design science research is similar yet different in area of which they focus. This difference in focus between these two approaches makes it possible to combine these approaches at times. As discussed AR have an action taking phase. The action taking phase can employ any available method in order to achieve the emancipative aim of the project. One of these available methods is the use of an artefact to alter the effect on the participants, emancipating the participant. Using existing artefacts may make the action taking phase relatively easy, however when an artefact is not available it is possible for a sub-study to emerge. The sub-study in this particular instance is subject to DSR. The sub-study is how DSR can be employed in AR (see Figure 5.2). The focus of this study remains on the participant and therefore the participant emancipation is evaluated before and after the action taking phase.

DSR, as discussed, contains an evaluation phase. This evaluation could be subject to quantitative and/or empirical and qualitative methods as stated by Hevner et al. (2004, p. 77). The value of the artefact according to (Gregor & Hevner, 2013) is demonstrated using criteria that can include validity, utility, quality and efficacy. Efficacy is central in this regard by incorporating AR into DSR (see Figure 5.2). This is to produce a desired effect on the participant, evaluating the artefact by means of its effect on the participant. This is typically done as part of a project to broaden the user base of an artefact to understand unintended consequences of use of the artefact.

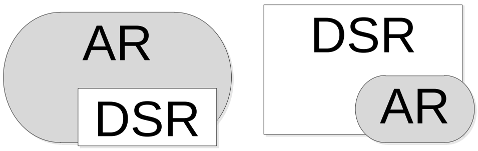

Figure 5.2: Combining AR and DSR

The combination of AR and DSR are commonly found, however the combination of DSR and AR is very uncommon. Most DSR projects just focus on completing the artefact and whether it's working. The next section outlines example scenarios for AR and DSR.

6. AR AND DSR SCENARIO EXAMPLES
This section demonstrates the ideas presented by showing how students can structure three different projects based on a single scenario according to their interests and abilities. Let us first examine the scenario:

All formative and summative evaluation marks are released to students by means of the learning management system (LMS) used by the university. Each lecturer has a web-like course site on the LMS which they use to publish marks. Students have access to the course sites for which they have enrolled. This information is not incorporated by anyone.

6.1 Possible project 1 (DSR)
Two students doing the module in data warehousing as part of their programme heard about a different data modelling technique called data vault modelling. They want to use this scenario to develop a data warehouse using data vault modelling for lectures to query. Furthermore they support the data-driven approach of Bill Inmon (2005) and not the requirements-driven approach of Ralph Kimball (See Kimball and Ross (2011), for more explanation). These students love programming!

Their project will be a DSR study as they will develop and evaluate an artefact. They will study the concepts of data vault modelling (SDL-style) and use a data-driven methodology as prescriptive knowledge. Evaluation of their artefact will focus on a lecturer using their system to query student performance (refer Figure 6.1).

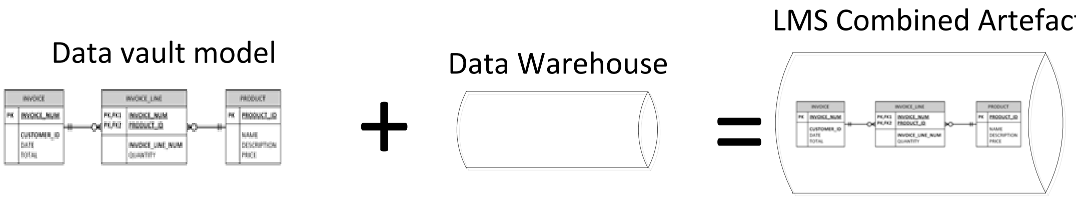

Figure 6.1: Data vault model-driven warehouse artefact

This project when done properly would have increased their SDL skills, as they had to study data vault modelling on their own. Their preparation for further study is also successful as they had to do a literature review and implement all the phases of DSR. They can even make an academic contribution on the use of data vault modelling and also of the effectiveness of data-driven methodologies for data warehousing.

6.2. Possible project 2 (AR)

Two other students come and focus on the graduate students. They argue that all the LMS data should be used to help students early in the semester that they do not fail their end of semester examination. They cannot believe that the university ignores the warning signs!! The students interested in this project indicated that they prefer the human-side of Information Systems and would prefer not to program! The aim of this project will be to use the LMS data to identify and assist high risk students (refer Figure 6.2).

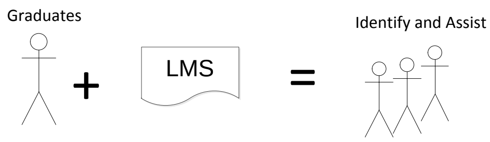

Figure 6.2: Data vault model-driven warehouse artefact

This is a typical action research project. During the diagnosis phase the student has to perform a literature review on risk factors and they have to do qualitative interviews with lecturers. Their planning and implementation of an intervention will focus on going through the LMS data and develop a strategy to identify high risk factors. Being IT students, it will be expected from them to use systems analysis ideas to refine and demonstrate their strategy. Since the improvement of the graduate students is so high on the agenda of the project team, they will expect lecturers to demonstrate how their developed strategy will be used to help the graduate students.

This project when done properly would have increased their SDL skills, as they had to study high risk factors in higher education on their own. They are also confronted with a new application of the systems analysis tools they studied before. Their preparation for further study is also successful as they had to do a literature review and implement all the phases of AR. They would be proud of the fact that their project made a real difference to future high risk students!

6.3 Possible project 3 (AR+DSR)

A combination of the ideas of the previous 2 projects but focused on a requirements driven methodology rather than a data-driven methodology. In this instance students will be allowed to use a familiar design method for the data warehouse.

The research methodology will be AR using DSR in the implementation phase. Since the scope of this project is larger, a larger group of students can be allowed to work on it. DSR focus on prototypes rather than complete systems. The improvement of the resulting prototype may be another DSR project for future students or even graduate students.

This project might result in a complete change of throughput management by the university as shown in Figure 6.3.

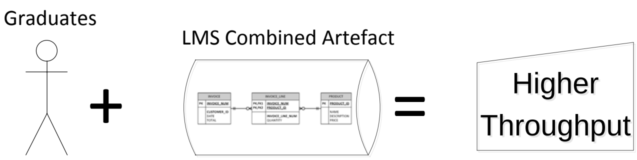

Figure 6.3: Data vault model-driven warehouse artefact

7. CONCLUSION

Learner-oriented learning rooted in self-directed learning (SDL) using project-based learning provides a valuable tool for fourth year IT students on their journey towards an IT professional or academic scholar. This fosters life-long learning for the students for which ever path they choose. Project-based learning in the 320 credit-hour project module places the responsibility on the student to complete it.

As IT students they are more interested towards the development of artefact such as games or systems. Most of these fall under DSR however due to the nature of the study or the student this may not be the case. Some would like to use an artefact or develop an artefact to emancipate others. This shifts the focus of their study from DSR to AR and possibly a combination of AR and DSR. The selection between AR and DSR need to be carefully evaluated based on the needs of the study and student. The focus of AR is people and the emancipation of people. The focus of DSR is the artefact and the artefacts performance.

This paper provided a thought process for selection between AR and DSR and when to combine them. The examples give clear illustrations for AR, DSR and the combined AR and DSR. The researcher however encourages life-long learners (IT professionals and scholars) to thoroughly review of AR and DSR literature and use this process as a starting point. The focuses of projects are not always clear at first but asking these questions should guide students to make the appropriate decision.

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EFFECT OF COMPUTER ASSISSTED INSTRUCTION WITH ANIMATION ON ACHIEVEMENT OF STUDENTS' OF COLLEGE OF EDUCATION, MINNA IN QUANTUM PHYSICS

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Abstract–Effect of computer assisted instruction with animation on state college of education student's achievement in quantum physics was determined. A pretest-posttest control group design was adopted. The population consists of all the national certificate of education (NCE) II students in Minna, Niger State. The sample size was 136 students of one intact class .A reliability estimate of 0.89 were obtained for the Quantum physics achievement test (QPAT). The data were analyzed using mean, standard deviation and Analysis of Covariance (ANCOVA).The result indicates that CAI is an effective tool in teaching. The implication of these findings is that quantum physics lecturers should use this strategy to teach quantum physics. It was recommended that, curriculum planners should infuse the use of CAI package in physics NCE programs. Authors of textbooks should involve programmers in order to add effects to their books by attaching CDs of CAI for the use of their audience.

Keywords: Computer Assisted Instruction (CAI), Animation, Achievement, Quantum Physics and Programmers

1.1 INTRODUCTION

1.1.1. Rationale for Studying Sciences in Nigeria

The pursuit of science as an imperative endeavor for achieving prosperity and advancement is conspicuous in the national development plans of many developed and developing nations. In Nigeria, these facts can be seen in the importance and priority accorded to science and manifested in various policy statements and steps that encourage her citizens to pursue science courses (FRN, 2004). Such government policies include the establishment of special schools, increasing the ratio 3:2 (in favors of science) of students' enrolment in sciences in tertiary institutions and the introduction of basic science in the primary school curriculum. All these are done with the hope that a solid foundation in the sciences would equip millions of Nigerian students for successful science-based careers thereby contributing to the much-needed scientific and technological advancement.

1.1.2. Physics and its Various Components

Physics is one of the compulsory subjects for one to read science and technology course in tertiary institutions. It is the natural basis of technology disciplines and applied science. Physics is the knowledge of properties and natural laws governing energy and matter also, it is the study of matter in relation to energy but there are various component of physics among which is quantum theory.

Quantum theory, in physics, is a description of the particles that make up matter and how they interact with each other and with energy. Quantum theory explains in principle how to calculate what will happen in any experiment involving physical or biological systems, and also how to understand how our world works. The introductory aspect of Quantum physics at National Certificate in Education (NCE) level is in two hundred levels that is PHY223: Atomic and Quantum Physics. The name "quantum theory" comes from the fact that the theory describes matter and energy in the universe in terms of single indivisible units called quanta (singular quantum). Quantum theory is different from classical physics because classical physics is an approximation of the set of rules and equations. Quantum theory accurately describes the behavior of matter and energy in the everyday universe. For example, classical physics explains the motion of a car accelerating or of a ball flying through the air. Quantum theory, on the other hand, can accurately describe the behavior of the universe, atoms and smaller particles on a much smaller scale. The rules of classical physics do not explain the behavior of matter and energy on this small scale. Quantum theory is more general than classical physics, and in principle, it could be used to predict the behavior of any physical, chemical, or biological system. Quantum theory not only specifies new rules for describing the universe but also introduces new ways of thinking about matter and energy. The tiny particles that quantum theory describes do not have defined locations, speeds, and paths like objects described by classical physics. Instead, quantum theory describes positions and other properties of particles in terms of the chances that the property will have a certain value. For example, it allows scientists to calculate how likely it is that a particle will be in a certain position at a certain time. Quantum description of particles allows scientists to understand how particles combine to form atoms, understand the chemical and physical properties of molecules, atoms, and subatomic particles. Quantum theory enabled scientists to understand the conditions of the early universe, how the Sun shines, and how atoms and molecules determine the characteristics of the material that they make up. Without quantum theory, scientists could not have developed nuclear energy or the electric circuits that provide the basis for computers. Quantum theory describes all of the fundamental forces except gravitation that physicists have found in nature. However the concepts in this area of quantum physics are not directly observable but can be inferred on the basis of its observable effects on technology such as the x-ray machines, photocells, alarm doors etc. Learning the concepts in quantum physics is hard because it contains abstract ideas, requires strong mathematical tools and possesses complicated operations (Richard, Michael, Lei, and Edward.1999). Students are also experiencing misconceptions in some concepts such as wave –particles duality and Bohr's model of atoms (Dickson, 2003).Also the philosophy of the Nigeria Certificate in Education (NCE) physics curriculum is inspired by the desire to help students become intellectually informed in physics, and by the need to produce competent and effective teachers with good mastery of content, method, and knowledge for the development of the learner. Furthermore the products should be able to apply acquired knowledge to information and technology and real life situations.

1.1.3. Objective of National Certificate of Education (NCE)

Hence the specific objectives of NCE include the following: at the end of the course the subjects should be able to:

- Have basic knowledge of the organizational concepts and techniques in practical physics and laboratory management.
- Be aware of the fact that the fundamental idea of physics evolve from a process of inquiry, which will enable them to develop scientific attitude which are transferable to other life situations.
- Plan and effectively execute physics-based lessons in secondary schools.
- Have sound basic knowledge of the physics concepts and principles to equip them for further studies in physics and other physics related courses.
- Explain the nature of science and use science resources effectively.
- Used information technology (IT) effectively to support pupils/students learning physics.
- Demonstrate the understanding of concepts of physics reflects upon them and revise them when necessary.
- Organize physics lessons for the whole class, groups and individuals effectively.
- Recognize the difficulties students faced with their physics learning.
- Remedy student's misconceptions in physics.
- Improve pupils' used of physics terminology and develop their skills of assessing students work (theory and practice) in physics.

The philosophy and objectives highlighted above suggests that quantum physics should be taught properly in the tertiary institutions such as Colleges of Education if Nigeria will develop technologically. Colleges of education institutions in Nigeria are faced with the challenges of preparing a new generation of physics teachers to effectively use the new learning tools in their teaching practices (UNESCO, 2002).There is also the quest to use technology in the teaching and learning in the 21st century and to employ approaches that are student centered in the colleges of education in Nigeria. This is evident in the number of computer installed in various Colleges of Educations. Quantum physics teachers in these institutions are still lacking the knowhow of using these tools to facilitate the teaching of quantum physics. There is the need for the students to be guided so that they are left to discover their ability through strategies which could encourage learner-centered activities, developing reasoning skills and process skills through scientific approaches.

1.1.4. Important Teaching Strategies in the 21st century for Teaching Quantum Physics

Researchers have identified poor teaching strategies as one of the reason for poor achievement in quantum physics in colleges of education. Also in a ten years computation of NCEII students' results in quantum physics by the researcher, it was revealed that only 20-30% of the students pass the course annually and visible improvement is not yet in sight. This is of great concerned to the researcher. If the situation continuous failure of the students in quantum physics is ignore, the result is that the teaching of integrated science in junior secondary schools and probably the teaching of physics in senior secondary schools and development of science in the nation will be affected .Students can learn if well taught but no teacher can give what he does not have when teaching .This situation calls for intervention in method of teaching by the teachers. This has necessitated the need to employ more interactive strategies for improved teaching and learning of students in quantum physics. An interactive strategy consider by the researcher for improvement is computer assisted instruction (CAI) with animation. Although, CAI is purported to have the potential to enhance student's learning, it is not quite clear whether, CAI may be more effective in achieving better learning outcomes and sustaining students retention in quantum physics. It is on the above premise that the study was carried out. Although, classrooms in Nigerian educational system are composed of boys and girls, a recurring theme among educators, especially science educators, and the society at large is gender equity or gender friendliness. The concept of gender has attracted the attention of many researchers (Okpala and Onacha, 1995; Oyedeji, 1996; Adesoji and Fisuyi, 2001; Anekwe, 2006; Anagbogu & Ezeliora, 2007; Popoola, 2007; Iwendi, 2007). Also gender issue has been linked with academic achievement in academic tasks. Results of study in the area of gender disparity regarding academic achievement are not tailored towards the same direction .Some studies show that male students perform better than girls in physics, chemistry and biology (Olaofe, 2005; Adeniyi, 2005; Paul and Babaworo 2006) while others revealed that female students are better off than males. Gender influence on the use of CAI has shown that female students perform better than males when introduced to individualized CAI while other researchers observed that gender has no influence on the performance of students when exposed to CAI (Paul and Babaworo, 2006; Adeniyi ,2005).Hence effect of CAI on boys and girls was aimed at finding out which gender group(s) will benefit more than the other through CAI instructional strategies . Hence the present study is an attempt to determine the moderating effect of whether gender is important variables in students' achievement when exposed to CAI package.

Also the present work has exposed the lecturers of colleges of education to technics of using technology and some of the ways of interactive teaching that is student centered so as to enumerate the concern of Adeniyi, 2005. Olaofe, 2005 and Njoku, 2004. The performance of students in quantum physics has been quite unsatisfactory over the years in Nigeria particularly in Niger state (see appendices A).The picture emerging from students enrolment in theoretical physics, medical physics and other areas of physics programs that has quantum physics as part of 70%-80% of the course content in Nigerian Universities show that the students may have no interest for the course or may have phobia for Quantum Physics since the enrolment level is always low. Also the main language which influences quantum physics understanding is mathematics and no meaningful learning of the course will be achieve without the knowledge of mathematics. Hence, the poor performances of students in Quantum Physics can be attributed to many factors which include among others, in appropriate use of teaching strategies and ineffective use of media. It will be improper to continue with the conventional method of teaching and learning which has not been helpful in promoting meaningful learning of quantum physics. The use of innovative instructional strategies as well as instructional media that will bring about meaningful learning of Quantum Physics has become imperative. CAI has the potential to improve learning therefore; it can be employed in the classroom in teaching Quantum Physics effectively.

Several strategies were employed to improve students' performance in school subjects in Nigeria among others is the recent method which involve the use of computer assisted animation in classroom instruction. This involved the development of computer assisted animation package and determining its effect on students' achievement. Researches have been carried out on CAI packages and compared its effectiveness with the traditional method in mathematics, English language, chemistry and so on. It was found that CAI was more effective than the traditional method. However the use of computer assisted animation strategy in the teaching and learning of physics in Niger State is dearth particularly in quantum physics. This was what prompted the research on effect of computer assisted instruction with animation on achievement in quantum physics among colleges of education students in Niger State. Therefore, the problem of the study put in question form is would computer assisted animation strategy be an effective way of improving students' achievement in quantum physics in Niger State College of education?

The main purpose of this study is to determine the effect of computer assisted instruction strategy on achievement in quantum physics among students of colleges of education in Niger State. Specifically it intends to:

- Determine the effect of computer assisted instruction (CAI) package with animation on the mean achievement score of college of education students in quantum physics and those taught without animation.
- Finding whether differences exist between the mean achievement scores of male and female students taught quantum physics
- Determine the Interaction effects of CAI package and gender on the mean achievement score of students in quantum physics.

1.1.5a. Theoretical Frame Work

The theoretical aspect of the literature review looked at cognitive load theory upon which this research is anchored. Cognitive load theory describes learning in terms of information processing system made up of long-term memory which stores knowledge and skills on a more or less permanent basis and working memory, which performs the intellectual tasks associated with learning. From the review of empirical studies, it was discovered to the best knowledge of the researcher that no attempt had been made to find out the effect of computer assisted instruction with animation on achievement and of NCE students in quantum physics in Nigerian Colleges of Education. This gap is however, what this study intends to fill. ns between the text and the diagram (Sweller, 1999).

1.1.5b.Principles of Mayer's Theory

Specific recommendations relative to the design of instructional material include:

- Change problem solving methods to avoid means-ends approaches that impose a heavy working memory load, by using goal-free problems or worked examples.
- Eliminate the working memory load associated with having to mentally integrate several sources of information by physically integrating those sources of information.
- Eliminate the working memory load associated with unnecessarily processing repetitive information by reducing redundancy.
- Increase working memory capacity by using auditory as well as visual information under conditions where both sources of information are essential (i.e. non-redundant) to understanding.

It is against this background that the present work is anchored on this theory, since computer assisted animation package consist of both audio and visual sections in the package which supports the mental theory views. All the information presented above have implication for teaching. The extraneous and germane load indicates that the teacher through an appropriate strategy or method should make effort to make his or her teaching interesting to the students. Teaching should be made meaningful, concrete, motivated, interesting and acceptable to students. The teacher should endeavor to present his or her lessons in a way the students can remember and reduce mental load as much as possible so that achievement in the class can be improved.

1.1.6. Conceptual Framework

1.1.6a. Computer Assisted Instruction

Computer Assisted Instruction (CAI) can refer to virtually any kind of computer use in educational settings including drill and practice, tutorials, simulations, instructional management. Supplementary exercises, programming, database development, writing, using word processors, and other applications (Cotton 2001). These may include either stand-alone computer learning activities which reinforce material introduced and taught by teachers. The use of CAI allows learners to discover knowledge at their own pace, which is considered an explanatory form of learning. Internet is one of CAI teaching, allowing students to search, retrieve and evaluate information as it is displayed and permitting users to be in control of their quest for information and students in high school have also been the subjects in CAI analysis.

However, this 'heralding' may still lack adequate research. Coffland (1999), in discussing the status of technology use in Mathematics education, observed that there is ample justification for research into how computers are used in education. In their focus on the status of research on the efficacy of CAI, Christmann and Badgett (2000) also suggest a need for further research by arguing that, 'despite the accolades heralding CAI as the effective teaching methodology, there is still no documented evidence verifying its perceived superiority'.

The research carried out by (Christmann, Badgett, and Lucking, 1997; Christmann and Badgett, 2000). showed that computer assisted instruction can be adequately effective in the mode of instruction in educational environment but there are no adequate research work to prove the superiority of computer assisted instruction and it is not offered to 'prove' the concepts of retention

We are aware of Physics concepts to be concepts that cannot be learnt properly by mere memorization through rote learning. Purdy and Abraham (1982) observed that the ability to remember takes place more effectively when experiences are passed across the students through an appropriate instructional method. The implication of this is that retention plays an important role for us to correctly and effectively apply whatever we have learnt. Ausubel (1969) explained that retention is the process of maintaining the availability of a replica of the acquired new meaning or some part of them. He suggested further that the amount of the original meaning that will be retained at any point in time is a variable of the quantity at hand. According to Gagne (1970), the type of material included in the learning programme structure in a carefully formed sequence is quite resistant to forgetting. The implication of this is that any instructional model, which is effective in student's conceptual change, can as well help students retain some concepts effectively. Since retention is critical, therefore the duties is to bring every necessary practical mode and skills such as initiative skills, creative skills, project skills, team spirit and positive mind set among others(Oniliofo 2006). Chang (2000) states that retention is direct correlate of positive transfer of learning, the later which is of primary essence in education. Therefore if student's retention is enhanced by the use of CAI invariably the achievement in quantum physics will be enhanced.

1.1.6b. Conditions for Appropriate Application of CAI

- The CAI should use a combination of text, graphic, sound and video in the learning process.
- CAI programs use tutorials, drill and practice, simulation and problem solving approaches to present topics to test students understanding

- Students should progress at their own pace as the CAI assist them in learning of the material
- The subject matter taught through CAI can range from basic facts to more complex concepts
- CAI packages should either present information or fill a tutorial role or testing the student for comprehension
- It should provide one on one interaction and producing immediate responses to input answers
- It should allow students to demonstrate mastery and learn new material at their own pace.

1.2 RESEARCH QUESTIONS AND HYPOTHESES

The following research questions and hypotheses guided the study.

1.2.1 RESEARCH QUESTIONS

1. What is the mean achievement score of College of education students taught quantum physics using computer assisted instruction (CAI) package with animation and those taught without animation?
2. What is the mean achievement score of male and female students taught quantum physics with computer assisted instruction with animation and without animation?

1.2.2 RESEARCH HYPOTHESES

HO_1 There is no significant difference in the mean cognitive achievement score of college of education students taught quantum physics using computer assisted instruction (CAI) package with animation and those taught without animation.

HO_2 There is no significant difference in the mean achievement scores of male and female students taught quantum physics with computer assisted instruction with animation.

HO_3 There is no significant interaction effect of package and gender on the mean achievement scores of students taught quantum physics with computer assisted instruction with animation.

1.3 RESEARCH DESIGN

The design used in this study was quasi-experimental design. A pre-test, post-test nonequivalent control group design was used to find out the extent to which the mode of CAI with animation and CAI without animation affect mean achievement scores of students in quantum physics. The design is as follows:

E : O_1 X_{A1} O_2

C : O_4 X_{A2} O_5

Where

E is experimental group and C is control group

X_{A1} is CAI with animation

X_{A2} is CAI without animation

O_1 and O_4 are pretest scores for experimental and control groups respectively

O_2 and O_5 are post-test scores for experimental and control groups respectively

Figure 1: Quasi-Experimental Design

The computer based physics instructional content was burnt in a CD ROM and presented to the client computers with input displayed devices on the computer and through which the learner respond to the computer prompts. The computer present information and display animation to the learner in the experimental group on each of the sub units after which the students attempted some multiple choice objective questions and the same process was repeated for the control group except the displacement of animation that was absent. Each of the units was presented by the computer through interaction mode, that is, exposure to information, facts and practice on the topic and immediate response/ feedback to the application question. The student could only proceed further in the unit on the condition that the questions are attempted thrice. The student must have at list

100% mastery of each question before moving on to the next. After each attempt if the student does not have 100% mastery up to three times, the package provides the answerer so as to enable the student proceed to the next question.

The production of the package was carried out with the help of a team of professionals and specialists including the system programmer and instructional designer who is the researcher.

1.5.1 INSTRUMENTS FOR DATA COLLECTION

The instrument used for data collection is the Quantum Physics Achievement Test (QPAT) developed by the researcher. The instrument has 30 multiple choice test items with four options (A-D) as possible answers to each item. For each item only one of the four options is the correct answer. The items were developed to reflect the concepts treated and in reference to the objectives of the lesson on which instruction was based. The test items were validated by three physics lecturers and two experts in educational technology

1.6 EXPERIMENTAL PROCEDURE

All the one hundred and thirty six students were numbered one to one hundred and thirty six there after those with odd numbers were to form a group while those with even numbered form another group.

Those with odd numbered were Pre-tested and exposed to the mode of CAI with animation. The CAI package is interactive so the students interacted with the package as they follow the instructions and procedures

Those with even number were Pre-tested and exposed to the mode of CAI without animation. The CAI package is interactive also so the students interacted with the package as they follow the instructions and procedures

For group' 1' which comprises of sixty seven (67) students made up of fifty (50) males and seventeen (17) females, each was given a CD containing CAI package with animation to interact with during the period of the lesson after which the CDs was withdrawn till the next lesson and this lasted for four (4) weeks after which the post test was administered

For group '2' which comprises of sixty nine (69) students made up of forty five (45) males and twenty four (24) females, each was given a CD containing CAI package without animation to interact with during the period of the lesson after which the CDs was withdrawn till the next lesson and this lasted for four (4) weeks after which the post test was administered at the end of the lecture periods. The two groups of students that is group 1(experimental) and group 2(control) had this activities at the same time and were tested with the same test instrument at the end of the treatment.

1.7 METHOD OF DATA ANALYSIS

The means and standard deviation was used to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the hypothesis. The significance of the various statistical analyses was ascertained at 0.05 alpha levels. The pre-test scores were used as covariate to the posttest scores.

1.8 RESULTS

The purpose of the study guided the presentation of the results.

1.8.1 RESEARCH QUESTION 1

What is the mean achievement score of College of education students taught quantum physics using computer assisted instruction (CAI) package with animation and those taught without animation?

Table 1: Mean Achievement Scores and Standard Deviations of Students who were taught with Computer Animation and Computer without Animation

Groups	N	Pretest		Posttest		
		Mean	Stand Dev.	Mean	Stand Dev.	Gain Scores
Experimental	67	29.72	15.169	49.75	13.194	20.03
Control	69	29.20	15.021	34.19	15.492	4.99

Table 1 shows the mean achievement scores of students who were taught with computer with animation (Experimental group) and those taught without animation (Control group). Those who were taught with animation had a mean of 49.75 in the posttest and standard deviation of 13.194 .Students that were taught without animations had a mean of 34.19 and a standard Deviation of 15.492 .The mean achievement scores of students taught with animation were higher than The mean achievement scores of students taught without animation. For the pretest, the mean achievement scores of students taught with animation and without animation were 29.72 and 29.20 respectively. Table 1 show that there is no significant difference in the entry behavior of the students before the commencement of the experiment since the standard deviation and the mean at the pretest is in significant.

1.8.2 RESEARCH QUESTION 2

What are the mean achievement scores of male and female students taught quantum physics with computer assisted instruction with animation?

TABLE 2: Mean Achievement Scores and Standard Deviations of Male and Female Students who were taught with Computer Animation and without animation

Group	Sex	N	Pretest		Posttest		
			Mean	Stand Dev.	Mean	Stand Dev.	Gain Score
Experimental	Male	50	31.90	15.488	48.82	15.488	16.92
Female		17	31.90	15.488	52.47	17.440	
Control	Male	45	31.90	15.488	33.89	15.092	1.99
Female		24	31.90	15.488	34.75	16.533	

Table 2 shows the mean achievement score of male and female students taught quantum physics using computer assisted instruction with animation and without animation. Those male students had a mean of (48.82 for experimental group and33.89 for control group) in the achievement test and standard deviation of (15.488 for experimental group and15.092 for control group).While the female students had a mean of (52.47 for experimental group and34.75 for control group) and a standard Deviation of (17.440 for experimental group and16.533 for control group) .The mean achievement scores of female students taught with animation and without animation were higher than the mean achievement scores of male students taught with animation and without animation.

Hypothesis 1

HO$_1$: There is no significant difference in the mean cognitive achievement score of college of education students taught quantum physics using computer assisted instruction (CAI) package with animation and those taught without animation. Hypothesis 2 and 3were tested by table 3

TABLE 3: Summary of ANCOVA Table of Students' Scores in the Quantum Physics Achievement Test (PATEQP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Result
Corrected Model	11430.617	8	1428.827	7.375	.000	
Intercept	15758.534	1	15758.534	81.334	.000	
Pretest	1.301	1	1.301	.007	.935	NS
Treatment	5981.245	1	5981.245	30.871	.000	S
Gender	93.319	1	93.319	.482	.489	NS
Treatment * Gender	630.437	1	630.437	3.254	.074	NS
Error	24606.441	127	193.752			
Total	274264.000	136				
Corrected Total	36037.059	135				

S=Significant at 0.05 probability level

NS=Not significant at o.o5 probability level

The 95%confidence interval of difference, the value of F, its degree of freedom and its P-value significance, the value of F is 7.375. and the result of the test is significant beyond the 0.05 level of significant as the exact probability level 0.00 is less than 0.05.Therefore the null hypothesis of no significant differences is rejected This means that there is a significant difference in the mean achievement scores of students' taught with computer animation and those taught without animation. Hence table 3 indicated that the use of computer with animation in teaching quantum physics is a significant factor in the mean achievement scores of students who were taught with computer assisted instruction with animation and without animation.

Hypothesis 2

HO_2: There is no significant difference in the mean achievement scores of male and female students in quantum physics. Hypothesis 2 is tested with table 3.

Table 3 revealed that the 95% confident interval of difference, the value of F, its degree of freedom and its p-value is not significant, the value of F is 0.482 and the result of the test is not significant above the 0.05 level of significant as the exact probability level 0 .489 is more than 0.05 .This means that there is no significant difference in the mean achievement scores of male and female students in quantum physics. Table 3 indicated that gender is not a significant factor in the mean achievement scores of students who were taught with computer animation and those taught without animation.

Hypothesis 3

HO_3: There is no significant interaction effect of package and gender on the mean cognitive achievement scores of students in quantum physics. Hypothesis 3 is tested with table 3.

Table 3 shows the interaction effect between modes (treatment or CAI package) and gender on students' achievement. In table 3 it was indicated that the interactions between CAI package (Treatment) and gender is not significant. This is because with the 95% confident interval of difference, the value of F, its degree of freedom and its p-value is not significant, the value of F is 3.254 and the result of the test is not significant above the 0.05 level of significant as the exact probability level 0.074 is more than 0.05 .Therefor the null hypothesis of no significant interaction effect is not rejected. This means there is no significant interaction effect between CAI package and gender on students' achievement score.

1.9 DISCUSSION AND INTERPRETATION OF RESULTS

The group presented with CAI with animation during instruction performed better than the group presented with CAI without animation. It is therefore; clear that the use of animation facilitates learning of quantum physics in physics class and the best way of presenting animation is after giving verbal explanation. The presence of the animation concretized the learnt concepts and provided nonverbal channel for further contrasting of the minimal pairs. The animations performed these functions best when they are used as post organizers .This is so because, in physics that is concerned with abstract concepts that are in form of constructs which are not physically observable, the presentation of examples is required before the animation that concretized and organized the minimal pairs more effectively in the memory of the learner. The presentation without animation denies the learners the opportunity of non-verbal encoding and processing of information and that might be the reason of low performance of this group.

The results are in line with the findings of Abhang, (2005), Budde, Niedderer, Scott and Leach, (2002). Abhang, (2005) found that the presentation of concepts without animation but with audio had a little advantage over presentation without audio and animation on students achievement in articulating the abstractness of quantum physics. Budde et al 2002 found that the efficacy of audio and animation interaction in quantum physics is due to some complementary of, and the synergy between audition and vision. These two factors operating at information and information processing levels respectively provided the modes with animation, the advantage which facilitated learning over the mode without animation

On the other hand the male did better than the female .How ever there is no significant difference influence of gender on students' performance in learning quantum physics. Also, no mode of presentation is really best for any particular gender. Hence, there is no significant interaction effect of mode and gender on student's achievement in learning quantum physics.

Therefore, when a particular mode of presentations is used, it benefits the students equally irrespective of gender.

2.0 CONCLUSION

The following conclusions can be drawn from the results:

CAI with animation mode of presentation of quantum physics to concretize the abstract concepts is the more effective mode with respect to students' achievement in articulating the Bohrs model of atom. The CAI without animation mode that does not involve the use of animation is the least effective.

Male and Female students perform equally in articulating the Bohrs' model of atom. Gender does not facilitate or hinder learning rate of quantum physics

No mode of presentation is particularly more effective for any gender. Interaction effect of mode and gender

2.1 EDUCATION IMPLICATION

The results of the study have implication for educational practice. The use of animation during quantum physics instruction improves students' performance in quantum physics. Thus, the method of teaching quantum physics in which animation is not used is partly responsible for students' poor performance in quantum physics.

2.2 RECOMMENDATION

Based on the findings and implication of this study, the following recommendation is made:

Teachers should use CAI with animation when teaching quantum physics for effectiveness.

Animation should be presented after explanation of any concept to concretize the meaning of the concept

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ENACTMENT OF TECHNOLOGY SUBJECT AFTER 15 YEARS OF ITS INSTITUTION: CASE OF FIRST YEAR TECHNOLOGY STUDENT

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Abstract–The development of Technology subject in schools has been a burning fire for some time and an area of concern in a South African Context. The aim of this paper is to explore the level of development of Technology subject content knowledge in school. The study adopted theory of "diffusion of innovativeness" that was developed by Roger. To explore the level of development of Technology subject content knowledge, two (2) research techniques were employed. Firstly, questionnaires of 95 first year Technology students were analysed to explore level of first year students' understanding of different Technology concepts. The findings revealed that students experience difficulties in understanding different Technology concepts. Lastly, interview technique of 30 students was used to explore students' view about Technology teachers' level of content knowledge in Technology subject. During interview most students indicated that most of the Technology teachers do not have sufficient content knowledge that can help them to understand the content knowledge of Technology subject. The study therefore, suggests a continuous support and in-service training to Technology teachers with respect to Technology Content Knowledge (TCK). In addition, further intensification of Technology Courses in teacher training institutions to provide relevant and contextual TCK training.

Keywords: Technology Education, Educational Technology, Technology, Technology students

1. INTRODUCTION

In order to understand the development of knowledge in Technology education, it is necessary to provide a brief account of its historical background. In South Africa, Technology Education was introduced for the first time in 1998 as a separate learning area in a new curriculum (Department of Education (DoE), 1997). The new curriculum, named Curriculum 2005 (C2005), was introduced to replace different curriculum that was established during the apartheid era (Ndimande, 2006). However it was accompanied by serious challenges that were identified in the literature like different understandings of the OBE pedagogy, unspecified content to support the outcomes, inadequate training for teachers to implement the new curriculum, and inadequate resources (Adler, Reed, Lelliot & Setati, 2002; Jansen, 2001; Potenza & Monyokolo, 1999). The challenges surrounding C2005 led to its revision and the introduction of the National Curriculum Statement (NCS) in 2002 (Makgato & Ramaligela 2012). However, for Technology Education the introduction of the NCS didn't the lack of qualified teachers, inadequate professional development and poor understanding of the OBE approach (Engelbrecht, Ankiewicz, & de Sward, 2007). Based on this unresolved challenges, it is very imperative to explore the development of knowledge in Technology subject at school level.

Technology is an engine of any countries' history, cultural, social and economy development and prosperities (Luckay and Collier-Reed, 2011). Barnard (1996) explain Technology as a term that is commonly used as a descriptor for specific knowledge and skills. Technology is the manufacturing and utilisation of equipment, tools, and machine that serve the need of the people (Jonas, 1954). The concept of technology in education curricula force some level of technology skills (Barron, Kemker, Harmes, & Kalaydijian, 2003), However, in this contemporary era the meaning of the word technology has been lost under a weight of varied usages and interpretation (Barnard, 1996: 435). Technology education brought a shift from only knowing the product but to also doing and; from only solving problems to problem-based learning McCormick (1992). McCormick further indicated that its systematic nature of idea is to bring technology into the real world of school. Therefore, it is very crucial to understand the students' level of understanding of the term Technology and how it has developed in the context of education as a new idea and a field of study.

2. RESEARCH QUESTIONS

The aim of this paper is to explore the level of development of Technology subject content knowledge in school. In order to understand the level of development two research questions were used.

- What is the level of first year students' understanding of different technology concepts?
- What are students' views about technology teachers' level of content knowledge in Technology subject?

3. DIFFUSION OF INNOVATION

This study adapted the theory of "Diffusion of innovativeness" (Roger, 1995). Roger (1995:990) explain "innovation as an idea, practice, or object that is perceived as new by an individual or other unit of adoption". In order to understand individual adoption of innovation Roger (1995) expand the concept and identified three elements that are associated with innovation i.e. innovation-decision process, innovativeness and innovation in rate of adoption. In 2002 Roger further explore the concept of "Innovativeness" in order to ascertain the degree to which an individual(s) adopt new ideas with respect to other members of a social system (Roger, 2002). In order to understand the degree to which an individual adopt new ideas Roger (1995) identified five innovativeness categories, or classifications i.e. innovators, early adopters, early majority, late majority, and laggards. In this study innovativeness was considered relevant in the sense that its classification can help the researcher to identify the level of knowledge that students holds with respect to Technology. The categories found in Rogers's theory were used as categories to identify students' level of understanding of different technology concepts. However, this article only adapter four categories: (1) innovators, (2) adopters, (3) majority, and (4) laggards.

In this study **Innovators** refer to technology students who are more knowledgeable about different terms and can explain them scientifically with reference to specialisation. **Adopters** as technology students who are relatively knowledgeable about different terms but could not scientifically explain. **Majority** is technology students who can relate different terminology with common understanding which is not scientifically. Common understanding refers to the understanding of everybody about a particular concept or understanding which holds a lot of misconception. **Laggards** as technology students who possess almost no understanding on terminology. Laggards are the lowest level students who are most irrelevant in the understanding of technology.

4. METHODOLOGY

This study adopted an exploratory qualitative approach. In order to explore the development of knowledge in Technology subject at school level the study used questionnaires and interviews as the main sources of data. A questionnaire was administered with 95 first year Technology students. The questionnaire was given to all ninety five (95) students who registered for Bed: intermediate/senor degree. Questionnaire was conducted on the first day of their class teaching, before they are taught. Open ended questionnaire were used to collect data in order to give student opportunity to think openly without limitation. This helped the researcher to explore student deviant level of understanding. Data were analysed using MS Excel. Based on the findings of the questionnaire, the researcher was inspired to further explore students understanding.

Chiu and Lin (2005) indicated that students understanding are motivated by their pre-knowledge. Therefore, the researcher then interview students about their view with respect to teachers understanding of technology subject in school context. This interview was done after they have been introduced to the course of Technology. The purpose of the interview was to explore students view about technology teachers' level of content knowledge in Technology subject. The interview focused on what teachers in school taught them and students' view on Technology teachers' knowledge concerning technology. Thirty (30) students were randomly selected based on their interest to participate in the interview. The interview was semi-structured and where analysed manually. Data were coded and analysed according to the categories identified in the data.

5. FINDINGS AND DISCUSSION

As indicated earlier, data were collected through questionnaire and interview. The study explores the level of understanding of technology concepts and their view about technology teachers' level of content knowledge. As indicated earlier, Roger (2002) theory of innovativeness where used to identify categories on students responses and as a lens to identify students level of understanding.

Students' understanding of Technology concepts

The questionnaire was developed to collect data with three research questions in order to investigate students' level of understanding. Students level where evaluated on their understanding in terms of the distinct between Technology as a subject; Technology as a source of information; and Technology as a terminology used in everyday life. As indicated earlier this was an open ended question, and students provided their answers differently. Interview was also conducted with the students to understand students view about teachers understanding of technology subject in school context.

What is your understanding of Technology Education?

In order to measure the level of students understanding of Technology Education Department of Basic Education (DBE) definition where employed. According to DBE (2011:9) Technology Education is "the use of knowledge, skills, values and resources to meet people's needs and wants by developing practical solutions to problems, taking social and environmental factors into consideration". Figure 1 below indicates the level of students understanding of Technology Education in each category statistically.

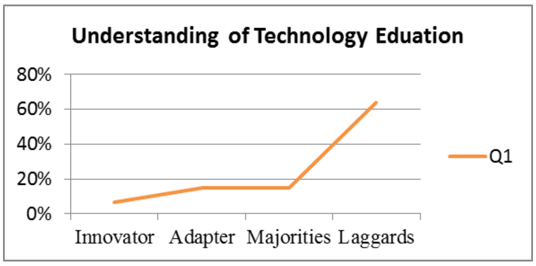

Figure 1: Students' understanding of Technology Education

Figure 1 reflected that only 7% of the students where innovators, 15% where adopters, 15% where Majorities, and 64% where laggards. Questionnaire data showed that students who are innovators understand Technology education as the use of knowledge, skills and resources and recognise, and solve problems by Design, Make & Evaluation to meet people's needs and wants. Students who are adopters view Technology Education as an activity or use of knowledge to meet peoples' needs and wants. Students who are majorities understand Technology Education as Learning electronics things, electrical components, structure and the form of design and building,; process of collecting, analysing and synthesis the information; gaining knowledge, skills and value about technology by making different things using design and evaluate strategies. Students who are laggards view Technology education as new methods of learning Technology in the department, learning and improving the past to new things related to nowadays, and creating new things.

What is your understanding of the term Technology"?

Moore & Bensbasat (1991) and Jonas (1954) understanding where used to understand students understanding of term Technology. Technology is the innovation of tools, machines, techniques, crafts, systems, and methods of organization (Moore & Bensbasat, 1991) in order to solve a problem or improve a pre-existing solution (Jonas, 1954). Figure 2 below show statistically the level of students understanding of the term Technology in each category.

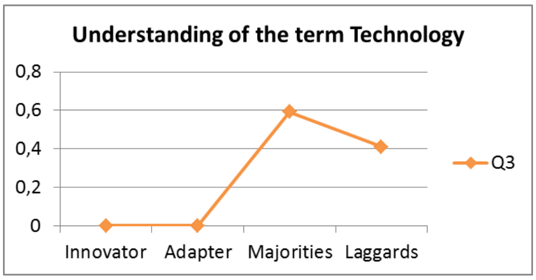

Figure 2: Students' understanding of the term 'Technology'

The data reflected the where no students who were categorised as innovators or adapters in this question. Figure 2 above showed that 59 % of students where Majorities and they associate the term Technology with easy access of tools; object, machines and materials; use of internet, ATM, Cell phones, TV, gadgets and other technology components; and development of electricity, machines and bridges. The data also reflected 41% students as Laggards. Laggards' students related term Technology with the designing process, knowledge gaining using the resources, electrical and electronic devices, system that brought change, knowledge of research or science.

In terms of understanding the term Technology Education, most of the students relate Technology Education with making of product than learning how to use different knowledge, skills, values and resources to develop practical solution in order to meet people's needs and wants. They view Technology Education as industrial activity where products are manufactured. The questionnaire data revealed that most of the students level of understanding Technology Education in inadequate. In terms of understanding the term Technology, most students' holds common understanding about the term Technology rather than scientific understanding. They mostly relate Technology with accessibility and use of technology product rather than creating and developing of new ideas and practice by individuals or group of a social system.

Students view students' view about technology teachers' level of content knowledge

The interview focused on two semi structured questions.

Do you think Technology was well taught in school? Why?

During interview 17 (seventeen) students indicated that Technology subject was not well taught at school. **Firstly**, students indicated that most of the teachers didn't understand the content knowledge of technology and teachers couldn't provide them with relevant content knowledge. They further indicated that most of the time it was confusing. For example, one student said that "*teachers didn't give relevant information and it was complicated". Other students also indicated that "teachers didn't understand as they were lacking information"*. They further commented that "*teachers failed to make it easy and enjoyable"*. One of the students concluded that Technology subject *"lack experience teacher"*. **Secondly**, other students indicated that most of the practical that were done is school were more context related rather that Technology content related. For example, one student indicated that *"the practical were more context orientated than technology concepts"*. Surprisingly, other students indicated that during their school experience *"no practical were done"* to enhance their understanding. Some of the students indicated that Technology subject was not well taught because *"teachers lack effort and time, and attention to individuals were insufficient"*. Students believed that if teachers put effort and enough time in their preparation, technology can be taught well. **Lastly**, most of the students indicated that lack of teaching and learning support materials as well as materials to do practical makes it difficult to understand the Technology content. For example, one student indicated that Technology subject was not well taught *"because of resources like learning materials and practical materials"*.

On the other hand 13 (thirteen) students indicated that Technology subject was well taught at school. This students only focused on practical and materials use. **Firstly**, students showed that Technology content "*it was done theoretically and practically".* For example, one of the students indicated that "*we were doing projects based on art craft*" and *"they (learners) can be able to solve problems and come up with solutions"*. The other student also showed that *"We were doing lot of practical things"*. **Lastly**, most of the students were satisfied with practical materials as well as teaching and learning materials. Students indicated that teachers provided them with textbook that were more informative and had more examples that makes them to understand. For example, one student indicated that *"they (teachers) had many resources and textbook that was having good and simple information with good examples to enhance our understanding"*. They further indicated that *"textbook gives us some projects to do that makes us understand.*

In conclusion, most of the students who indicated that Technology subject was not taught well were able to indicate specifically the area that were not adequately taught. Whereas student who showed that Technology was adequately taught were not specific and did not refer to the teacher but refer to the textbook structure. For example, they indicated that Technology content knowledge was irrelevant and they make it complicated to understand. In addition most of the teachers lack understanding of the content knowledge which make it difficult for learners to understand and enjoy it. This findings was in line with Botha (2012) findings that science teachers need to understand science as a discipline which includes understanding the nature of science and the integration of the various knowledge domains. Although students who thought that Technology subject were done properly didn't indicate how adequate Technology content knowledge were taught.

They also indicated that even though practical work was done, they were more context related. Whereas students who thought that Technology subject were done properly didn't indicate the relevancy of practical with content knowledge required. Students also indicated that most of the schools that they were attending to lack materials for both teaching and learning as well as practical (Ramaligela & Makgato 2012). Whereas students who were content with what was taught at school indicated that the materials provided by the teachers were more informative and had a lot of examples to make them understand. Based on this, it seems like student who thought Technology subject was well taught was referring mostly to the textbook rather that how the teacher explain, relevancy of the content knowledge and practical with reference to Technology subject.

Do you think teachers who taught you Technology subject they understand the subject? Why?

During interview sixteen (16) students indicated that most of the teachers did not have understanding of the subject. **Firstly,** they indicated that teachers lack understanding on what to teach and how to teach. For example, one students said that *"they (teachers) don't have a clue on what they do"*. Other student said that *"she only talked about technology things, she didn't go deeper "*and *"no clear understanding to teach to our level of understanding"*. In addition, one student also said that teachers "*only taught us what was in the textbook and their knowledge is limited to the textbook*". **Secondly**, students indicated that most of the teachers cannot relate content knowledge with real life context. They indicated that most of the time teachers didn't give them practical examples to make them understand better (Botha & Reddy, 2011). For example, one student indicated that *"they didn't have a background information as they were just reading a textbook without giving practical's".* Other student also indicated that teachers lack in-depth because *"they (teacher) couldn't use practical ways to make us understand".* **Lastly,** they indicated that teacher perceive Technology subject as learning about different Technology product. For example during class presentation *"they come with the laptops to show them that this is technological done"*. Other student indicated that *"they (teachers) were not sure about what they were teaching, they only knew that technology involves garget like computers"*.

Twelve (12) students indicated that most of the teachers have understanding of the subject content knowledge. **Firstly,** they indicated that teachers have understanding of the subject because they can explain technology concepts clearly and also provide them with relevant examples. For example one student said *"she gave clear and sound explanation"*. Other student said that "*they (teachers) have a very good sound knowledge of what they are teaching because they also can explain and give good examples*". However, students' response about teachers' understanding cannot be validated. But other students were more open as they compared what they have been taught at the university with what they have learned at school. For example, one student indicated that *"because I use what I have been taught at high school even today"*. Other student also said that *"most of them made it easy for us to understand, we were taught about the same technological process we came across now"*. In addition, student indicated that "They (teachers) understand the subject very well because they always provide use with knowledge that is usually not in the textbook. **Secondly,** students indicated that teachers were giving them practical projects that are related to the content knowledge. For example, one student said that *"because we were giving us practical's to do at home about the things that they were teaching"*. Another student indicated that *"because they did explain and give practical showing that they understood"*. However, other two students even though they believe that the teachers has a good understanding of the subject, it was very clear that the student doesn't know if whether the teacher has understanding or not. For example, one student said that *"they (teachers) do understand it but they can't explain it to learners"*. **Lastly,** students were satisfied *"because they made me to have internet in it. They made me see the necessary of promoting it as its part of our lives*".

In conclusion, both student indicated that teachers who have understanding of the subject must be able to explain clearly and give examples. Surprisingly, both students also indicated that teachers who have understanding of the content knowledge must not be limited to textbook information (Ramaligela, Gaigher & Hattingh, 2014). They also indicated that lack of practical makes learning not meaningful. However, students who indicated that Technology teachers do not have adequate knowledge of the subject indicated that other teachers perceive technology products as content for Technology subject rather that the output process of technological/designing process.

6. CONCLUSION

The purpose of this paper is to explore the level of development of knowledge in Technology subject at school level. The data indicated that the development of Technology subject in South African school is very slow because most of the Technology teachers do not have sufficient content knowledge that can help to enhance learners understanding. Hence, teachers' lack of adequate content knowledge have significant impact on students understanding about Technology subject. In terms of students' level of understanding different Technology concepts, the data revealed that students experience difficulties in understanding different Technology concepts. Firstly, students relate the term Technology Education with making of product rather than learning how to use different knowledge, skills, values and resources to develop practical solution in order to meet people's needs and wants. Lastly, most students' holds common understanding about the term Technology rather than scientific understanding. They mostly relate Technology with accessibility and use of technology product rather than creating and developing of new ideas.

In terms of students' view about technology teachers' level of content knowledge in Technology subject, the data indicated that most of the Technology teachers do not have sufficient content knowledge that can help students to understand the content knowledge of Technology subject. Firstly, students indicated that most of the teachers lack understanding of the Technology content knowledge relevant and meaningful and teachers' practical activities were irrelevancy with respect to Technology content knowledge. Secondly, most of the teachers did not have understanding of the Technology Content Knowledge (TCK) because teachers were unable to explain clearly technology concepts; give practical examples; only limited to textbook information and teachers perceived technology products as content for Technology subject rather that the output process of technological/designing process. The study therefore, suggest a continuous support and in-service training to Technology teachers with respect to Technology Content Knowledge (TCK). In addition, further intensification of Technology Courses in teacher training institutions to provide relevant and contextual TCK training.

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IMPROVING FORMATIVE ASSESSMENT PRACTICES THROUGH TECHNOLOGY: WHAT WE KNOW FROM SOUTH AFRICA

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Abstract–Assessment when used properly in for example identifying learner strengths and weaknesses, providing teachers with ideas for relevant interventions, allowing teachers to evaluate their teaching approaches, and providing information to learners on what they need to do to improve their understanding can lead to improved teaching and learning. However, more than a decade after the implementation of the new post-apartheid curriculum, the effective usage of classroom assessment opportunities and technological tools present challenges to most teachers in South Africa. The challenges include: inadequate teacher pedagogical and content knowledge; poor understanding of assessment and the new curriculum; high workloads and large class sizes; and teachers' lack of basic computer technology skills. To address these challenges, a computerised assessment system referred to as TARMII—Teacher Assessment Resources for Monitoring and Improving Instruction has been developed with objective of assisting teachers improve their assessment practices. The system was piloted in a number of primary schools in South Africa where data were collected through site visits and telephonic interviews. The report based on the analysis of the pilot data indicates that teachers' classroom assessment practices are skewed towards recording and reporting of learner performance with less attention paid to using assessment results to enhance teaching and learning. We contend that teachers' lack of confidence in using computer technology skills in their assessment practices provides possible explanation to this practice. Furthermore, teachers' unwillingness to go beyond what the written curriculum and the South Africa Department of Education expects them to cover for the year seems to be the key challenge preventing them from engaging in new teaching innovations such as TARMII to improve assessment practices. These issues are being addressed in the current project TARMIIfp (TARMII for the foundation phase teachers) through the development of more functions on the software remote data collection system that allows us to track teachers' use of the software.

Keywords: Assessment, Technology, Teaching and Learning, South Africa;

1. INTRODUCTION

A number of research studies have demonstrated the positive impact of assessment on learning and learner performance (Black & William, 1998; Harlen, 2005; Stiggins, 2001), in for example identifying learner strengths and weaknesses, providing teachers with ideas for relevant interventions, allowing teachers to evaluate their teaching approaches, and providing information to learners on what they need to do to improve their understanding (McMillan, 2001; Stiggins, 2001). However, more than a decade after the implementation of the new post-apartheid curriculum, the effective usage of classroom assessment opportunities and tools present challenges to most teachers in South Africa (SA). Many South Africa teachers manifest inadequate teacher expertise and content knowledge; they have poor understanding of assessment and the new curriculum; and they have high workloads and large class sizes. As a result, these teachers often rely on traditional assessment practices and are unwilling and/or unable to adapt their assessment practices to the changing demands of the new education system (Combrinck, 2003; Kanjee, 2003; Pryor & Lubisi, 2002; Vandeyar, 2005; Vandeyar & Killen, 2007). All these impact negatively on effective classroom assessment. To address these challenges, the National Department of Education with support from other research organisations initiated the District Development Support Programme to improve teaching and learning. In this paper, we track this programme and the technology innovation (software) developed to improve formative assessment practices in South African classrooms. To address the challenges, the development involved a close participation of district officials, link of the software to the South African Annual National Assessment (ANA) and a remote function that allows us to track teachers use of the software.

2. THE DISTRICT DEVELOPMENT SUPPORT PROGRAMME

The District Development Support Programme (DDSP) was a USAID-sponsored school development programme managed by the Research Triangle Institute (RTI). The South African National Department of Education, in collaboration with the Research Triangle Institute, implemented this programme in 2000. The overall goal of the programme was to improve the quality of learning and teaching across 450 primary schools in the most rural districts in four provinces (i.e. Eastern Cape, KwaZulu-Natal, Limpopo and Northern Cape). A number of local service providers were contracted to implement appropriate interventions for improving management and teaching practices in the participating districts and schools. As part of the programme, the Human Sciences Research Council (HSRC) was commissioned to develop and pilot relevant resources for supporting Foundation Phase (i.e. Grades R to 3) teachers to improve their classroom assessment practices. These resources, known as Assessment Resource Banks (ARBs), were piloted in the four DDSP provinces over a period of a year. All participating DDSP schools received a set of the ARBs while a number of training and support workshops were provided.

Teachers were trained to use the ARB to identify learner strengths and weaknesses, develop relevant intervention programs for specific learners, and record and monitor learner progress. An unintended result was that teachers also used the resource banks for developing lesson plans, writing their own items, and setting homework exercises, indications that the ARB can perhaps be used in teacher development programs. The rationale of providing teachers with ARB resides in a documented irony that availability of varied and relevant assessment tools is critical to apply classroom assessment effectively, (National Research Council, 2003); yet, in practice, the provision of relevant tools to assist teachers is not a common practice. For example, in South Africa, no such resources were available to teachers prior to the DDSP programme. Instead, most teachers are expected to develop their own assessment instruments and tools, occupying their valuable working hours.

Furthermore, the difficulty of implementing effective classroom assessment was exacerbated by the adoption of a new and radical change to the national curriculum: outcomes based education (OBE). In particular, teachers had to digest a whole suite of assessment related policies and guidelines that place greater emphasis on classroom assessments, most notably the Assessment Policy in the General Education and Training Band (Grade R to 9) and the national protocol on assessment for schools in the General Training Band (Grades R to 12) (Department of Education, 2005). More recently, the government revised its 1998 assessment policy. This new policy (Department of Education, 2007) placed greater emphasis on classroom assessment by outlining the range of assessment information available to teachers, specifying the frequency and types of assessment information required for reporting on learner performance at the different grade levels and providing templates for recording and reporting the performance of learners.

While the intent of the policies is laudable, they pose further challenges for teachers in the SA classroom. In particular, teachers are faced with a considerable demand to address the more transformational assessment for learning approach that underpins the new curriculum, demands that differ significantly from the traditional assessment of learning that had been a pillar of the old education system (Grosser and Lombard, 2003). Furthermore, a number of researchers (Pryor & Lubisi, 2002; Sokopo 2004; Vandeyar, 2005; Vandeyar & Killen, 2007) have observed that teachers often struggle to negotiate the demands of the changes in relation to aspects such as balancing formative and summative assessment as well as the recording and reporting of data. Vandeyar and Killen (2007) describe how teachers still held very strong teacher-centred conceptions of assessment which conflicted fundamentally with an outcomes based approach to assessment, while Sokopo (2004) notes that teachers interpreted the implementation of classroom assessment as merely serving the purpose of accumulation of marks rather than for use in improving learning and teaching.

It was in this context that the development and piloting of the ARBs was formulated in collaboration with the South Africa education officials. The ARB developed for the DDSP programme contains a set of booklets, including assessment tasks and posters for teachers to assess learner performance against the Assessment Standards specified in the National Curriculum Statements. All assessment items were written in English and translated into the seven other official languages used in the DDSP schools, and some items were pilot tested to establish the validity of instructions (for additional details, see Kanjee, 2003). The assessment tasks were designed so that teachers had the option of either writing the items on the board for the learner to respond on paper, or make photocopies and hand these out as worksheets. For each assessment task, specific guidelines for teachers were included. These guidelines listed the learning outcome associated with each task, the skill being assessed and the level of difficulty of the task for learners, instructions for administration and scoring, and a scale for interpreting scores. This scale was based on the proportion of questions answered correctly and categorised according to the attainment levels outlined in the National Curriculum Statements (Department of Education, 2005).

In addition to the assessment booklets, posters portraying common scenes such as building sites, classrooms, villages, and playgrounds were also developed as stimulus material for the assessment tasks. Teachers were also provided with guidelines on how to create a learner profile sheet to record results of all classroom assessments (e.g., projects, oral tests, examinations, ARB tasks). To ensure the successful implementation of the ARBs, nine HSRC staff members, known as Teacher Support Staff (TSS), were deployed to the participating DDSP districts. In addition, all schools were required to establish a School Assessment Team comprising two staff members, preferably a teacher and a school management team member. Initial training workshops were conducted with the School Assessment Team members who were required to cascade the training to their colleagues. These workshops were also attended by district and provincial officials and were conducted in clusters of between 10 and 15 schools. The workshops were conducted by HSRC teams that comprised a senior researcher as well as the local TSS. For each school cluster, three sets of workshops were conducted at the beginning, the middle, and the end of the pilot phase to familiarise participants on the use of the ARBs, to receive feedback, monitor progress and discuss problems in the implementation of the ARBs, and to evaluate the use of the ARBs. In addition, the TSS regularly visited schools over a period of eight months to provide classroom-based support to teachers.

In the program evaluation to determine the effectiveness of the ARBs in supporting teachers in the DDSP schools to improve their classroom assessment practices, towards the end of the pilot, data were collected, over a period of four weeks, using teacher and school questionnaire to all DDSP schools, and classroom observations (n=99), document review, and interviews with teachers, members of the School Management Team (SMT, n=76) and members of the School Assessment Team (SAT, n=74) in a number of selected DDSP schools. The finding from this evaluation exercise, published in Kanjee (2009) demonstrates an overwhelming positive response from the teachers and education officials, with clear indications that ARBs were received well and being used by most teachers. There was also encouraging evidence that ARBs were used in these classroom relatively widely, including activities that were not specifically for assessment purposes, but for purposes such as lesson planning. There were also a number of additional innovative applications of the ARBs recorded. All proved that ARBs are a valuable resource that can be effectively applied by most teachers to enhance their classroom assessment practices. Challenges identified in this evaluation exercise mainly point to insufficient classroom resources (eg, ARB materials, photocopying facilities, workbooks for individual learners, time wasted in writing the tasks on the chalkboard) and language (appropriate translation of the ARB material into the mother tongue).

3. TARMII—a technology innovation to improve classroom assessment practices

The success of this program (also see Dye, Horn, Naidoo, Weber & Wolf, 2003), has led to the development of the computerised assessment system referred to as TARMII—Teacher Assessment Resources for Monitoring and Improving Instruction. In essence, the TARMII system is an extension of the ARBs. It was pioneered by the HSRC with financial support from the (then) National Department of Education. The system was developed for teachers of English (First Additional Language, or FAL) and Mathematics in grades 4, 5 and 6 and comprises a database of English FAL and Mathematics assessment items. All assessment items in the system are aligned to the Learning Outcomes (LOs) and Assessment Standards (ASs) of English FAL and Mathematics as stipulated in the National Curriculum Statement (NCS) (DoE, 2002a; 2002b). In addition to assessment items, the system also provides diagnostic information on the performance of learners that teachers can use to develop ideas for intervention at the classroom level.

The system is unique in a number of ways: 1) It includes a feature that allows teachers to track learner performances over time; 2) The development of the system from 2008 to 2010 involved intensive discussions with a number of district, province and national education officials; 3) The assessment items were developed largely by teachers who are still in the teaching service; 4) The system is run by an open source program so that schools, districts and national can modify TARMII to suit contextual needs; 5) The structure has four main modules that allow users to create a class list, generate and mark a test, enter marks of test and generate diagnostic reports on learner performance: and 6) With access to test items (both multiple and open-ended items) and the expected correct responses, the system provides opportunity for teachers to improve their content knowledge and hence develop their confidence in teaching.

The TARMII system was field tested and piloted in a number of primary schools in South Africa. Data were collected through site visits and telephonic interviews. The report (see details from Makgamatha, Moodley, Molefe, Diedericks, & Kanjee, 2010) based on the analysis of the field test and pilot data indicates that teachers' classroom assessment practices are skewed towards recording and reporting of learner performance with less attention paid to using assessment results to enhance teaching and learning. Teachers' unwillingness to go beyond what the written curriculum and the South Africa Department of Education expects them to cover for the year is the key challenge preventing them from engaging in new teaching innovations such as TARMII to improve assessment practices. Other challenges include: 1) teachers Computer Literacy Skills that seem to determine their engagement with TARMII; 2) school ICT Infrastructure and Support Materials that often determine sustained access to TARMII; and 3) limited teachers' access to computers.

4. TARMIIfp—a technology innovation for foundation phase teachers in South Africa

In this project, we have proposed an extension of the TARMII facilities to cover assessment resources for reading in the foundation phase—primary grades. We contend that our proposed TARMII foundation program (TARMII_fp) is consistent with the USAID objectives to improve reading in the foundation phase and the current education priorities as outline in the action plan 2014. A number of the test items that would be used in the TARMII_fp has been tested and demonstrated that with adequate support systems, the items have the potential to improve teacher assessment and learners' reading skills. We intend to build more test items largely through curriculum experts and teachers who would be using TARMII_fp. We argue that the involvement of teachers developing assessment items for the system would help them develop a sense of ownership and therefore contribute to the sustained use of TARMII_fp. The system also has functions that allow teachers to manage and diagnose the impact of classroom instructional practices. With quality test items and well functioning computerised item bank system, TARMII_fp as an innovative assessment management tool has the potential to enhance teacher effectiveness in classroom assessment practices and therefore improve reading outcomes. We envision TARMII_fp developing into a web based system and possibly leading the technological and pedagogical innovations to support teachers in their quest to improve teaching and learning within schools in South Africa. This will be of particular relevance at a time when a revised curriculum (Curriculum and Assessment Policy Statement – CASP) will be introduced, and there is a strong emphasis on monitoring of performance and learner outcomes in the country.

We intend to evaluate TARMII_fp through a quasi experimental design where 20 schools within each of our four participating provinces with our proposed program would be matched to 20 control schools. Through propensity score matching (psm) statistical procedures, schools with the TARMII_fp would be matched with schools in the control group with similar characteristics so that any changes or an improvement in teacher classroom assessment practices and their learners' reading achievement could be attributed to the our proposed program. Our analysis would also determine if the impact of our program depend on school and background characteristics (such as gender) of teachers and learners. We intend to use data from the Annual National Assessment (ANA) to track improvement in learners' reading skills attributable to TARMII_fp. This link with ANA would also ensure the continuous evaluation of the program.

Through a grant from the USAID and ELMA foundations, TARMII has been redesigned for foundation phase teachers (see the diagram below). As indicated in the diagram the TARMIIfp software allows teachers to create their profiles, develop a class-list, view assessment activities on the system, generate assessment activities for learners, mark these activities (evaluate learners) and generate reports about learners' performance. The system also includes teaching resources and pedagogical video clips. An important aspect of the system is the remote data collection function that allows us to track teachers' use of the software.

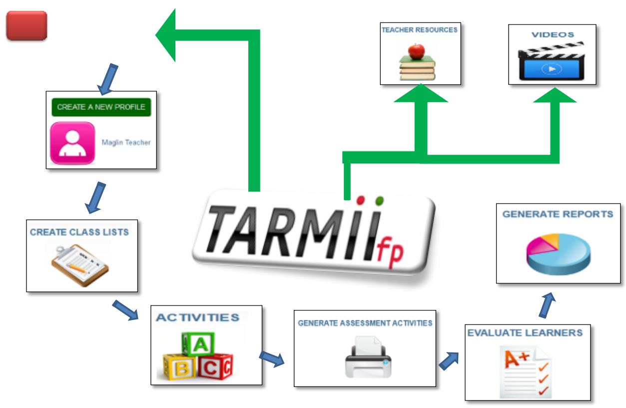

Figure 1

5. CONCLUDING REMARKS

Technology such as TARMII can play a significant role in improving teachers' formative assessment practices and hence enhance teaching and learning. In South Africa, the major challenges seem to be teachers' inadequate pedagogical and content knowledge that often makes them less confident to try innovative teaching practices and rather stick religiously to their curriculum guidelines. We contend that a vision to use technology to improve teaching and learning through assessment would have to address these challenges along with strong support to help teachers develop confidence in their basic computer skills. The current TARMIIfp project is quite unique in the sense that all project activities are linked to the curriculum and most importantly, teachers, principals and district officials in four provinces are actively involved in all project activities to ensure sustainability. The TARMIIfp software has been developed and is currently being piloted in 80 schools in four provinces (Limpopo, North West, Free Sate and Mpumalanga). Teachers and district officials have received training and are comfortable navigating through the different functions of the software. However, given that, for most of the foundation phase teachers involved in the project, this is their first engagement with computers, it will require incentive like a professional certification link to teachers' participation in the project to motivate teachers' continuous use and capacity development. This would be a unique innovation linking impact research and teacher professional development with significant policy implications for developing and enhancing teacher capabilities

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INFLUENCE OF PEER COLLABORATION ON JUNIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN BASIC SCIENCE AND TECHNOLOGY

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Abstract–This study was designed to determine the influence of peer collaboration strategy on Junior Secondary School (JSS) students' achievement in basic science and technology (BST) in Federal Capital Territory (FCT), Abuja. Three research questions and three hypotheses formulated to guide the study. The design for the study was a quasi-experimental. Specifically, the study adopted a pretest-posttest control group design involving one experimental and one control group. The population of the study consists of all the JSS III students in Gwagwalada and Kwali Area Councils of FCT, Abuja. The sample for the study was made up of 153 (87male and 66 female) students of 4 intact classes. The instrument used for data collection was basic science and technology achievement test (BSTAT). The internal consistency reliability estimate of 0.87 and stability estimate of 0.77 were obtained for BSTAT. The data generated were analyzed using mean, standard deviation and analysis of covariance (ANCOVA). The result of the data analysis showed that peer collaboration strategy facilitated the achievement of the students in BST. The study also showed that gender is not a significant factor on students' achievement when taught using peer collaboration strategy. Based on the findings it was recommended that BST students irrespective of their gender should be taught using peer collaboration strategy.

Keywords: influence, Peer Collaboration, achievement and Basic Science and Technology

INTRODUCTION

The knowledge of science and technology has been described as an indispensable for a successful and balanced human existence. Science and technology is a tool needed for effective functioning in any society and serves as foundation for all scientific and technological development (Adegboye, 1997). The study of science and technology in secondary schools builds up in the students, the basic skills, knowledge and competencies needed for scientific and technological development. According to Omosewo, Akanmu and Asebiomo (2013), the accomplishment and realization of these important educational goals in Nigeria depends on the effective implementation of the science and technology curriculum.

Despite the effect of Federal Government of Nigeria to improve the performance of students in science and technology, the achievement of most Nigerian secondary school in science and technology has consistently been to be low and unimpressive (Nenty 2001, Betiku, 2002, George 2008). Annual results from Federal Capital (FCT) Education Resources revealed poor performance of students who enrolled for basic science and technology examination at Junior Secondary School level. From records of Nigerian students' achievements in JSSCE basic science and basic technology (from 2006-20012) obtained from FCT Education Resources Department of Research, less than forty five percent (45%) of the students who enrolled in basic science and basic technology examination credited the subject while above fifty five percent (55%) either had ordinary pass or failure grade each year (FCT Education Resource Centre, Abuja). This implies a gross underachievement of Nigerian students in basic science and technology.

Report from the various examiners in basic science and technology for Junior Secondary School Certificate Examination 2012 showed that candidates' answers revealed students ignorance of the basic rudiments of basic science and technology. The report further indicated that many of the candidates could not carry out instructions that were needed to solve the science and technology problems; that the candidates lacked the skills and techniques of presenting the answers coherently. The suggestions are that if no urgent and serious steps are taken to arrest the incident of mass failure of students in the subject, the nation's scientific and technological developmental desires and expectations may remain a dream. Besides, a good mastery of basic science and technology is required by students in order to do well in other sciences and engineering related fields at senior secondary and tertiary institutions. Students who are handicapped in science and technology are likely to be handicapped in the acquisition of skills in science and technology subjects (Osafehinti, 1990). These observations of consistent poor achievement of junior secondary school students in basic science and technology underscore the need to explore other techniques of teaching the subject such as peer collaboration approach.

Peer which refers to the child's own friend and mate has a powerful effect on learning (Hoxby, 2000)). Most students feel freer and more interested in asking their fellow classmates questions, where they do not understand, than asking the teacher thereby making the students to develop positive toward the subject. It is even claimed that the most powerful and sustainable learning process occurs among peers who pull each other rather than being pushed by experts or the teacher (Hooper, 1992). In collaborative learning, learning is shared and the more that is shared, the more that is learned. The basic premise is that learning emerges through the shared understanding of multiple learners (Leidner and Jarvenpaa, 1993).

Peer collaboration which is a learner centered strategy has been suggested to minimize passivity and has the potential of enhancing students' interest and achievements in science and technology since it involves active participation of the learners. What one observes cannot be the same as what one is fully evolved in doing. Peer collaboration has also been suggested to be effective in teaching such subjects like physics (Ahaneku, 2002), chemistry (Anakwe, 2004 & Anyawu, 1993), Mathematics (Samuelsson, 2010; Murray, Xin Ma & Mazur,2009). Not much literature seems to be available so far showing the effectiveness of peer collaboration in improving the achievement of junior secondary school students in science and technology especially in basic science and technology.

Though a number of efforts have been made through research, workshops and seminars, science and technology has not secured its rightful position in the mind of students and as a result, interest continue to be low. Science and technology learning especially basic science and technology has continued to be seen as threat to students and this has been attributed to inappropriate teaching methods (Oranu, 2003). Although some other variables might have affected students when learning science and technology, Osafehinti (1990) stressed on teaching methodology as a major problem associated with low interest and poor achievement in science and technology contents.

A number of researchers relevant to gender issue on students' achievement had been done. Many studies have found out that female students under-achieve in science and technology in relation to their male counterparts (Adigwe 1999, Bateson and Parsons-champman 1998, Madu 2004). However, peer collaboration as a teaching and learning strategy has been suggested to possess a high tendency of bridging this gap between male and female in achievement (Hoxby, 2000)). Since peer collaboration involves the development of rational critical thought processes in the students as they explore, question, discuss, discover and cooperate among themselves, exposing them to the strategy may bridge the gender gap usually observed in science and technology achievement. Peer collaboration strategy seems to possess the potential of offering students equal opportunity of learning. According to Adigwe (1999), equal exposure to effective teaching methods could lead to the reduction of gender differences in learning. This study, therefore, seeks to investigate the effect of peer collaboration on junior secondary school students' achievement in basic science and technology.

STATEMENT OF THE PROBLEM

Students' achievement in science and technology has been observed to be generally poor and discouraging. The poor achievement has been linked to the low interest exhibited by the students in the study of the subject and apathy towards science and technology as a subject. Observation has shown that in the Nigerian classrooms, teachers dominate the teaching and learning processes and students' participation are usually very minimal. Literature evidence suggest that teachers' use of ineffective methods and strategies in teaching science and technology have among other factors contributed to the students' low interest and achievement in science and technology. This situation calls for the need to examine the effectiveness of some other teaching approaches such as peer collaboration.

THEORETICAL FRAMEWORK

Learning theories if well explain predict behaviour. According to Merril (1997), they open our eyes to other possibilities and ways of seeing the world. Most design decisions are certainly based on the knowledge of learning theories. Shwirer (1997), pointed out that, the function of instructional design is more of an application of theory rather than a theory itself. Based on this, cognitive, social motivation and social cohesion theories of learning are reviewed in the study.

The cognitive learning theory sees learning as a reorganization of knowledge structure. The knowledge structures are stored in semantic memory as schema or cognitive maps (UNESCO, 2002). Shell (1986) noted that the main emphasis of cognitive theory is on sequence of learning materials and experiences in a well organized environment so as to create order, meaningfulness and understanding, that is, learner-environment interacting meaningfully.

The developmental psychology of Jean Piaget also recognizes the active role of both learner and his environment in the learning process. Piaget asserts that the basis of all learning is the learner's activity as he interacts with his physical and social environment. For learning to take place, the environment must be stimulating and encouraging learning (Nwachukwu, 1995). Based on his research on the development of learner's cognitive functions, Piaget observed that learning occurs through adaptation to interactions with the environment. Disequilibrium (mental conflict which demands resolution) gives rise to Assimilation of a new experience, which is added to the existing knowledge of the learner, or to Accommodation, which is modification of existing understanding to provide for the new experience (UNESCO, 2002).

Specifically, Piaget posited that the existing cognitive structures of the learner determine how new information is perceived and processed. If the new information makes sense to the existing mental structure of the learner, then the new information item is incorporated into the structure (i.e., Assimilation). If, however, the information is very different from the existing mental structure of the learner, the information is transformed in ways that it fits into the mental structure (i.e., Accommodation) (Ngwoke and Eze, 2004). The learner has an active role in constructing his or her own knowledge in both of these ideas. According to UNESCO (2002) Piaget was of the notion that as children assimilated new information into their existing mental structures, their ideas gained complexity and power, and their understanding of the world grew in richness and depth. These ideas are core concepts of the constructivism view of the learning process.

Bruner in his own theory emphasized that learning is an active process in which learners construct new ideas or concepts based upon their prior knowledge and experience (Nwachukwu, 1995). According to UNESCO (2002) Bruner identified three principles that guide the development of instruction. These include: (1) instruction must be concerned with the experiences and contexts that make the student willing and able to learn (readiness); (2) instruction must be structured so that the student can easily grasp it (spiral organization); and, (3) instruction should be designed to facilitate extrapolation and/or fill in the gaps (going beyond the information given).

Other common theories that are related to peer collaboration include social-motivational (Slavin, 1986; Stevens, Madden, Slavin, & Farnish, 1987), social-cohesion (Johnson & Johnson, 1991), sociocultural (Scardemalia, Bereiter, & Lamon, 1994), cognitive-elaboration (O'Donnell, 1999; Palinscar & Herrenkohl, 2002), and Piagetian and Vygotskian theories (Delisi, 2002; Hogan & Tudge, 1999). Social-motivational and social-cohesion approaches emphasize the motivational aspects of peer learning more than cognitive processes involved in peer learning (Slavin, 1986). In contrast, cognitive-elaboration and the developmental Piagetian and Vygotskian theories focus more on the cognitive and social-cognitive processes of peer learning with less emphasis on motivational aspects (e.g., O'Donnell et al., 1990). Social-motivational theories posit that rewards provided to the group as a whole will motivate each member to work hard at the task, which leads to more effective learning (Slavin, 1996), while the cognitive-elaboration perspective holds that students learn in collaborative situations through heightened use of processing activities (O'Donnell, 1999).The theories also drive the way in which students are grouped, the directions they receive, and the goal and reward structure provided while they collaborate (O'Donnell, 2006; Webb & Palinscar, 1996). Conclusively, the theories discussed so far believe in the environmental influences on the learner's achievement in learning and that meaningful learning occur as learner and his environment are always participating in a simultaneous mutual interaction.

PURPOSE OF THE STUDY

The study sought to determine:

1. The effect of peer collaboration on students' achievements in basic science and technology.
2. The effect of peer collaboration on achievements of male and female students in basic science and technology.
3. The interaction effect of methods and gender on students' achievements in basic science and technology

RESEARCH QUESTIONS

1. What are the mean achievement scores of students exposed to peer collaboration strategy and those not exposed in basic science and technology?
2. What are the mean achievement scores of male and female students taught basic science and technology using peer collaboration strategy?
3. What is the interaction effect of method and gender on students mean achievement scores in basic science and technology?

HYPOTHESES

The following null hypotheses were tested at 0.05 level of significance.

HO_1: There is no significant difference in the mean achievement scores of students exposed to peer collaboration strategy and those not exposed to the strategy in basic science and technology.

HO_2: There is no significant difference in the mean achievement scores of students taught basic science and technology using peer collaboration strategy.

HO_3: There is no significant interaction effect of method and gender on students mean achievement scores in basic science and technology.

RESEARCH METHODS

The design of the study was quasi-experimental research design. The researchers make use of pre-test, post-test non-equivalent control group design. The researcher randomly assigned intact classes to treatment and control groups. This was necessary in order not to disrupt the normal classes of the students and the school time-table. The design is symbolically represented as follows:

Treatment group O_1 X_1 O_1

Control group O_1 X_2 O_1

Where

O_1 stands for Pre-test and Post-test

X_1 stands for treatment PC (peer collaboration)

X_2stands for Conventional method

Population for the Study

The study was carried out in Gwagwalada and Kwali area councils of Federal Capital Territory Abuja. The population of consist of all the 2011/2012 JSS III students numbering 5024 (2540 males and 2484 females) in Gwagwalada and Kwali Area Councils (FCT education Resources Centre 2012). The sample consists of 153 students (87male and 66 female) in the four intact classes randomly selected for the study. Purposive sampling technique was used to select the four co-educational schools with at least two streams for the study. The two co-educational schools were randomly assigned to treatment and control group and in each school; two intact classes were randomly selected and used for the study. The reason for the use of co-educational primary schools is to take care of the gender variables in the study. Co-educational schools were also chosen because there are no single sex schools in the study area.

Instrument for Data Collection

The instrument used for the study was Basic Science and Technology Achievement Test (BSTAT). The test items were generated based on the stated objectives of basic science and technology curriculum for JSS and the time required to teach each unit (Federal Ministry of Education, 2013). The achievement test consists of 20 multiple choice questions (See appendix). The BSTAT was subjected to both face and content validation. The BSAT was face validated by giving the test blue print for the instrument to three specialists, two in basic science and technology education and one in measurement and evaluation. The specialists were required to determine whether the number of items testing each level of knowledge mirrors the level of objectives in the curriculum. The content validity was assured using the test blue print validated by the experts in generating the test items. They examined the test items generated in relation to the test blue prints to be sure that the items reflect the specification in the blue print.

The BSAT was trial tested using 30 students in primary six a co-educational junior secondary school in Kogi Local Government Area of Kogi State. The data obtained through the trial testing was used to determine the internal consistency of the items. This was achieved through the use of Cronbach alpha method since the obtained scores were not dichotomously scored. The obtained internal consistency reliability estimate is 0.87. This suggests high reliability of BSTAT. In order to determine the stability of BSTAT over time, a test retest analysis using Pearson correlation method was conducted and a Pearson r of 0.77 was obtained. This is necessary since the same test, though to be reshuffled, will be used for both pretest and posttest.

Lesson Plan

Daily lesson plan were developed to guide the teaching of Basic science and technology in the treatment group using peer collaboration strategy. Conventional lesson plans were also planned for teaching the students in the control group. These lesson plans were based on the contents to be covered in the study and the objectives as indicated in the curriculum. These lesson plans highlighted the objectives to be achieved, the instructional materials, strategies, entry behaviour, the teachers, activities, learners, activities and the evaluation techniques. These lesson plans were designed for the six weeks period of treatment. There are 12 lesson plans in all, six for treatment group and six for control group. Each lesson plan covered one week. To ensure the usefulness of the lesson plans in achieving the desired objectives, they were given to experts in science and technology education for review, criticism and suggestions for further improvement. Their comments and inputs were used in providing the final form of the lesson plans. To further determine the suitability of the lesson plan in achieving the desired purpose, it was subjected to field trial using sample from outside the study area. Observations made during the field trial helped in improving the lesson plans. However to ensure effective implementation of the study programme, the class teachers that used the two set of lesson plans were trained by the researcher.

Experimental Procedure

On the first day, before the lesson commences, the BSTAT pretest were administered to both the experimental and control groups after which proper teaching commenced by using the prepared lesson plans. The pre-test helped to ascertain the subjects, level of Basic science and technology achievement and interest before the experiment and to determine how equivalent the two groups were before the treatment. The teacher for each group was supervised by the researcher during the teaching process to be sure they did not deviate from the prepared lesson procedure. Each lesson lasted for 70 minutes and the treatment lasted for 6 weeks. At the end of the treatment, a posttest was administered on both groups with the BSTAT; the scores obtained from both groups were compared to determine if there is any significant difference in the performance of the two groups. The data collected was used for further analysis; therefore they were collected and kept under the custody of the researcher.

Method of Data Analysis

Data collected for this study were analyzed using mean and standard deviation to answer all the research questions. The null hypotheses were tested using Analysis of Covariance (ANCOVA) at 0. 05 level of significance.

RESULTS

The results of data analysis were presented according to the research questions and hypotheses that guided the study.

Research Question One

What is the influence of peer collaboration strategy on pupil's academic achievement in basic science and technology?

Table 1: ***Mean Scores and Standard Deviation of Experimental and Control Groups in the Academic Achievement Test***

Group	N	Pretest		Posttest		Mean Gain
		$\bar{X}$	SD	$\bar{X}$	SD	
Experimental	79	5.53	4.45	29.83	3.87	24.30
Control	74	5.77	3.88	16.63	2.57	11.14

Result presented on Table 1 show the pretest and posttest means scores and standard deviations of students exposed to peer collaboration strategy and those not exposed. The data show that experimental group had pretest mean score of 5.53 with a standard deviation of 4.45 and posttest mean score of 29.83 with a standard deviation of 3.87. The pretest posttest mean gain score is 24.30. The students in the control group had pretest mean score of 5.77 with a standard deviation of 3.88 and a posttest mean score of 16.63 with a standard deviation of 2.57. The pretest posttest mean gain score is 11.14. The close range in the standard deviations observed in the score of both treatment and control groups showed that their scores were homogeneous. From the data presented, it could be inferred that students exposed to peer collaboration achieved better than those in the control group suggesting that peer collaboration facilitated more students' achievement in basic science and technology than the conventional method of teaching.

Research Question 2

What are the mean achievement scores of male and female students taught basic science and technology using peer collaboration strategy?

Table 2:*Mean scores and standard deviation of Male and Female Students Taught* basic science and technology *in the achievement test*

Gender	N	Pre-test		Post-test		Mean Gain $\overline{X}$
		$\overline{X}$	**SD**	$\overline{X}$	**SD**	
Male	87	5.28	4.90	30.58	6.10	25.30
Female	66	5.87	3.78	28.89	6.79	23.01

Table 2 shows that male students taught basic science and technology with peer collaboration had a mean score of 5.28 and standard deviation of 4.90 in the pretest and a mean score of 30.58 and standard deviation of 6.10 in the posttest making a pretest, posttest mean gain of male students taught with peer collaboration strategy to be 25.30. Female students taught basic science and technology with peer collaboration strategy had a mean score of 5.87 and standard deviation of 3.78 in the pretest and a posttest mean of 28.89 and standard deviation of 6.79 with a pretest, posttest mean gain of 23.01. The close range in the standard deviations observed in the score of both treatment and control groups showed that their scores were homogeneous. With these results male students taught basic science and technology had higher mean scores than female students in the achievement test. Thus, there is an influence attributable to gender on the achievement of students taught basic science and technology.

Research Question Three

What is the interaction effect of treatment methods and gender on students' means interest scores in basic science and technology?

Table 3: Mean Scores of Students on BSAS by Treatment and Gender

Treatment Groups	Gender	N	$\overline{X}$	SD
Experimental	Male	43	30.48	3.78
	Female	36	28.94	4.10
Control	Male	44	17.45	2.89
	Female	30	15.78	3.23

The data presented in Table 3 indicate that male students exposed to treatment using peer collaboration had post treatment mean achievement score of 30.48 and standard deviation of 3.78 while male students in control group had post treatment mean achievement score of 17.45 and standard deviation of 2.89. Female students in the experimental group had post treatment mean achievement score of 28.98 and standard deviation of 4.10 while female students in the control group had post-achievement mean score of 15.78 and standard deviation of 3.23. With this result, both male and female students in the experimental group achieved higher mean achievement score than male and female students in the control group. This suggests that both males and females exposed to peer collaboration consistently benefitted more than those in the control group.

Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

HO_1: There is no significant difference in the mean achievement scores of students exposed to peer collaboration strategy and those not exposed to the strategy in basic science and technology.

HO_2: There is no significant difference in the mean achievement scores of students taught basic science and technology using peer collaboration strategy.

HO_3: There is no significant interaction influence of method and gender on students mean achievement scores in basic science and technology.

Table 4: Summary of Analysis of Covariance (ANCOVA) for Test of Significance between the Mean Scores of Experimental and Control groups in the Achievement Test, Influences of Gender and Interaction Influence of Treatments given to Students and their gender with respect to their mean scores on the basic science and technology Achievement Test

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	6234.423[a]	4	1041.555	33.654	.000
Intercept	2123.123	1	2123.123	284.567	.000
Pretest	148.342	1	148.342	5.871	.381
Group	3994.23	1	3994.23	78.879*	.000
Gender	41.651	1	41.651	1.344*	.071
Group * Gender	59.678	1	59.678	1.114	.251
Error	7841.856	120	50.313		
Total	89947.000	125			
Corrected Total	13416.439	123			

*Significant at sig of F< .05

The data presented in Table 4 shows F-calculated values for mean scores of experimental and control groups in the achievement test, gender and interaction influence of treatments and gender on students' achievement in basic science and technology. The F-calculated value for Group is 78.879 with a significance of F at .000 which is less than .05. The null-hypothesis is therefore rejected at .05 level of significance. With this result, there is a significant difference between the mean achievement scores of students taught basic science and technology with peer collaboration strategy and those taught with conventional method. The F-calculated value for gender is 1.344 with a significance of F at .071 which is more than .05. This means that there is no significant difference between the effects of Gender on students' achievement in basic science and technology. Therefore, the null hypothesis of no significant difference between the effect of gender (male and female) on students' achievement in basic science and technology is not rejected at .05 level of significance. The interaction of treatments and gender has F-calculated value of 1.114 with significance of F of .251. Since .251 is higher than .05, the null hypothesis for interaction influence of treatment and gender is accepted. Hence, there is no significant interaction influence of treatments given to students and their gender with respect to their mean scores on the basic science and technology Achievement Test.

DISCUSSION OF FINDINGS

The results of this study indicate that the use of peer collaboration strategy has a significant influence on students' achievement in basic science and technology. The students taught basic science and technology using peer collaboration strategy performed significantly better than the group taught the same concept using conventional method. This result is in agreement with some earlier research finding on the effect of peer collaboration on students' academic achievement. Studies conducted by Adeoye (2002), Murray, Xin Ma & Mazur, (2009); Samuelsson, (2010) and are supported by the findings of this study. The studies carried out by Samaha & DeLisi (2000) and Ahaneku (2002) confirmed that peer collaboration has positive effect on students academic achievement. This is also in consonance with the works of Fawcett & Garton, (2005). and Ullah & Wilson, (2007)which confirmed that peer collaboration strategy has a great impact on the students' academic achievement. The better achievement of students taught using peer collaboration strategy could have been the consequence of active involvement of the students as they asked questions, exchanged ideas, differed in opinions, discussed, argued and finally arrive at a conclusion by solving the task. The fact that the instruction was conducted in small groups which enabled every pupil to teach, ask, clarify, monitor and summarize instruction may had contributed to the significant influence of peer collaboration strategy on basic science and technology achievement.

The result of this study can be attributed to the fact that peer collaboration offers students equal opportunity of learning and thereby possess a high tendency of bridging the gap between male and female in achievement. Therefore, the non significant difference in the achievement of male and female is attributed to peer collaboration strategy used during instruction. This enabled the active participation of both male and female students as they collaborated in groups sharing and constructing ideas through braining storming and exploration.

The results of this study show that there is no significant influence of gender on the students' achievement in basic science and technology when exposed to peer collaboration strategy. In other words, it suggests that gender is not a significant factor in students' achievement in basic science and technology when taught using peer collaboration strategy. This finding is in agreement with the study conducted by Owodunni (2011) which revealed that gender has no significant effect on achievement when exposed to a reflective inquiry instructional technique; that being a boy or a girl did not directly contribute to any substantial difference in the level of students' achievement. This indicates that the relative influence of treatment was consistent across the two level of gender suggesting that both the male and female students benefit significantly from the peer collaboration strategy instruction. Thus gender was not a factor in the effect of peer collaboration on students' achievement in basic science and technology. However, the finding of the study in respect to gender and achievement contradicts some previous research results. For instance, Anyanwu (2003); Batiku (2002) separately reported that gender has a significant effect on achievement.

CONCLUSIONS

This study has shown that the use of peer collaboration strategy has a facilitative influence on students' achievement in basic science and technology. There is a significant difference in basic science and technology mean achievement scores between students exposed to peer collaboration strategy and those who use conventional method. Gender has no significant influence on students' achievements in basic science and technology when taught using peer collaboration strategy. Thus, gender is not factor in the basic science and technology achievement of students when exposed to peer collaboration. There is no significant interaction effect of treatment and gender on student students' achievement in basic science and technology. The effects of treatment on achievement of the pulps were not as a result of gender.

Implications of the Study

The result of this study has some important educational implications. It has provided an empirical evidence of effectiveness of the use of peer collaboration strategy to build up and enhance students' achievement in basic science and technology. This suggest the need for teachers particularly science and technology teachers to adopt the use of peer collaboration which could be developed in accordance with the prescribed characteristics in peer collaboration strategy.

The fact that peer collaboration strategy was shown to enhance students' achievement in basic science and technology implies that the authors of textbooks for the students should pay proper attention to the teachers and students activities in planning their texts. In other words, the inclusion of teachers and students in activities in the textbooks will create the opportunity of active participation of the learners. Teachers who are the curriculum implementers should use various learning/teaching strategies, like peer collaboration which a beneficial to the students rather than using the strategies which are easy but do not have any positive effect on the students.

Recommendations

Based on the findings and implications of this study, the following recommendations are suggested

1. Teachers should not dominate the lesson; they should carefully guide and expose the students to peer collaboration strategy; they should pay greater attention to students' activities when planning their lessons.
2. School administrators should always keep their eyes on the current teaching/learning strategies; holding seminars, workshop and in-service training for their teachers.

3. Administrators should also make appropriate and regular supervisions in the schools so as to ensure that the teachers are making appropriate lesson plan that will enable the students to actively participate in the lessons.
4. Government and relevant professional associations such as science teachers association of Nigeria should sponsor further research on the efficiency of peer collaboration strategy on the other science subjects.

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INFORMATION AND COMMUNICATION TECHNOLOGY INTEGRATION IN CLASSROOM TEACHING: WHY SOUTH AFRICAN EDUCATORS LACK INTEREST?

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Abstract–Information and Communication Technologies (ICTs) are effective tools for transforming classroom teaching and learning and have a potential to improve outcomes of subjects such as Science, Mathematics and Technology. South African secondary schools remain marginalised in ICTs integration despite various organisations' efforts in equipping schools with information technology equipment. The Department of Basic Education embraces ICTs with the intention of solving problems in the teaching and learning in some subjects. It is becoming clearer that the existing top-down model of ICTs integration is unlikely to achieve intended objectives. Several factors militate against the successful and meaningful integration of information and communication technologies in South African secondary schools. Research indicates that most of the teachers who embrace ICT are aware of its effectiveness in improving classroom practice and are willing to integrate it. However, results on the ground are contrary to what is expected. Teachers in secondary schools with good ICT facilities lack interest in integrating ICTs into their classroom practices. Teachers have failed to take advantage of the opportunities offered by information and communication technology based learning materials to improve their practices. This conceptual paper explores teacher factors that are likely to affect ICT integration in South African secondary schools.

Keywords: information and communication technology, ICT integration, teaching and learning, classroom practice, teaching and learning materials

1. INTRODUCTION

Information and communication technologies include traditional communication equipment such as radio and television, and newer digital technologies such as computers and the Internet (Tinio, 2004). There has been rapid developments in ICTs in recent years and these have opened new horizons in the field of education (Unal, Ozturk, Onsekiz, & Education, 2012). ICTs have emerged as powerful tools for diffusion of knowledge and information. ICTs are recognized as integral components of broader curricula reforms, which will change not only how students learn, but what they learn; altering the organisation and structure of schooling itself. In recent years there has been a significant increase in availability and developments of ICTs based techniques and teaching materials. Research emphasises that ICTs have a critical role of enhancing the quality of education, for example, improving outcomes in subjects such as Science, Mathematics and Technology. Many countries, developed and developing are experiencing some difficulties with the integration of ICTs in education. Most research studies in ICTs have focused on understanding the variables that determine the integration of ICTs into teaching and learning environments. In this respect, such studies have focused on measuring the major variables such as computer attitudes (Albirini, 2006) and computer experience.

Successful teaching depends on teachers being responsive to their students' needs, therefore adopting a range of teaching methods is an important means of engaging, involving and sustaining learning in a varied group of students. The repertoire of strategies available to teachers can be broadened by ICTs which affords them an opportunity to extend their personal teaching styles. This calls for teachers to examine particular ICTs as teaching and learning tools. According to Morrison (1989), the search for a new technology to revolutionalise teaching is not a new phenomenon and it seems that each new technological development for storing and delivering information rekindles the hope of increasing the outcomes more than older media.

Since the turn of the 21st century, there have been high hopes that ICTs could be the possible panacea for most of the problems in classroom teaching. Teachers have always been encouraged to constantly look for new methods of delivering teaching materials, new methods for accessing information, new sources of information to motivate and raise levels of achievements of students (Corbett, 1995). However, there seems to be little or no improvement in the outcome of the education systems as a direct result of ICT integration by teachers. McKenzie (1999) posits that even as schools are busily filling classrooms with computers, a large percentage of teachers remain reluctant, not interested and sceptical in integrating ICTs into their teaching. McKenzie (1999) apportions the blame on the technology professional development of the past decades which the author says were designed by technology enthusiasts with little empathy for reluctant teachers. The argument is that the designers have failed to convert reluctance into enthusiasm and also to address the very real concerns of reluctant teachers. Similarly, Maddux (1993) says that there have been flaws such as lack of clear cognitive development or educational benefits derived from ICT and as a result there is no automatic educational value in the mere exposure to ICTs for the vast majority of learners. Since then, things have changed dramatically in the ICTs field. A variety educational materials and software have been developed to meet some of the teaching requirements; still the majority of teachers in South African schools are still stuck in the traditional modes of pedagogue. What is disturbing is the fact that most teachers are aware of and acknowledge the positive contributions that ICTs can make to teaching and learning, but show no interest or initiatives in integrating ICTs.

This observation deserves scholarly discussions that would establish possible causes of ICT integration apathy by teachers in South African secondary schools. In this paper we explore a number of factors with a view to explain why South African teachers who embrace ICTs lack interest in its integration. The paper reviews literature related to ICTs integration in general and then contextualise to South African secondary schools, working environments, teacher factors and demands made by the Department of Education that may impinge negatively on integration of the technology.

This paper consists of the introduction, research problem, literature review, challenges of ICT integration, discussions of what could be the possible causes of ICT integration apathy and conclusion.

2. RESEARCH PROBLEM

The research problem addressed by this paper is based the question stated below:

- Why do South African teachers who embrace ICTs not integrate it in classroom teaching and learning?

3. LITERATURE REVIEW

3.1 Benefits of ICT integration in teaching and learning

The benefits of ICTs in teaching and learning are well documented. For example, Tinio (2004), Bialobrzeska and Cohen (2005), Hennessy, Harrison and Wamakote (2010) and Buabeng-Andoh (2012) wrote extensively on why and how could teachers adopt and integrate ICTs in classroom teaching. These authors concur that there exist possible pedagogical benefits that secondary schools could derive from the integration of ICTs in teaching and learning. There seem to be a consensus that the appropriate integration of various ICTs could help to increase access to education, strengthen the relevance of education to the increasingly digital classroom, and raise educational quality by helping make teaching and learning into an engaging, active process connected to real life. In South Africa, there has been a rise in the supply of ICT equipment such as desktop computers, laptops and tablets to several schools, all with capabilities of accessing the Internet. One reason for the focus on computers and the Internet is the role that ICTs could play in enhancing learning, especially in the context of recording, processing, storing and sharing information with others (Bialobrzeska & Cohen, 2005). This ICTs' bandwagon is based on previous studies on the impact of ICTs on teaching and learning which conclude that ICTs have an important role to play in education at all levels, although it will not solve all educational problems (Bialobrzeska & Cohen, 2005). The Department of Education (2004) proposed that the integration of ICTs into schools was to take place over three phases projecting that the final phase would be complete in 2013. It was expected that by the end of the integration project:

- All South African schools were expected to have access to a networked computer facility for teaching and learning, and to high quality educational resources;
- All South African teachers and learners were expected to be confident and competent users of ICT, and ICTs would have been integrated into teaching and learning in all schools.

The benefits of ICTs integration can be viewed from two perspectives, namely the conventional and the emerging standpoints. Conventional perspectives base ICTs integration benefits on basic assumptions such as those provided by Bialobrzeska and Cohen (2005) listed below. Through ICTs:

- teachers are able to create interactive classes and make the lessons more enjoyable, which could improve student attendance and concentration;
- images can easily be used in teaching and improving the retentive memory of students;
- teachers can easily explain complex instructions and ensure students' comprehension;
- teachers can individualise and customise the curriculum to match learners' developmental needs as well as personal interests;
- data can be captured and stored for informing data-driven decision making; and
- avenues for collaboration among family members and the school community are enhanced.

Emerging perspectives view ICTs integration on a holistic approach that goes beyond the classrooms' four walls. Briefly, integration of ICTs in classroom teaching:

- Enables information and knowledge to travel faster among learners and further than the classroom where the lesson is held. Current ICTs that support chatting and conferencing overcome the barriers of learning, distance and time. ICTs now significantly improve the accessibility of information and knowledge. The advent use of mobile phones is evident to the potential impact that ICTs can have bringing together learners, teachers and parents. Additionally, distance learning using ICTs offers the potential learning opportunities to previously excluded learners;
- Supports information and knowledge sharing on a large scale. One of the deficiencies of traditional modes of learning is the inability to create environment in which learners can acquire and share information and knowledge. New affordable ICTs are increasingly becoming available making it possible to widen the scope and scale of constructive knowledge sharing and learning among learners;
- Makes available just-in-time information and knowledge for learning for learners. Just-in-time learning is viewed as a highly individualist model of learning which emphasises on learner-control, time and place-independence to information access and functional use of information by learners (Riel, 1998). Ideally, ICTs can enable learners to open up a wealth of information and learning resources either by on-line searching or by using databases or repositories for self-paced learning. This implies that just-in-time learning enables learners to acquire knowledge and skills as they need. It is driven by each learner's need and the content can be customised to meet this end. Most importantly, just-in-time learning takes place at the moment when the learner is going to apply the knowledge and skill, therefore the learner is in an active and ready-to-learn mode (Hake, 1998; Marrs & Novak, 2004; Paulson, 1999). In this context, learning is more likely to occur when the learner needs information, knowledge or skills to apply to the solution of an immediate problem or to complete a task (Riel, 1998). In this regard ICTs provide

teachers with an alternative way of structuring and delivering learning resources and opportunities when learners require them;

- Can reduce learning cost in resource constrained schools when large numbers of learners access the same learning materials at a low cost. This can also extend to the reduction of costs of textbooks which need to be replaced annually when they get outdated or torn. Electronic copies of recommended books can be provided on hand held mobile devices and desktop computers (Melita, 2012).

3.2. Factors affecting the ICT integration in classroom teaching

There have been high expectations that by equipping schools with ICT equipment, teachers would automatically integrate ICTs into classroom teaching. This notion is supported by Chigona, Kayongo and Kausa (2010) who argue that the potential of ICTs to enhance curriculum delivery can only be realised when the technologies have been well-appropriated in the school. Such a belief leads to an increase in government or donor-funded projects aimed at providing ICTs to schools. However, this seems to be not working because some basic ICT integration requirements have never been put in place. ICT integration goes beyond mere provision of ICT equipment. Previous research in ICT integration has cited a number of factors that influence teachers' integration of ICTs in teaching and learning. Factors that recur in most of the literature reviewed include teachers' attitudes to technology, teachers' ICT competence, computer self-efficacy, teaching experience, teacher workload, leadership and technical support (Plomp, Anderson, Law, & Quale, 2009; Sherry & Gibson, 2002). These factors have been investigated in previous researches and were found to be crucial in ICT integration. For of this research a brief elaboration each of the factors is given below:

3.2.1 Availability and accessibility

Top of the list of factors affecting integration is the availability and accessibility of ICTs by the teachers and learners in the school (Hennessy, Harrison, & Wamakote, 2010; Riel, 1998). First and foremost, a school should have functioning ICT equipment within reach of all teachers and learning who seek to integrate ICTs in teaching and learning. Secondly, access to ICT equipment and resources in schools is deemed a necessary condition to the integration of ICT in in the teaching and learning situation. Plomp, *et al* (2009) emphasise on this requirement when they say that effective adoption and integration of ICTs into teaching in schools depends mainly on the availability and accessibility of necessary ICT resources. Therefore, in order for teachers to integrate ICTs, the equipment and appropriate software should be available and accessible to them. This paper is based on schools with well-equipped ICT laboratories but teachers are not integrating ICTs into classroom teaching. In view of this, availability is not a militating factor.

3.2.2 Teachers' attitudes to technology

An attitude is usually a disposition or tendency of an individual to respond positively or negatively towards a certain thing such as an idea, object, a person or situation (Abimbade, 2014). Attitudes entail or are closely linked to an individual's opinions and beliefs and are based upon on an individual's experiences. Teachers' attitudes towards technology are regarded as key factors that greatly influence their willingness to adopt and integrate ICTs into classroom teaching. According to Buabeng-Andoh (2012), to successfully initiate and implement educational technology in school's program depends strongly on the teachers' support and attitudes. Teachers who perceive that ICTs integration can fulfil their needs and those of learners are likely to adopt and integrate ICTs in their teaching (Hennessy et al., 2010). However, teachers' attitudes of ICTs dominate their perceptions of the usefulness of the use of ICTs. Teo (2008) established that teachers were more positive about their attitude towards computers and intention to than their perceptions of the usefulness of the computer and their control of the computer. Most of the teachers in South African secondary schools seem to have positive attitudes to ICTs and still they do not integrate them into their everyday classroom teaching and learning. This seems to suggest that teachers' attitude is not a key variable in the lack of interest by South African teachers. Huang and Liaw (2005) also argue that teachers' attitudes towards technology influence their acceptance of the usefulness of technology and its integration into teaching.

3.2.3 Teacher's ICT competence

Regardless of the quantity and quality of technology available in classrooms, the key to how ICTs are used is the teacher; therefore, teachers must have the competence and the right attitude towards technology (Kadel, 2005). Competence is defined as the ability to combine and apply relevant attributes to particular tasks in particular contexts (Danner, 2013). Competence is the combination of awareness, skills and attitude that enables an individual to perform a task to the standard required for successful job performance (Zorba, 2011). Computer competency, therefore, refers to ability of an individual to handle a wide range of varying computer applications for various purposes (Tondeur, Valcke, & van Braak, 2008). An ICT competence describes what a teacher should know to be able to use technology in his/her professional practice (Danner, 2013). In this regard, teachers' computer competency can be an important variable to predict an individual teacher's ability to integrate ICTs in teaching. Research by Kirschner and Woperies (2003) identify a number of major ICT competencies that teachers should have in order to be able to integrate ICTs in classroom teaching. Teachers should:

- make personal use of ICTs that are relevant to classroom teaching and learning such as computers, laptops, tablets, smartphones and Internet;
- master various educational perspectives encourage integration of ICTs in teaching;
- make use of ICTs as minds tools to improve the teaching profession;
- use ICTs as tools for enabling classroom teaching and learning;
- master a variety of assessment paradigms which involves use of ICTs;
- have a clear understanding of the policy dimensions that relate to the integration of ICT for teaching and learning.

Teachers can only integrate ICTs when they have acquired a certain level of ICT competence. Acquisition of ICT competencies demands a lot of time and commitment of which most teachers in South African secondary schools may not have. In South African secondary schools, ICT competency seems to be one of the key variables that lead to teacher's lack of interest in integrating ICTs in teaching. Although teachers may embrace ICTs, their computer competence may hinder their willingness to integrate ICTs.

3.2.4 Teachers' ICT self-efficacy

Many researches emphasise on the importance of an individual's computer self-efficacy. The concept of self-efficacy is central to Bandura's social cognitive theory, which emphasises the role of observational learning and social experience in the development of personality (Kendra, 2008). According to Bandura (1986) self-efficacy is people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances. Self-efficacy measures the belief in one's own ability to complete tasks and reach goals (Bandura & Wood, 1989; Bandura, 1977). One's sense of self-efficacy plays a major role in how one can approach goals, tasks, and challenges (Khorrami-Arani, 2001). According to Bandura's theory, an individual with high self-efficacy, (one who believes that he/she can perform well) is more likely to view difficult tasks as something to be mastered rather than something to be avoided (Kendra, 2008). In the context of computer technology, computer self-efficacy can be defined as a judgment of one's capability to use a computer to accomplish challenging tasks. In light of this, computer self-efficacy can have a major impact on an individual teacher's expectations towards using computers according. Teachers with high computer self-efficacy are likely to use integrate computers in their classroom teaching than those with low computer self-efficacy. Teachers' computer self-efficacy could be a contributory factor in South African secondary teachers to integrate ICTs in their teaching. Teachers may be lacking necessary confidence to integrate ICTs in teaching as a result stick to traditional methods of teaching.

3.4.5 Leadership and technical support

According to Anderson and Dexter (2005) school technology leadership support is a stronger predictor of teachers' use of computer technology in teaching. Without both good technical support in the classroom and whole-school resources, teachers cannot be expected to overcome the barriers preventing them from using ICT (Lewis, 2003 cited in Melita 2012). Pelgrum (2001) found that in the view of primary and secondary teachers, one of the top barriers to ICT use in education was lack of technical assistance.

When ICTs are being used, there are likely to be technical problems that non-technical teachers may face. Such technical problems may include delays in websites to open, Internet connection failures, malfunctioning of computers computer that teachers are not able to deal with. Teachers could be discouraged to integrate ICTs if such problems become perennial and they no technical support offered. Teachers disdain any barriers that disrupt the smooth delivery of the lesson or the natural flow of the classroom activity. Korte and Husing (2007) cited in Melita (2012) argue that ICT support or maintenance personnel in schools tends to help teachers to integrate ICTs in teaching without losing time through fixing software and hardware problems. Without both good technical support in and out of the classroom and whole-school resources, teachers cannot be expected to overcome the barriers preventing them from using ICT (Lewis, 2003 cited in Melita (2012).

3.4.6. Pedagogical skills in ICT integration

Pedagogy refers to the art or science of teaching (Riel, 1998). Lack of pedagogical skills is a crucial accessibility barrier highlighted in many previous studies. Lundal and Howell (2000) studied the use of computers in South African schools and concluded that the problem in schools was not always caused by the lack of resources, but how teachers use the available educational tools in their teaching. This is an indicator that most South African teachers who aspire to integrate ICTs in classroom teaching could be hindered by lack pedagogical skills. Teachers can learn how to use ICTs more effectively when they see the technologies not as generic and decontextualised tools but as tools for teaching, that is, for motivating, managing, facilitating, enhancing, and evaluating learning. When teachers perceive ICT as a tool to meet curricular goals they are more likely to integrate ICT in their lessons (Riel, 1998). While the ICT in Education policy, (Department of Education, 2004) strongly advocates for the pedagogical integration of ICTs assuming that they promote the development of higher-order thinking skills in learners, it is silent about how this would be achieved. According to Bingimlas (2009) schools may be well equipped with educational technological materials but teachers hardly use them because of a lack of pedagogical or skills-related (practical) training in how to use these ICT resources. Teachers' lack of pedagogical skills reduces the integration of ICTs into secondary school education.

When schools are supplied with computers and the Internet, teachers are sometimes trained in basic computer hardware and software. Such training is provided by people outside the education field who are ignorant of the pedagogical needs of teachers. In most cases no pedagogical training is provided. The results of a research by Cox, Preston and Cox (1999) show that after teachers undertook professional development courses in basic ICTs they were still unable to use ICTs in their classrooms; instead they just knew how to run computers and set up printers. The ICT courses provided normally mainly focus on teachers acquiring basic ICT skills and do not teach teachers how to develop the pedagogical aspects of ICTs (Bingimlas, 2009). In order to convince teachers of the value of using ICT in their teaching, their training should focus on the pedagogical issues instead (Cox, *et al* 1999).

Coupled with pedagogical deficiencies, South African teachers face workload and time constraints that impinge negatively on ICT integration. The following subsection discusses the likely effects of large workloads and shortage of time on ICT integration.

3.4.7 Teachers' workload and lack of time

Studies in ICT integration show that teachers' workload has an influence on the teacher's preparedness to integrate ICTs in their classroom teaching. A teacher who has a big workload has insufficient time to contemplate integrating ICTs because they demand more time than normal lessons. Generally, with some encouragement, teachers are inclined to get involved in their personal development if they have less work to do in the classroom (Granger, Morbey, Lotherington, Owston, & Wideman, 2002). Some studies also indicate that many teachers who have competence and confidence in using ICTs in the classroom, still make little use of ICTs due to insufficient time to do this (Franklin, 2007). This time factor makes it difficult for teachers to schedule enough ICT/computer time for every class for teachers who integrate ICTs in their teaching (Bingimlas, 2009). Teachers who want to integrate ICTs are also reported to have insufficient time to plan lessons where they integrate ICTs, explore the different Internet sites, or look at various aspects of educational software (Sicilia, 2005 cited in Bingimlas, 2009). In South African secondary schools, time could weigh down on the possibility of teachers integrating ICTs. This is worsened by teachers' workloads in which they teach have very big classes that make the integration even more complicated. In such circumstances teachers may lack time to take staff development courses in ICTs.

4. CHALLENGES IN ICT INTEGRATION IN CLASSROOM TEACHING

The experience of introducing ICTs in the classroom and other educational settings all over the world over the past decades suggests that the full realisation of the potential educational benefits of ICTs is not automatic (Tinio, 2004). The process of integrating ICTs into the educational system is a complex, multifaceted process involves, getting the ICTs in place (the easiest of all tasks), curriculum and pedagogy, institutional readiness, teacher competencies, and long-term financing (Tinio, 2004). In developing countries such as South Africa, there has been a rush in adopting ICTs in education without enough preparation for teachers. Education departments are always pressured to acquire and force schools to adopt ICTs due to claims of what ICTs can do to aid teaching and learning and also to leapfrog the current stagnant educational development (Balanskat & Blamire, 2007). These activities are undertaken without the departments really understanding the potential and reach of the ICTs, or without having analysed school environments and contexts for appropriateness, applicability and impact. The consequence is that expensive ICT equipment will gather dust in computer laboratories or will be misused altogether. Hawkins (2002) observes that in many circumstances ICTs especially computers are installed in schools around the world without sufficient thought being given to how these computers will be used. This implies that discussions and planning for ICTs in education are driven by a technological imperative with little thought being given to the wider educational context within which the technology is to be used (Balanskat & Blamire, 2007).

5. DISCUSSIONS

- Why is there a lack of interest amongst South African teachers in integrating ICT in classroom teaching and learning

There has been a common misconception that access to ICTs on its own motivates teachers to apply it in their teaching. At this juncture, it has been shown that the availability of ICT resources in South African secondary schools does not guarantee effective implementation without taking into consideration a number of factors likely to make teachers translate willingness into action. The following subsections briefly discuss how key factors explored above are likely to contribute to teachers' lack of interest in integrating ICTs in their classroom teaching in schools where ICTs are available.

5.1. Teachers' pedagogical preparedness to integrate ICTs.

Teachers in schools which are equipped with ICTs lack pedagogical skills to implement ICTs in their classroom teaching. Teachers may have ICT skills to operate computers, mobile devices and search the Internet for information for their own use, but cannot translate this to useful classroom teaching. ICT integration requires teachers to have skills and knowledge on when to use ICTs, how to plan to use ICTs and how to manage large classes in lessons that integrate ICTs. The danger is that inappropriate and poor timing in the use of ICTs in teaching may result in learning outcomes not being attained. Poorly planned ICT integrated lessons may frustrate teachers when it comes to classroom behaviour. Keeping learners focused on tasks can be problematic; instead learners may end up learning how to operate computers instead of learning the subject material. When teachers perceive ICT as a tool to meet curricular goals they are more likely to integrate ICT in their lessons (Riel, 1998; Tedla, 2012).

5.2 Teachers are scared of displaying their ICT ignorance to learners

Teachers are generally sensitive about displaying ignorance of technology to their learners who may have more ICT skills than them. Most teachers, especially the ones who have been in the teaching field for a long time are may not be able use ICTs because of their fear or conservatism, as a result they do not even attempt to acquire new skills. Such teachers prefer to do things the old way because it is familiar and are used to it even if it is not giving them the required results. To them, making a change to their teaching is totally new is not easy and a bit frightening. They fear to even attempt to learn it because they think they will not understand it and that this will cause them to lose face amongst the students and their peers.

5.3 Learners understand technology better than teachers

Learners are always abreast in the efficient use of ICTs in areas outside their education compared to teachers and other adults. This may force teachers to shun ICTs because they think that learners have more ICT skills than them. This may make teachers feel they will look out of place in front of the learners they teach. This lack of confidence lack of confidence makes teachers succumb to their inadequacies. This has a detrimental effect on the integration of ICTs by such teachers.

5.4. Teachers are too busy to integrate ICTs

In South African secondary schools, teachers are always too busy with teaching and administrative work. Teachers have to complete work schedules within set time and also achieve set work targets and pass rates, which is always 100%. Instead of developing and adopting teaching methods that focus developing lifelong skills, they adopt those methods that make it possible for them to finish work with minimum effort. Such methods do not require the integration of ICTs that may require a lot of time and have classroom management issues.

5.5 Piece-meal integration options

South African curriculum does not practically accommodate ICT integration per se but offers piece-meal approaches. Therefore teachers see no need to integrate ICTs if they can achieve the same result through the old methods of teaching. If ICT integration is left to teachers' discretion then teachers choose the method which best suit their style of teaching and their commitment to their job. The Department of Education offers lip service to ICT integration because they seem to have no clue on what it takes to achieve such a feat.

5.6 Problems with learner discipline when ICTs are used in the classroom

Most South African secondary school classes are too big to be handled by a single teacher for a normal lesson. The problem is also compounded by the behaviour of some of the learners who are always difficult to control under normal class conditions. To avoid discipline problems, teachers tend to ignore teaching strategies that will require time in dealing with learners discipline problems. It is difficult to ascertain what learners could be doing during the use of ICTs, therefore, learners may tend to be wayward during the lesson by doing what they want instead of what they ought to do.

5.7. ICT integration demands a lot of effort from the teachers

ICT is an added teaching tool which under normal circumstances should be used by the teachers without giving too much consideration. However, South African teachers seem to lack intrinsic motivation to in taking initiatives to integrate ICTs due to the effort in planning and classroom control required. A teacher who may want to integrate ICTs may have to work for longer hours to plan, prepare and execute the lessons. Most of the teachers do not have time to commit themselves to these unpaid services. With the implementation of work-based pay system, it is highly unlikely that South African teachers could integrate ICTs where their efforts will not be rewarded.

5.8 Theft and vandalism of ICT facilities by learners

Due to behavioural problems in congested classrooms, teachers may face by a dilemma of dealing with vandalism and theft of ICT equipment particularly tablets and laptops. No teacher will want to take the risk of writing reports of equipment vandalism or theft. To stay out of problems teachers would choose to ignore or shun school ICTs.

5.9 Teachers' union have no interest in technology

South African teachers' unions appreciate the role of ICTs in teaching and learning and they encourage schools to acquire ICT equipment. However, they seem to be not proactive in encouraging teachers in the implementation of ICTs in the classroom. Teachers' unions claim that they are committed to quality education, therefore there is a need to actively encourage their members to integrate new technologies to benefit learners.

5.10 Poor Software design

The software used in schools could be based on models of learning which are analogies of the storage and processing operations of computers and does not fit the human learners' needs. This means that using ICT to teach various subjects is being moulded to suit the available software and Internet resources. Crawford (1997) says that to first look at microcomputers would implicitly suggest that we accept machines as the given and then decide how to adapt teaching to their current mode of operations. This makes teachers more sceptical about the effectiveness of ICTs in improving learning outcomes in different subjects. Organisation for Economic Co-operation and Development OECD (2000) says that there is a potential conflict between the principles that inform most software development and that ought to guide development of educational software. In most software design, it is desirable to make the software as intelligible as possible and to demand as little intelligence as possible from the user. Educational applications should be aimed at developing the intelligence of the user. Although teachers may embrace ICTs, they may be not finding any educational value in the software in their schools because the software might be outdated.

5.11 Effects of emerging technologies

The current trends in information technology are rendering the desktop computer unattractive to the new generation of users of ICTs. The advent use of mobile technologies such as smartphones and tablets means that teachers have immediate access to ICT facilities which they use to access from computer laboratories. Teachers no longer go to the ICT laboratory for Internet and other services. Mobile technologies are more convenient to teachers than the traditional desktop computers because they offer instant chatting, especially WhatsApp, and social media networking such as Facebook with great easy. Teachers now spend a lot of valuable teaching time on these social media chatting with friends or gaming. Staffroom are a hive of activities in which teachers share text message, pictures or music clips from the social media. These have no educational value to the learners as long teachers do not integrate ICTs in their teaching.

5.12 Teachers' attitudes towards their own learning of ICTs

An attitude is a positive or negative view of a person about a place, thing or a phenomenon (Ahmad, Said, Zeb, & Rehman, 2013). An attitude is a relational mental state that directs the behaviours of an individual. Teachers are an essential determining factor in the process of education, therefore their positive attitude towards their profession defines the parameters of teaching and learning (Hawkins, 2002; Ahmad, *et al* 2013). Teachers' abilities to perform their duty or get involved professional development courses are affected by their attitudes. Research shows that teachers' who have positive attitudes towards teaching tend to be engaged in professional development that enables them to perform their duties efficiently. Knowledge is expanding rapidly, and most of it is available to teachers and 21students at the same time and this puts an unavoidable burden on teachers to continue updating their skills and knowledge on ICTs (Bitner & Bitner, 2002). Integration of ICTs depends on teacher's competences in ICT uses which can be acquired after several years of professional development. To acquire such competence teachers should have positive attitudes towards their own learning of ICTs. As it stands, secondary school teachers seem to be having negative attitudes towards their own learning of ICTs.

5.13 School authorities are not concerned about ICT integration

Many teachers are reluctant to use ICTs, especially computers and the Internet. Hawkins, (2002) identifies some of the reasons for this reluctance: poor software design, scepticism about the effectiveness of computers in improving learning outcomes, lack of administrative support, increased time and effort needed to learn the technology and how to use it for teaching, and the fear of losing their authority in the classroom as it becomes more learner-centred.

6. HOW TEACHERS COULD BE MOTIVATED TO INTEGRATE ICT

ICT integration in classroom teaching is affected by various variables and as such no single solution could be prescribed. As pointed out in the foregone discussions, it requires a concerted effort from various educational institutions to inspire teachers to be actively involved in the integration of ICTs. However, there are important aspects of ICT integration that could receive first priority towards a holistic approach to ICT integration. There is a great need to make teachers realise that there is a direct link between ICTs and the curriculum for which they are responsible. This implies that teachers need to acquire pedagogical skills in the use of ICT in the context of their subject matter. Teachers could be better trained in the integration of ICTs through school-based and classroom-focused approaches that takes into account the fact that teachers need to learn about emerging technologies. According to Bitner and Bitner (2002) using technology as a teaching and learning tool in the classroom can bring fear, anxiety and concern to a greater extent since it involves both changes in classroom procedures and the use of the often-unfamiliar technologies. Therefore, all fears, anxiety and concerns that teachers have about change induced by ICT integration need to be addressed. Some of the ways could include funding teachers to attend and present in local and international conferences, seminars and workshops. Schools could also make attempts to set up communities of practice amongst the teachers.

7. CONCLUSION

Many factors militate against the integration of ICTs by teachers in South African secondary schools. Secondary schools which have good ICT facilities are not taking advantage of the technology to improve classroom teaching. Research indicates an abundance of ways in which ICT integration could be beneficial to classroom teaching, however, paints a gloomy picture on the lack of interest by teachers in ICT integration. Education authorities and donors are interested in equipping schools with ICTs regardless of the inability of teachers adopting and integrating ICTs. Teachers' lack of interest seems to be pinned mainly on the lack of pedagogical skills in teachers. This paper discussed a number of possible factors that may causes teachers to lack interest in ICT integration.

It is important that teachers see a direct link between technology and the curriculum for which they are responsible. Schools should develop school-based and classroom-focused approaches to teacher training in ICT use that take into account the fact that teachers need to learn about technology in the context of their subject matter and pedagogy.

Teachers' training should help them to differentiate between three types of ICT learning which are learning 'about ICT' which refers to ICT skills, not how ICT can support learning, learning 'from ICT' which refers mainly to a behaviourist view of learning and lastly learning 'with ICT' which refers to a constructive view of learning.

Lastly it is critical for teachers to have an understanding that technology is not replacing traditional classrooms. Fears, anxiety, and concerns that teachers have about change must be addressed. Using technology as a teaching and learning tool in the classroom does bring fear, anxiety and concern to a greater extent since it involves both changes in classroom procedures and the use of the often-unfamiliar technologies (Bitner & Bitner, 2002). Knowledge is expanding rapidly, and most of it is available to teachers and 21students at the same time. This puts an unavoidable burden on teachers to continue updating their knowledge and skills.

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ONLINE SCIENCE PRACTICAL WORK: HOW CAN STUDENTS DO IT?

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Abstract–Many distance students lack relevant expertise, and the requirement to work in an online environment can be a major barrier. A number of challenges continue to affect the teaching of science using the online mode and at a distance. These challenges include barriers such as unavailability of online science practical activities linked to modules. Efforts to come up with innovative programmes to teach science practical work to students who do not have access to face-to-face practical science is essential. Hence this article focuses on the challenges and opportunities with regard to teaching practical work to students studying science at home. Through the lens of the literature, this study explores how online students can engage in scientific processes as they conduct relevant and real-world experiments from online science activities.

Keywords: online, science, practical work, computer simulations, virtual labs

INTRODUCTION

Research shows that teaching online science practical work at a distance is one of the neglected areas and as such it needs to be given special emphasis, since there are many students who do study science practical work at a distance. Undoubtedly, there is a need to construct an effective online learning environment for studying science practical work at a distance.

Even though there are few formal studies on the effectiveness of online laboratories, especially from the pedagogical perspective. New technologies are becoming more reliable and available. As a result, institutions should explore the use of online laboratories and develop more experiments. For example, one upcoming trend is the increased availability of mobile devices and interest in mobile learning. Development in this area offers the possibility of increasing access to online laboratories. With a handheld wireless devise one could literally be almost anywhere and carry out an experiment online. The biggest challenge is for the instructor to monitor if students have done the experiments independently. However, if the technology can allow for the instructor to monitor the online experiments done by students., it would be a step in the right direction. Exploration of new technology will bring the cost of laboratory down to affordable levels. This means that institutions can explore alternative ways to the traditional laboratory. To further reduce the cost, schools and institutions can share the experiments and equipment (Kennephohl, 2010).

In this paper the delivery of online science practical work is highlighted. This paper will focus on the challenges and opportunities with regard to teaching practical work to students studying science at home. These types of students are generally referred to as distance education students. It attempts to address questions relating to the challenges these students face in attempting to do science practical work while studying from home. The question is how distance education students can be empowered to have experiences similar or better than students who have done traditional experiments. At this point, the study reviewed and analysed the literature in order to investigate the possibility of teaching online science practical work to distance education students, as well as benchmarking online modes. The research is guided by the underlying question: Can science practical work be taught online? If so, what are the current strengths and limitations presented throughout literature on the teaching of online science practical work.

The study reviewed literature in order to identify the strengths and limitations of teaching online practical work to distance education science students. Questions regarding the methodological and pedagogical issues associated with the online teaching of science practical work is examined by searching the literature bases, Eric, Science Direct, and professional development collections hosted by WebSPIRS and EBSCOhost accessed via the university's library website. Keywords or phrases including online science practical work, virtual labs, computer simulations and remote laboratories were used.

It is hoped that this article will inform a number of stake holders. These include current teachers teaching science at a distance and future teachers who may assume responsibilities as distance teachers of science. Most importantly, the article endeavours to make an impact on administrators and policy makers so that proper and sufficient resources can be in place for teaching online science practical work.

LITERATURE REVIEW

This article draws from Kennephohl and Shaw's (2010) book entitled *Accessible elements: teaching science online and at a distance*. The challenge of teaching science online and at a distance is very real. A number of these challenges (Kennephohl & Shaw, 2010) continue to affect the teaching of science using online mode and at a distance. Firstly, it is crucial to consider that the concepts and skills that a student must master are numerous, complex and often build on each other. Secondly, science teachers do not necessarily always have sufficient technological know-how or logistical support to create their courses. Thirdly, the literature available specific to online and distance delivery of science courses, especially the laboratory component, has appeared in widely scattered sources. There is little organised pragmatic information readily available in the sciences for distance teachers. Fourthly, science teachers who bring with them very strong disciplinary and research backgrounds often do not have any formal pedagogical training. To develop their teaching skills, these science teachers depend on their own learning experiences, model colleagues, and research the literature. Finally, many science courses consist of a laboratory component, but it is one of the more difficult components to deliver effectively at a distance.

Access to science education and scientific literature is of concern globally. The challenges mentioned imply that innovative programmes to teach science practical work to students who do not have access to face-to-face practical science are essential. Efforts to introduce online and distance delivery can offer practical alternatives to distance education students facing barriers such as classroom scheduling, physical location, financial status, as well as job and family commitments (Kennephohl & Shaw, 2010).

There is a general acknowledgement that teaching scientific inquiry using online mode is difficult. As pointed out by Mosse and Wright (2010) one way of trying to teach science online would be to use computer simulations to illustrate scientific concepts and to introduce experimental techniques. However, only hands- on sessions can ensure that students acquire appropriate laboratory skills. For this reason, many lecturers and teachers avoid experimental sciences. In addition, many distance students lack relevant expertise and the requirement to work in an online environment.

Scanlon, Morris, Di Paolo and Cooper (2002) reported on a range of different ways in which information and communications technologies (ICT) have been incorporated into practical work. For example, ICT has been used effectively for providing collaboration and simulating experimental conditions. As noted above, the use of simulation or virtual science in the place of practical work has increased significantly over the past two decades. Cooper (2005), in comparing simulation and "real" approaches to experimental work, comments on the importance of being in a "real" laboratory and, in particular, the experience of manipulating and handling apparatus. So, one addition to the idea of virtual science extending the range of possibilities offered by technology is that of remote experimentation. This line of work also can include the manipulation or control of real apparatus online. This feature has the particular benefit of allowing students with disabilities to use their computers and the programs they use to control them to, in turn, control laboratory equipment online.

While experimentation is regarded as a fundamental part of the education, Kennephohl (2010) argues that a variety of methods have been employed to address delivery of the practical components online. These include supervised face- to-face sessions offered in a concentrated format on campus or at regional sites, home study laboratory kits, video demonstrations of experiments, as well as interactive computer simulations. There is no correct solution for delivering laboratories for online students and often an assortment of methods are used in concert to overcome the challenge. However, some teachers have now directed their efforts toward allowing students remote access to real experiments via the internet. Even though they are not hands-on, these remote experiments have benefits for both online and on-campus students alike. Scientist also found that remote access is an excellent method for sharing expensive equipment and facilities with other researchers (Kennephohl, 2010).

Remote control over the internet for teaching experiments was first established in the 1990s (Cox & Baruch, 1994, Penfield & Larson, 1996). However, the use of remote access for teaching laboratories in the natural science and physical sciences has not been as common. In contrast, there is an increasing availability and robustness of new technologies which necessitate the use of remote laboratories and remote access being explored by many teachers as a viable method of offering practical experience for the students (Kennelphohl, 2010).

The next sections will explore virtual laboratory in relation to remote laboratories as well as computer simulations.

Virtual laboratory versus remote laboratories

There is a great deal in terms of bringing the student laboratory experience online. This is because of the World Wide Web which offers a wide range of possibilities. One of possibilities is to simulate online laboratory components and thus offer students a virtual laboratory experience. In discussing the role of remote laboratories it is vital to realise the difference between a virtual laboratory environment and remote teaching laboratories. A virtual environment is created through interactive computer simulations of instrumentation and experiments. The role of virtual laboratories can prepare students for a real laboratory environment or, conversely, reinforce concepts from theory or experiments. In contrast, remote access achieves many of the same things as a virtual laboratory, but also allows learners to physically carry out real experiments over the Web. Students can obtain real results using real substances and make real conclusions, just as they would if they were in the laboratory with the equipment. Remote laboratories are a step beyond the virtual realm and their computer generated laboratory simulations. They represent the best alternative to working in a real laboratory (Kennephohl, 2010).

Even though there are variations in the use of remote teaching laboratories they can be employed in four basic ways. Firstly, it allows a student to make observation of natural phenomena or experiments. In remote observations, the observer interaction is minimal and often limited to controlling the camera. Secondly, the student can carry out measurements. Thirdly, remote teaching allows the student to manipulate instruments or physical objects in experiments. In most experiments observation, measurement and manipulation are incorporated in one experiment. For example, a remotely controlled simple ball-drop apparatus used by physics students to determine gravitational constant (g), a steel ball is physically moved to a specific height determined by the student and released (manipulation), the student reads the output from a timer which automatically starts upon the ball's release and stops when the ball passes by an optical sensor (measurement), and the entire process is captured on a Web camera (observation). Lastly, it allows for collaborative work online. Students can share experiments and instruments (Kennephohl, 2010). The idea of using remote laboratories to facilitate collaboration has already been employed to a limited degree by science researchers during these last two decades and is described as col-laboratory (Sonnenwald, 2003). [Spelling here differs from spelling in Biography, please check which one is correct]

Computer simulations

Computer simulations in virtual laboratories have advantages over real laboratory work such as allowing students to do more complicated and hazardous experiments, obtain reproducible results more quickly, and acquire a deeper understanding of the experiments. The importance of the opportunity to do real experiments as opposed to simulations cannot be understated. Since these remote laboratories exist in the physical world with real experiments on real samples, there is also the possibility of operational problems, errors and non-ideal results. Ironically, creators of some simulated experiments put in a great deal of effort incorporating errors into their programs to make them more real and place the learner into a problem-solving environment. Real-life experiments, whether accessed in lab or remotely, seem to do this automatically and we should see this as an opportunity to encourage learning (Kennephohl, 2010).

Computer simulations present theoretical or simplified models of real-world components, phenomena or processes. Examples of these include animations, visualizations and interactive laboratories. A wide variety is freely and commercially available on the internet and in conjunction with textbooks and other print and digital curricular materials. In contrast to multi-user virtual worlds and environments, simulation users are not fully immersed in the computer-generated world for extended time periods. Computer simulations also have a primary educational purpose as opposed to technologies designed to be entertaining yet educational (Smetana & Bell, 2012).

Much of the research on the effectiveness of computer simulations has examined the impact of computer simulations on learning content knowledge in the physical, biological, and earth sciences. The studies reviewed employ a variety of research designs and tackle a range of research questions comparing the use of computer simulations and traditional instructional practices. For example, some studies incorporate multiple simulations covering a variety of concepts, others consider long-term comprehension and still others compare simulations to several other modes of instruction (Smetana & Bell, 2012).

The National Science Education Standards (NRC, 1996) stipulate that scientific literacy involves the mastery of scientific process skills such as observation, inference, and experimentation as well as the ability to combine these skills with scientific reasoning and critical thinking. Computer simulations have been used to teach a variety of science process skills, including visualization, problem-solving, identification, classification, data interpretation, and experimental design (Smetana & Bell, 2012).

Computer simulations can be used in conjunction with the accepted cognitive dissonance model. Intelligibility in computer simulations was consistently established, and aided by features such as symbolic representations and animations. Support provided by the simulation and/or the teacher and classroom environmental factors is critical to success. Studies showed evidence of simulations successfully exposing students' original beliefs. However, findings confirmed the challenge of achieving lasting conceptual change due to the tenacity with which students hold onto original conceptions (Smetana & Bell, 2012).

These studies also demonstrate that specific design features, such as access to supplemental visualizations and textual and virtual information, enhance the effectiveness of computer simulations. Furthermore, allowing the flexibility to explore ideas, as well as prompting students to justify their actions and providing timely feedback, are additional factors that may have promoted learning with simulations. However, there is evidence that students may not take full advantage of these features or opportunities if not given the time, support or encouragement to do so. Similarly, the importance of the teacher in providing guidance and support during simulation use is clearly demonstrated. Additionally, studies suggest that whole-class instruction with computer simulations is a viable option (Smetana & Bell, 2012).

Computer simulations have been shown to be a worthwhile tool for teaching and learning physics, chemistry, biology, and earth science content knowledge, particularly when used in combination with other learning experiences. Computer simulations have demonstrated the advantage of catering to differences among learners and giving them ownership of the learning process. Computer simulations can be particularly appropriate for teaching a variety of scientific process skills, including visualization, classification, data interpretation, problem-solving, and experimental design. The opportunity to practice and apply these skills to novel and/or increasingly difficult situations is an important finding. Additionally, computer simulations have proven effective in revealing and challenging students' alternative conceptions by promoting cognitive dissonance. However, achieving lasting conceptual change has proven equally challenging with computer simulations as with traditional instructional approaches. A more recent shift in the research shows that there is an interest in exploring pedagogical issues regarding the most effective ways to use computer simulations in science instruction. The importance of support, both embedded in the program and provided by the teacher, is a consistent message across the most research reports. So, too, are the benefits of combining traditional and simulated learning experiences (Smetana & Bell, 2012).

As pointed out by Lindgren and Schwartz (2009) interactive simulations are a powerful tool for scientific thinking. They are dynamic, they can be highly interactive, they can scaffold inquiry, they can provide multiple representations, and they can be readily disseminated and incorporated into both industry and classroom settings. This is because simulations are a growing part of the scientific enterprise. A worthwhile goal for science education should be to develop simulation pedagogies that maximize student learning. Thus far, simulation research in science education has been informed largely by the information processing literature, and more recently the socio-cultural literature.

THEORETICAL FRAMEWORK

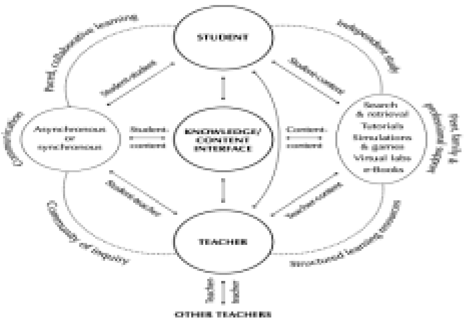

Figure 1.1. Model of E-Learning (Anderson, 2004)

The study is rooted in the model of E-learning as proposed by Anderson (2004). The model illustrates the two major human actors, students and teachers, and their interactions with each other and with content. In the context of this study, teachers refer to online lectures and learners refer to the online students. The model proposes that students can interact directly with content. This content can be found in multiple formats, especially on the Web. In their interaction with the content, students may choose to have their learning sequenced, directed, and evaluated with the assistance of a teacher. The interaction can take place within a community of inquiry, using a variety of Net-based synchronous and asynchronous activities (video, audio, computer conferencing, chats or virtual world interaction). Institutions can provide an environment that is particularly rich with Web-based science activities. The online science students can learn social skills and thus collaborate with other students in the learning of content, and the development of personal relationships with other students. However, the community binds learners in time, forcing regular sessions or at least group-paced learning. Community models are also, generally, more expensive, as they suffer from an inability to scale to large numbers of learners.

Independent learning is very crucial for online distance education students. On the right side of the model, the model illustrates the structured learning tools associated with independent learning. Online students can use tools such as computer-assisted tutorials, drills, and simulations. Most importantly, online science students can make use of virtual labs. In virtual labs, students can complete simulations of lab experiments, and make sophisticated searches and retrieval tools are also becoming common instruments for individual learning. In addition, printed texts can be made available for students for distribution, or alternatively made available online for reading. These can help to convey the teacher interpretations and insights into independent study. However, it should also be emphasised that, although engaged in independent study, the student is not alone. Often colleagues in the workplace, peers located locally (or distributed, perhaps across the Net), and family members have been shown to be significant sources of support and assistance to independent study learners (Potter, 1998).

Using the online model, then, requires that teachers and designers make crucial decisions at various points. A key decision factor is based on the nature of the learning that is prescribed.

CONCLUSION

The rationale for having practical work in the sciences, the role of the teaching laboratory, and its changing nature have been discussed and will continue to be discussed. Making correct links in the institution's Web, students can access the virtual labs and navigate experiments. Having done the experiments, students can send through the experimental reports to the lecturer online. The system should be such that the lecturer can monitor whether the student really did the experiment. The challenge may be that students may not do the experiment on their own.

Even though there is a number of students who study science online, many teachers and researchers still believe that science can only be taught in a face-to-face situation. As pointed out by Jeschofnig and Jeschofnig (2011) one of the differences between online and face-to-face teaching of science practical work is that the teacher cannot physically observe the student in an online class. The teacher may never see their online students in person and may never hear and speak to them. There is no body language to observe and read and no vocal intonation to convey meaning. For face to face, it is possible to look around the classroom or lecture hall to observe students' faces for the purpose of determining whether they understood salient points. However, for an online class it is not that easy.

Science primarily deals with problem solving. As a results not being able to physically observe and interact with students can be an obstacle to the teaching of science. The lecturer may not be able to gauge how well students are following the problem-solving process. It is not possible to see the illumination on students' faces when light bulbs of understanding are turned on or the wrinkled brows and perplexed looks of complete incomprehension. Instead, online science teachers have to prod students to tell them when something is amiss, and they must be extra sensitive to verbal clues of comprehension or confusion in students' lab reports, online discussion board and exam papers. However, given the importance of science practical work, especially for distance education, this review provides valuable information for those teaching science practical online. By reviewing the literature, a foundation is provided for sound methodological and pedagogical practices while attention is still drawn to the limitations and concerns regarding online science practical work.

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STUDENT COMPETENCY AMONG FIRST YEARS LEARNING COMPUTER PROGRAMMING: EXPECT THE UNEXPECTED?

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Abstract–This paper address two issues related to learning an introductory computer programming (CS1) module. Firstly, the learning objectives of an introductory computer programming module relates to the ability of students to learn the fundamental skills needed to code, execute, debug and produce a workable set of instructions written in a computer programming language, such as Java or C#. However, concerns are voiced as to whether students achieve these objectives. Secondly, the paper highlights fundamental computer programming concepts that students have difficulties with. To investigate this, results of a computer programming assessment were analysed quantitatively in terms of code generation, code comprehension and students ability to articulate strategy. The outcomes indicate that although the majority of students demonstrate a basic programming competency, very few students achieve a reasonable level of competency.

Keywords: Computer Programming, Curriculum, Articulation of Code

1. INTRODUCTION

World-wide the number of students enrolling for Computer Science degrees and Information Technology diplomas is falling (deRaadt, 2004). The reason for this may be threefold. Firstly, computer programming is a difficult subject to learn. This is due to students requiring higher order thinking skills, such as the ability of a student to transfer knowledge from one context to another. Secondly, teaching a module that requires students to have such skills is equally challenging. More often than not traditional pedagogical approaches are used with little positive effect (deRaadt, 2008). Educators have to apply alternative pedagogical approaches and "think out of the box" when teaching. This may be difficult for educators to do. Thirdly, psychological studies indicate that it is very difficult for students to become competent computer programmer in a three year degree or diploma (Winslow, 1996), as the time it takes to become a competent programmer requires at least 5 years of concentrated computer programming practice. Such a person would have a range of skills. For example, programmers would be able to trace, describe and generate code as well as successfully transfer their skills from one context to another (Lister, 2011).

This paper investigates which computer programming concepts are easy for students to learn and which are cognitively challenging. The paper also investigates the extent to which students achieve competency. The paper is structured as follows: Section 1 discusses the learning objectives related to introductory computer programming modules. Educators need to reflect on this standardised list and determine whether such objectives can realistically be met. Section 2 provides a background regarding the difficulties faced by students when learning how to become computer programmers. As difficulties also arise from the pedagogical approaches used for computer programming, these are also briefly debated. Section 3 and 4 provide the analysis and findings related to a cohort of students in South Africa enrolled for an introductory computer programming module are discussed. Finally, the paper is concluded.

2. BACKGROUND

This section describes the cognitive tasks associated with computer programming, as well as the difficulties that students face when learning to be computer programmers. It also illustrates that such difficulties arise from the pedagogical approaches used to teach computer programming, as well as the overwhelming curriculum that needs to be completed during a semester.

2.1 Learning objectives for CS1

According to the ACM a computer programmer is someone that is able to describe computer programming concepts, formulate algorithms, and reason about solutions (ACM, 2012). Such solutions are step by step algorithmic instructions, which are written in a format that the computer understands, enabling the computer to act upon such instructions and generate results. Computer programming can therefore be defined as a subject that requires students to solve problems by creating, designing, developing, debugging and revising computer programs. Students enrolled for a computer programming module should be able to:

- Design and analyse algorithms (problem solving);
- Select appropriate paradigms (programming constructs);
- Utilise modern development tools (programming languages); and
- Utilise testing tools (integrated development environments or IDE's).

Although these are very broadly described, they embody the following foundational computer programming concepts used by tertiary institutions world-wide as a curricula guideline for CS1 modules. These concepts are (deRaadt, 2008, Farrell, 2013):

- The development of pseudo code and flowcharts;
- Data and memory;
- Variables;
- Assigning values to variables;
- Operations;
- Modularisation (functions, modules, procedures);
- Calling functions
- Development of functions
- Returning a value from a function
- Debugging;
- Selection (if / else / …);
- Repetition (loops);
- Arrays;
- Java, C# or any other chosen language; and
- Being able to write computer programs using Visual Studio or any other chosen development environment.

These foundational concepts are recommended and used for a CS1 module at a university in Johannesburg, South Africa, as they conform to internationally recognised standards (ACM, 2012). However, due to a number of reasons students pass rates are poor.

Although there are many reasons for these poor results the under-preparedness of students at tertiary institutions is worth mentioning as it describes a broad spectrum of problems. Under-preparedness relates to the credibility gap, societal, cultural and behavioural changes amongst students (Dzubak, 2006). For example, the credibility gap relates to the decline of secondary schooling standards and a sharp incline of distinctions (Jansen, 2012). Societal and cultural changes relate to demographics and trends such as single parent homes, first generation university students and less parent support. Behavioural changes include students who learn visually and are kinaesthetically sophisticated, have short attention spans and expect classroom experiences where they are able to actively participate (Dzubak, 2006). The majority of students within South Africa experience one or more of these challenges. These challenges are compounded by the difficulty of the module.

2.2 Difficulties of CS1

There has been an abundance of research completed regarding the difficulties that students and educators face when teaching-and-learning introductory computer programming modules (Gray, 1993, Matthiasdottir, 2006, Cachia, 2010). Researchers agree that introductory computer programming modules are difficult. These difficulties are due to students' inability to:

- Solve problems (Development-OECD, 2004, Mead, 2006);
- Articulate a problem into a programming solution (Lahtinen, 2005, Garner, 2005);
- Construct mechanisms and explanations (Soloway, 1986);
- Combine syntax and semantics into a valid program (Winslow, 1996);
- Understand larger entities of a program instead of smaller details (Lahtinen, 2005);
- Apply fundamental computer programming concepts (Robins, 2003, Garner, 2005);
- Understand abstract concepts (Lahtinen, 2005);
- Formulate schemas that facilitate categorizing and processing information (Mead, 2006);
- Properly estimate their level of understanding (Lahtinen, 2005); and
- Curricula and the methods used to deliver it, fails to adequately teach students (deRaadt, 2008).

It is therefore well researched that students learning computer programming for the first time experience many difficulties. Many of the difficulties are linked to the content or concepts related to computer programming. The following section analyses which concepts students find the most difficult.

2.3 Pedagogical approaches for CS1 modules

When compared to other disciplines Computer Science and Information Technology are relatively new areas of research. There has only been three decades of active research on the teaching of introductory computer programming, as illustrated in Figure 1.

Although pedagogical approaches to teaching-and-learning computer programming are traditional ones, there are also pockets of innovation. For example, Meyer and Land have devoted extensive research in the area of threshold concepts and troublesome knowledge (Meyer, 2003). Their research is based on the premise that all academic disciplines consist of foundational knowledge which is mandatory for students to learn if they are to become proficient in that discipline. De Raadt (2008) believes that teaching should focus on explicit teaching, as well as the inclusion of strategies and plans, originally pioneered by Soloway (1986). Robins (2012) research investigates students "learning on the edge of what they know". These pockets of innovation have provided opportunities for students to achieve greater success with CS1 modules.

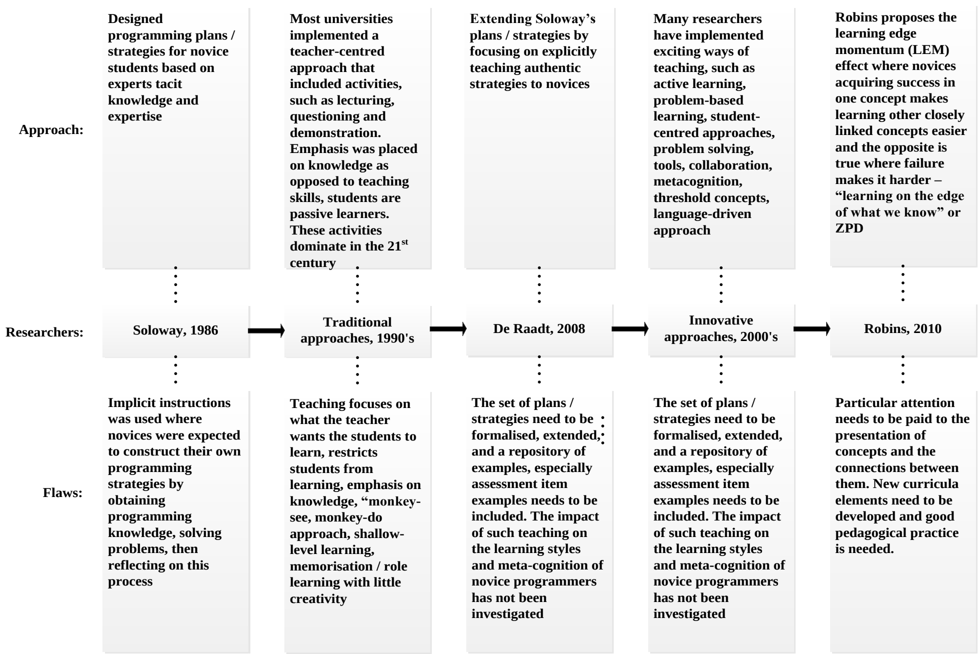

Figure 1: Timeline indicating teaching-and-learning of computer programming

3. METHODOLOGY

3.1 Participants

The study was conducted in 2013 and again in 2014 at a university in Johannesburg, South Africa. In 2013 there were 104 students that participated in the study and in 2014 there were 139 students. During both 2013 and 2014 the students were enrolled for a CS1 module that formed part of a National Diploma in Information Technology (IT).

3.2 Material and procedure

In both 2013 and 2014 the students were assessed weekly. Toward the end of the module, before the examination was conducted, the students were given an end-of-semester assessment to prepare them for the examination. The assessment was aligned to previous teaching-and-learning activities (Herrington, 2013). The students were asked to solve a problem and develop a computer programming solution. In 2013 the problem was based on the following scenario:

A teacher would like to capture test marks for the 30 students in the class. The student marks need to be stored in an array. The solution must provide a menu that allows the teacher to: (a) enter every student's mark; (b) print a report that shows each student's mark; (c) find a particular mark; (d) find the lowest and / or the highest mark; and (e) sort the students' marks into ascending order.

In 2014, the problem was based on 2 questions, namely Question 4 and Question 5. Question 4 was presented to the students as follows:

Given the following problem, solve it by developing an algorithm using pseudo code. Please take note that Appendix A illustrates a number of strategies that you can make use of to assist you in solving the problem and developing the pseudo code.

The All Stars Company decided to increase the salaries of all their employees. Enter the employee number (empNbr), department code (deptCode) and current annual salary for the year (annualSal). The increase in salary depends on the employee's department code, as seen in the following table:

Department Code	*Percent Increase*
AY	*6%*
HT	*6.3%*
KL	*6.9%*
Other departments	*5.8%*

Display the employee number and new annual salary (newAnnual) of each employee. At the end of the program, display the total amount spent on the annual increases (totalAmtInc) for all employees.

Question 5 was presented to the students as follows:

Write an algorithm using pseudo code that will allow a user to enter all 20 different pets in the pet shop into an array (PetArray). The array must be able to print out a list of all the different pets in the pet shop.

Additionally, students needed to ensure that their solutions were error free (compile and execute programs); and that programs were written in such a way that other programmers could easily read the programs (indent code and include comments).

3.3 Analysis and results

Once the assessment had been completed it was individually marked and the students received their assessment results. As illustrated in Table 1, in 2013 the class average was 58%, the highest mark obtained was 98% and the lowest mark obtained was 11%. In 2014 the class average was 76%, the highest mark obtained was 99% and the lowest mark obtained was 24%. The vast difference between the averages in 2013 and 2014 may be due to some of the following changes that took place in 2014:

- Curriculum changes;
- Educational design principles were introduced and implemented;
- Academic development and support introduced (extra 2 hours of support for struggling students); and
- The role of educational problem solving games and puzzles that were introduced.

The pedagogical changes that took place are currently being researched. This research is part of a larger project, namely a PhD.

Table 1: Year-on-year (2013, 2014) assessment averages

Year	Average	Highest	Lowest
2013	58%	98%	11%
2014	76%	99%	24%

3.3. 1 Core computer programming categories

Each student's assessment was analysed to determine which fundamental computer programming concepts were understood and which ones presented difficulties. The analysis was divided into a number of core categories that represented the fundamental computer programming concepts taught universally. These categories can be explained as follows:

- Did the program compile?
- Compiling a program means converting the Java instructions to machine code to enable the computer to "understand" the instructions (Farrell, 2010). As compilation of code is one of the first aspects learnt, it was disappointing to note that only 60% of students were able to achieve this.
- Did students indent their code to increase readability of the code?
- Although not necessary indenting code is good programming practice as it improves the readability of the code when another programmer is reading the code. This was done well as 76% of students indented their code.

- Did the program include comments?
- Comments are descriptive instructions to other programmers reading the code that describe what the program sets out to achieve as well as providing information regarding the author of the code (Farrell, 2013). Additional comments are also included at various sections within the code. Again, it was disappointing to note that only 11% of students included comments.
- Did the program make use of a sentinel value correctly?
- A sentinel value is a variable that controls how many times a loop (repetition) is executed and ensures that the program stops at the appropriate time.
- Did the program declare an array? Declaring an array means providing the programming instructions that inform the compiler that an array is to be used. The compiler sets aside memory locations so that data, such as student marks, can be stored for a period of time (Knox-Grant, 2006). This is a complex concept to understand but students are also able to learn this rote style as the instruction format is fixed. The majority of students, 85% were able to perform this instruction, but it is difficult to interpret their level of understanding regarding arrays.
- Did the program allow the user (in this case the teacher) to enter values into the array? Entering values into an array requires the understanding of a few fundamental programming concepts. Firstly, students must understand and be able to apply the idea of repetition using a loop, such as the FOR loop (Farrell, 2010). Secondly, students must then be able to write the instructions that allow each and every student's mark (using the loop) to be entered and captured into the array. Again, these concepts can be learnt rote style but it is impressive to note that 82% achieved a competency in this area.
- Did the program include modularisation (calling of methods)? Modularisation allows the programmer to develop a section of instructions pertaining to a particular task separately. Modularising code is very useful as it not only allows other programmers to read the program more easily, but it also provides an opportunity for programmers to a module of code, also known as inheritance (Farrell, 2010). Only 47% of students achieved this.
- Did the program allow the user (in this case the teacher) to print values from the array? Printing values from an array requires a very similar process to entering values into an array. Students who understood how to enter values into an array using a loop and the notion of arrays should be able to transfer that knowledge across to print values as the process is very similar. It is interesting to note that students achieved a competency of 69% in this area. This value is far less than the value of 82% for entering values into an array. This is indicative that students learnt the "entering data into arrays" rote style, thus not fuller comprehending the concept, and they were therefore unable to transfer knowledge learnt from one context to another. This confirms the idea that transfer of knowledge from one context to another is difficult for students to achieve (Dann, 2012, Sutch, 2007), even when the transfer gap is relatively small.
- Did the program find the smallest and largest value (in this case the student mark)? Finding a value that forms part of a set of data within an array can be considered to be a complex task. Students are required to have achieved a reasonable competency level regarding selection, repetition and arrays (all of the fundamental concepts related to introductory computer programming). As illustrated in Figure 1 students' competency level in this area was 41% for "find the smallest mark" and 44% for "find a mark". Finding the smallest value does require more logical thinking than finding any value so that is why the one value (find smallest) is slightly lower than the other value (find any).
- Did the program include a sorting algorithm? Sorting values in an array is a difficult process. However, sorting values makes use of standardised algorithms that have been used in the programming industry for decades (Farrell, 2013). It is very common for students to study such algorithms rote style instead of trying to understand the underlying concepts of how the sort algorithm works. Thus, it is not surprising that 56% of students achieved a level of competency in this area.

- Did the program make use of incrementing and accumulating properly? Incrementing is when a variable increases its value, normally by 1. For example, x = x + 1, where x will increase by 1 each time the loop is executed. Accumulating is when a variable is used to accumulate values for a particular purpose. For example, accumulating student marks would be illustrated as total = total + studMark. Each student's mark is accumulated into total.

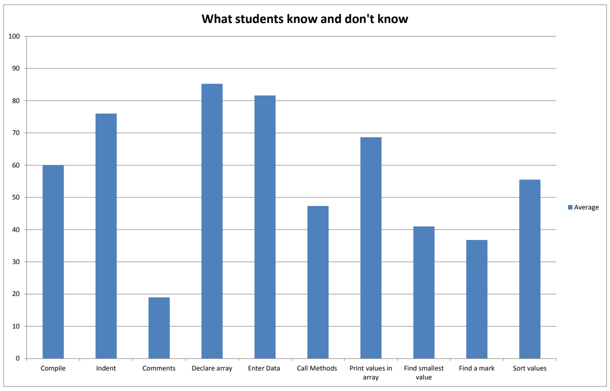

Figure 2: Student competencies for CS1 in 2013

3.3. 2 Results for 2013

As illustrated in Figure 2, it is pleasing to observe that students achieved a competency above 50% for more than half of the fundamental areas related to the curricular of an introductory computer programming module. However, on closer examination of the areas that students were most competent in, it is disappointing to note that these areas either consisted of non-programming skills or programming skills, where students could have made use of shallow learning. Non-programming skills are seen as the soft skills, such as learning how to insert comments, indenting a program and compiling / executing a program. From a programming skills perspective student competencies related to the ability to write programming code that makes use of programming constructs, such as input-processing-output, selection, repetition, declaring an array, entering data into an array, printing values from an array, and sorting values into an array.

Many of these constructs can be rote-learnt. For example, students can learn the code needed to declare an array or to sort values in an array. However, even if students' rote learnt the code, they were able to transfer the learning from one context to another as they had to be able to apply the code to a particular problem. This is encouraging.

3.3.3 Results for 2014

Question 4 consisted of a cognitively demanding problem. Students were expected to understand the problem presented to them, analyse and determine the computer programming constructs needed to develop a solution, and apply the constructs to the problem at hand. Although students were given a generic plan or strategy that could be used to assist them in developing a solution, as illustrated in Figure 3, on the left-hand side, students struggled to develop an algorithmic solution. Less than 40% of the constructs needed to develop the solution were correctly applied by the students. However, Figure 3, on the right-hand side, illustrates that students were able to develop a solution for Question 5. This was probably because the problem presented to them was less cognitively challenging. The general plan that was given to them as part of the question was also very similar to the solution.

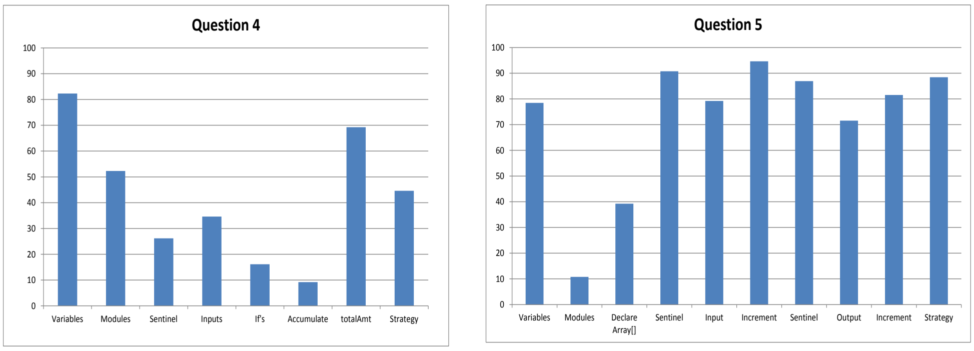

Figure 3: Student competencies for CS1 in 2014

It is interesting to note that students who are unable to achieve a competency of 70% or higher struggle to complete further computer programming modules (Rountree, 2002). Given this value it could be true to suggest in this case that very few of these students have the programming ability to further their computer programming studies and become competent programmers in the workplace. Table 2 illustrates the actual programming skills of students in 2013.

Table 2: Analysis of student competency regarding fundamental computer programming concepts for CS1 in 2013

Programming construct	Achieved below 50%	Achieved 50% or above	Achieved 70% or above
Compile		X	
Indent			X
Comments	X		
Declare an array			X
Enter data into the array			X
Modularise	X		
Print values from the array			X
Find the smallest value	X		
Find a value	X		
Sort values in an array		X	

3.3.4 Pedagogical approach in 2014

In 2014 the approach used to teach students how to develop algorithmic solutions was different. Students were given computer programming strategies that were explicitly taught to them. Teaching a set of computer programming plans and strategies was pioneered by Soloway (1986). A set of computer programming strategies is presented to students, based on experts' tacit knowledge. Students construct programs based on such strategies (Soloway, 1986, deRaadt, 2008). For example, a common concept that students must learn is the idea of "accumulating totals within a loop". Students can be given a computer program (a strategy) that reflects this concept and use the strategy to learn how to "accumulate totals within a loop" themselves. Once the student understands the strategy, it is hoped that they can then adapt the strategy to any problem that requires the same mechanics associated with the strategy.

De Raadt (2008) extended Soloway's work by *explicitly* teaching computer programming strategies to students (deRaadt, 2008). De Raadt also studied experts in the field of computer programming and adapting their tacit knowledge into computer programming strategies. Unlike Soloway, de Raadt researched the importance of *explicitly* teaching such strategies to students. He believes that it is important for students to develop the "*correct*" mental model of a computer programming strategy. Explicitly teaching such a strategy would ensure that students do not develop their own, skewed, mental models of the strategy (deRaadt, 2008). Table 3 and 4 illustrates students' competencies in 2014.

Table 3: Analysis of student competency regarding the assessment - Question 4 in 2014

Programming construct	Achieved below 50%	Achieved 50% or above	Achieved 70% or above
Variables			X
Modularisation		X	
Sentinel value	X		
Inputs	X		
Selection	X		
Accumulation	X		
Calculation		X	
Use of strategy	X		

As discussed, Question 4 was a difficult problem to solve. However, many of the computer programming constructs were fundamental concepts that students had been learning for the first half of the year. They should have been able to complete the task, especially as a computer programming strategy was provided to them. In their defence it could be said that, after 6 months of learning to write algorithms, students possess only fragile knowledge of constructing an algorithm. This study will be repeated at the end of the year to determine if there has been an improvement of skills.

Table 4: Analysis of student competency regarding the assessment - Question 5 in 2014

Programming construct	Achieved below 50%	Achieved 50% or above	Achieved 70% or above
Variables			X
Modularisation	X		
Declare an array	X		
Sentinel value			X
Input values into an array			X
Incrementing values			X
Output values from an array			X
Use of a strategy			X

Table 4 illustrates that students were able to apply most of the computer programming constructs needed to solve the problem given to them in Question 5. However, most students could not declare an array and they found it difficult to modularise the algorithmic solution sufficiently.

4. DISCUSSION

Table 5 illustrates a list of computer programming constructs that students either struggle with, are competent in, or are able to complete with ease. It is of concern that students achieved a competency level of 50% or less on 73.68% of the fundamental concepts related to learning computer programming. Students are only very competent in 26.31% of fundamental concepts. Research indicates that unless a competency of 70% or more can be achieved, students will struggle to learn more advanced computer programming concepts. This is a major problem and obstacle that educators teaching computer programming should be aware of. As students' computer programming knowledge is fragile, i.e. they have minimal expertise after 6 months of learning computer programming, this study will be repeated towards the end of the year (2014) to assess any improvement in baseline skills.

Students should improve as the fundamental concepts taught to them in the first semester (first half of the year) will be taught again in the second semester, in this instance, using a computer programming language, C#. During the first semester students were introduced to computer programming using a problem solving technique, where pseudo code and Scratch were the mediums students wrote algorithmic solutions in.

Table 5: Overall analysis of student competency regarding fundamental computer programming concepts

Programming construct	Achieved below 50%	Achieved 50% or above	Achieved 70% or above
Compile		X	
Indent			X
Comments	X		
Modularise	X		
Variables			X
Modules / functions / procedures / methods		X	
Sentinel value		X	
Inputs into a program	X		
Selection (if/else…)	X		
Accumulating values	X		
Incrementing values			X
Calculations general		X	
Make use of a computer programming strategy		X	
Declare an array		X	
Input values into an array			X
Output values from an array			X
Find the smallest value in an array	X		
Find a value that is part of an array	X		
Sort values in an array		X	
Total number:	**7**	**7**	**5**

5. CONCLUSION

Students studying a computer programming module for the first time face many difficulties related to the content of the module. They struggle to understand computer programming concepts as the content requires students to possess good problem solving skills, analytical and abstract thinking as well as an ability to transfer knowledge from one context to another.

This paper analysed the fundamental computer programming concepts taught to students' during a CS1 module. The results indicate that students' know far less than educators may expect them to know. This means that educators may need to alter the pace at which teaching-and-learning occurs. Alternatively, other pedagogical approaches that include collaborative learning and more time-on-task, many be a better solution and provide the support that students' need in order to understand computer programming concepts better.

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THE EFFECT OF USE OF COMPUTER SIMULATIONS ON ACQUISITION OF SKILLS

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Abstract–The aim of the study was to determine the effect of the use of computer simulations (CS) in geometrical optics on the acquisition of skills with a specific focus on gender. The topic was geometrical optics in physical science. For this study it was decided to focus only on one of the integrated skills that of describing relationships between variables and was used in the context of geometrical optics. The study was based in the rural part of Limpopo Province in South Africa. The research used a switching replications design in four schools with 103 grade 11 learners. When the female learners were compared to the male learners they showed that despite obtaining low scores on the pre-tests, they had the greatest improvements in the post-tests. The findings show the effect of the CS decreasing the digital divide with regard to gender. Studies from other countries that have been using technology indicate that there is no difference in the attainment based on gender however in developing countries this is different (Hyde & Mertz, 2009; Dong & Zhang, 2011). High effect sizes of 0.7 to 1.12 are observed with regard to improvement in the knowledge acquisition, however the skills are the reverse. The use of teachers led to better gains though not significant for the skills acquisition.

Keywords: Computer simulations, Physics Education, skills, Cognitive load Theory, Cognitive Theory of multimedia learning

BACKGROUND TO THE STUDY

The development of skills in physical science is important as it encourages growth in science, technology engineering and mathematics (STEM). The progress in these subjects is essential for the advancement of a nation (Bayrak, 2008).Skills can be cognitive as well as practical (Singer, Hilton, & Scheiwngruber, 2005). Cognitive skills are described as when information is manipulated in the head rather than a practical task. A practical task involves the need to manipulate equipment and normally a site for these to take place like laboratories.

Science process skills can be categorised into two broad categories namely: basic and integrated science process skills (Rambuda, 2002; Kazeni, 2005; Abungu, Wachanga, & Okere, 2014). In this paper, science process skills will be considered as cognitive skills (Özgelen, 2012) and not for the physical manipulation as indicated in the revised Bloom's taxonomy (Pillai, 2013). Basic process skills are observing, classifying, predicting, measuring, inferring and communicating. Integrated science process skills are: identifying variables, constructing tables of data and graphs, describing relationships between variables, acquiring and processing data, analysing investigations, constructing hypotheses, operationally defining variables, designing investigations and experimenting (Rambuda, 2002; Kazeni, 2005; Abungu, Wachanga, & Okere, 2014).

One of the skills namely "Identify and describe variables" is used for the purposes of the study (Department of Education, 2008, p. 8).This is classified as an integrated skill and was used in the context of geometrical optics.

The study was undertaken to determine if computer simulations (CS) would be useful in enabling learners to acquire this skill given the fact that there are more computer laboratories than science laboratories in the Limpopo Province where this study was done(NEIMS, 2009).

In a study in the past decade (2001 – 2010) on the learning effects of computer simulations in science education, strong evidence is provided that computer simulations can enhance traditional instruction especially as far as laboratory activities are concerned (Rutten, van Joolingen, & van der Veen, 2012). They found that computer simulations could be used for better understanding, more knowledge expansion, improved attitude toward the subject and better performance on retention and problem-solving tests (Rutten, van Joolingen, & van der Veen, 2012). This was also found in a study by Smetana and Bell (2012) where they reviewed 61 studies on the efficacy of and implications for computer simulations. Their findings were that computer simulations are as effective as and sometimes even more effective than traditional teaching (using lectures, textbook and physical hands on) in developing science content knowledge, creating process skills and enabling conceptual change.

In addition when learning abstract concepts like electromagnetic fields, students have the opportunity to confront their own conceptions and receive immediate feedback (Dega, Kriek, & Mogese, 2013)

The teacher centred approach was used for this study since it is prevalent and used throughout South Africa (Kriek & Grayson, 2009). It could be prevalent because of the big sizes and ease of reaching the objectives (van Merrienboer, Kirschner, & Kester, 2003; Klahr & Nigam, 2004)This approach is able to give stability and growth in the expected direction and with the challenge of big class sizes it creates stability and learners can be guided (Chukhlomin, 2011). It is easier to reach the objectives (van Merrienboer, Kirschner, & Kester, 2003; Klahr & Nigam, 2004) set out for the lesson and the curriculum unit. Since the teacher is central in guiding the learners it was decided to use the Information processing model. The information processing model, uses cognitive theories of learning advocates for scaffolding, or guidance for learners to perform well (van Merrienboer, Kirschner, & Kester, 2003), desperately needed in specifically the rural areas of South Africa.

In order for information to go the long term memory, it is important that it passes through the working memory; the working memory is limited with regard to how much information units it can process. It is important to determine the appropriate load and is called cognitive load. The cognitive load (Paas, Renkl, & Sweller, 2003; Mayer, 2002) is what will be researched in terms of what and how computer simulations can change the cognitive load especially the load that leads to taking the information to the long term memory. Any teaching strategy that will be able to reduce the cognitive load would lead to gains in learning or ending up in the long term memory (Paas, Renkl, & Sweller, 2003). This study will explore ways to reduce the cognitive load by using computer simulations in the acquisition of a skill in geometrical optics.

AIM OF THE STUDY

It was to determine the effect of use of computer simulations on the acquisition of a skill to grade 11 male and female learners in geometric optics using a teacher centred approach with a special focus on gender.

Objectives

To determine the effect when the computer simulations were used for the acquisition of skill of describing relationships between variables in geometric optics to grade 11 male and female learners using a teacher centred approach.

And furthermore, to determine the effect when computer simulations were not used but the teacher centred approach was used alone in the acquisition of a skill of describing relationships between variables in geometric optics.

THE RESEARCH QUESTIONS FOR THE STUDY WERE:

What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of a skill:

- *with* the use of computer simulations?
- *without* the use of computer simulations?

THEORETICAL FRAMEWORK

Cognitive load theory is based on the Information processing model, and it deals with how what is learned ends up in the long term memory. It can also be referred to as Sweller's Cognitive Load theory (Deschri, Jones, & Hekkinen, 1997; Plass, Hommer, & Hayward, 2009; Zheng, Yang, Garcia, & McCadden, 2008). The information processing model, uses cognitive theories of learning (Mayer, 2002; Paas, Renkl, & Sweller, 2003) as its tenets. The theories which handle how knowledge can end up in long term memory through appropriate instructional strategies are called cognitive theories of learning (Paas, Renkl, & Sweller, 2003; Paivio, 1991). The cognitive load theory can be any of the three components of the load, intrinsic, extraneous and germane. What instruction tries to do is to reduce this extraneous load. If the extraneous load is reduced then the third component, germane load is reduced. Germane load is the good cognitive load which leads to understanding and what is learned ending up in the long term memory. The germane load leads to discrete or disparate knowledge pieces being put together in "chunks" or at times called "schemas" and it would be easy to memorise these since they have connections in the mind. The cognitive load theory posits that once what has been learned ends up in the long term memory then the learner cannot forget at all what has been learnt. It also goes further to indicate that once it is in the long term memory it can easily be retrieved, one does not have to think about it, it is more or less automatic. It is this being automatic that led to the study that if they have committed the information to long term memory then it should be quite easy to retrieve it.

The theoretical framework combines the two theories and the teacher centred approach that was used for the study. It is indicated in Figure 1. The cognitive load and the contribution of the cognitive theory of multimedia learning are indicated.

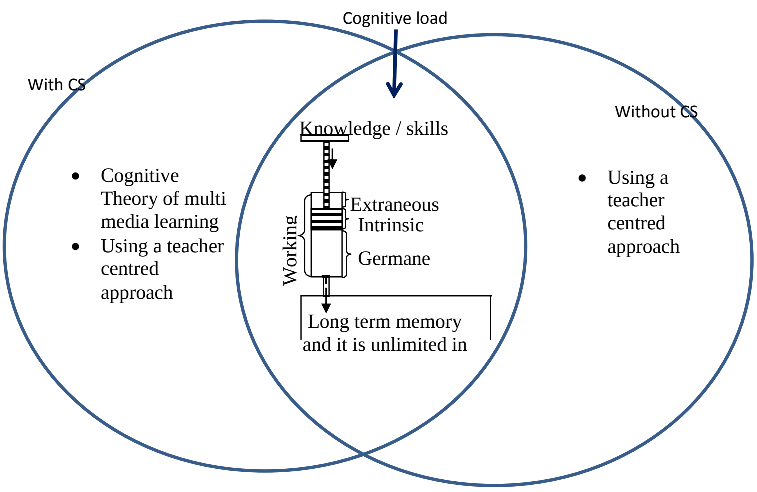

Figure 1: Theorectic Framework (Kaheru, Mpeta & Kriek,2011)

The cognitive theory of multimedia learning contributes to the model in the way that it states the channels in which the learning is processed have a limited amount of information which can be processed. When the information that have to be acquired comes in only a small amount will be given attention (Chou, 1998; Mayer & Chandler, 2001; Muller, Sharma, & Reimann, 2008; Zheng, Yang, Garcia, & McCadden, 2008). The channels that were alluded to in the study were the visual and the audio since the teacher was also talking to complement the computer simulation. The whole scenario is captured in a teacher centred approach at times called traditional approach (Hake, 1998; Schwerdt & Wuppermann, 2011; Taşoğlu & Bakaç, 2010), where what the teacher does is focused on him, he is the main player and he is trying to make sense to the learners of what is happening. In the case where the computer simulations are not used then the teacher tries to use other examples that are in the life of the learners. This study in the big picture studies this and for the particular focus on acquisition of a skill with or without use of the CS as the focus.

RESEARCH METHODOLOGY

Research design*:* A non-equivalent quasi experimental design with switching replications design was chosen whereby learners in four schools took part in the study (Trochim, 2006). It was chosen since we had to work with schools with as little disruption as possible and consequently with intact classes without changing them. The learners participated intact and were not divided differently from what they normally were. For the purposes of the research, it was the same educators in each of the schools who taught the same classes. The number of learners was not made equal but as already indicated it was intact. The timetable remained the same and could not be altered to address the researcher's needs, because the learners had to follow the sequence of topics at the same time allocated as it was prescribed in the "Pace setters". Pace setters is an initiative from the Department of Education of the Limpopo province which prescribe to the teachers what specific content needs to be taught in a specific timeframe and they were not allowed to deviate. The only difference was the use of computer simulations different from their normal classroom situation.

Within the non-equivalent group design a switching replications design (Trochim, 2006; Alexander & Winne, 2006) was used. By design each of the treatment groups had a control built in. The switching replications design was chosen for this study since it increased internal validity with regard to subjects that may have contact with one another, it reduced rivalry (Kothari, 2004). Each group had turns at becoming a treatment and control in the course of the study. The disadvantage of this could be that there could be a continual improvement even after the treatment would have been withdrawn (Trochim, 2006). For the purposes of this research, it was to be presumed that if a treatment was strong enough to even continue after the treatment has been withdrawn then it would mean it had a very strong effect.

N	O	X	O		O
N	O		O	X	O

Figure 2 Switching replications design for research

The N (see Figure 2) indicates that it was a non-random sampling and assigning of the groups. Schools were requested to participate and where they accepted it was decided which school would start as an experimental group and which would be in the treatment group.

The O (see Figure 2) indicates the observations made where a research instrument was used. The instrument was a split timer. To further explain the top line, it can be summarised as OXOO where the three O's in the order they appear are pre-test, post-test1 and post-test2. These tests were the same.

The X (see Figure 2) indicates the use of computer simulations with a teacher centred approach during that period. Where there is just a space between the Os it indicates that no computer simulations were used instead, it was simply a teacher centred approach.

The two lines in which the design is shown are also significant. As shown in Figure 2, if one considers the first arrangements in the top line of OXO and the bottom arrangement of OO it means in the first instance there is a group using computer simulations on top (treatment) and one which is not using computer simulations, the one below. Then the treatment is switched and now the top group is the control of the bottom group.

SAMPLING AND SAMPLING TECHNIQUE

The population was all the grade 11 learners taking physical science in Vhembe district in Limpopo province. The sample of the study was 104 learners in four schools in a district in the Limpopo province in South Africa. There were 50 male and54 female learners. All were in grade 11 with the age ranging from 16 to 20 years old.

The school were chosen using purposive sampling wherein the selected schools were far from each other, and the principal and teachers of physical science were willing to carry out the research. Telephonic communication started the discussions then a site visit followed and a commitment by both the researcher and the participating role players through signing of the willingness to participate

Data collection: The three tests; pre-test, post-test 1 and post-test 2were identical in all respects. The unit was covered in two weeks where after the first week post-test 1 was written and after the second week, post-test 2.

Data analysis: Descriptive statistics based on the gender were used considering the groups taught with computer simulations and those who did not use computer simulations. Independent samples t- test and the paired samples t- test were also used to determine if there was a difference in the samples and also if there were changes as a result of the teaching using the computer simulations (CS) or lack thereof.

Instrument: The Test of Describing Relationships between Variables in Geometrical Optics (TDRV-GO) was developed to collect data to measure the acquisition of the learners' skill of describing relationships among the variables. The instrument had items adapted from the following instruments: a Test of Integrated Process Skills (TIPSII) (Burns, Okey, & Wise, 1985); a Test of science process skills (TISP); and another instrument developed for the local conditions by Kazeni (2005) which also included achievement test items for geometrical optics. There were 26 items in the TDRV-GO instrument. Of the 26 items: 18 questions were on the skill of describing relationships between variables.

Validity of the instrument

The instrument was sent to 2 educators one educator had 19 years of teaching experience in teaching physical science and was a Chief Examiner of physical science, the other had 22 years of teaching experience teaching physical science and was an award winner of the best Mathematics and Physical science Educator of South Africa. It was also sent to a professor of Physics Education, a professor of Chemistry education and a lecturer of science education in 3 different tertiary institutions. They were given the curriculum and the questions and were asked to indicate suitability on a five point scale of the different items. After following their suggestions of inclusion or adjusting the questions, a 26-item question test was accepted.

Reliability of the instrument

The test was paper based and had been found to be valid in the testing of the process skills. The items in this instrument had been tested for reliability in their original forms, with TIPS II (Burns, Okey, & Wise, 1985) having a reliability of 0.86; the reliability using the instrument developed by Kazeni (2005) tested in Limpopo province was 0.81 using the split-half reliability. Coupled with these, there were also questions on content knowledge from tests which were set from the common examinations which were written at the provincial level. They were incorporated in the TDRV-GO

A pilot study with 39 learners was conducted and the instrument was pilot tested. Adjustments were made. The results of the test-retest were analysed and the reliability of 0.83 was established using SPSS version 19.

Teaching in a Teacher Centred Environment with the Use of Computer Simulations
The learners were taught a topic on geometrical optics wherein one of the two groups was taught by the a teacher using the teacher centred approach while the other one was taught by a teacher using computer simulations in a teacher centred environment. The unit on geometrical optics could be conveniently divided into two sections, the first one was on the characteristics of lenses and how images are formed and the associated changes in variables. The associated changes in variables include image distance, object distance, size of the image and objects and magnification. The second section may be categorised as the practical applications to instrumentation or use. How the eye is able to "see", issues of long sightedness and short sightedness; how telescopes and microscopes work and the same related issues as in the first section of the image and object distances and the different heights. The computer simulations were used in each of the different sections but for the different groups.

RESULTS AND DISCUSSION

The following data and subsequent analysis leads to conclusions on how CS affected the acquisition of a skill of describing relationships between variables.

Data and analysis of skills items of Test 1

Independent samples t-test

An independent samples t-test was also used to analyse the skills items of the TDRV-GO. It was noted that there was no significant differences ($p > .05$) between the two groups (See

Table 2Without CS (M = 5.86, SD =1.89) and With CS (M = 6.09, SD =1.80) conditions $t(99) = -0.61$, $p = .54$ and d = 0.13 (small effect).

Table 2: Descriptive statistics for Skills items in Test 1S

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test1S	Without CS	43	5.86	1.89	0.29
	With CS	58	6.09	1.80	0.24

The independent samples t-test and Levene's test indicated that the means were not significantly different, that is to say they were the same with regard to the performance on the skills items in the test and therefore it was assumed that the two groups were at the same level in terms of skills.

Data and Analysis of Skills Items Based On Gender Of Test 1

Independent samples t-test

Given that the homogeneity of variance by the Levene's test, $F(1, 47) = 2.10$, $p = .15$ ($p > .05$) was upheld for the male learners, a test assuming equality of variances was calculated The result of this test indicated that there was no significant difference in the scores $t(47) = -1.19$ and $p = .24$ and d = 0.34 (small effect). These results suggest that the male learners in the group Without CS (M = 6.09, SD =2.02) and the group With CS (M = 6.67, SD = 1.36) conditions were the same (seeTable 3). It is indicated that there was no difference in the two groups of males learners before teaching started.

Table 3: Descriptive Statistics for Skills Items Test1 Based on Gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test1S	Without CS	22	6.09	2.02	.43
		With CS	27	6.67	1.36	.26
Female	Test1S	Without CS	21	5.62	1.75	.38
		With CS	31	5.58	2.00	.36

For the female learners that the homogeneity of variance by the Levene's test, F(1, 50) = 1.73, *p* = .20 (p > .05) was upheld, and a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(50) = 0.07 and p = .94 and d = 0.02 (very small effect). These results suggest that the female learners in the group Without CS (M = 5.62, *SD* =1.75) and group With CS (*M* = 5.58, *SD* = 2.00) conditions were the same. This indicates that there was no difference in the two groups of females before teaching started

Independent samples t-test for Test2S

(a) Independent samples t-test for Test 2S

Given that the homogeneity of variance by the Levene's test, F(1, 101) = 1.40, *p* = .24 (p > .05) was upheld, a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(101) = 1.09 and p = .28 and d = 0.25 (small effect). These results suggest that those in the Without CS (*M* = 6.74; *SD* =2.23) and With CS (*M* = 6.28; *SD* = 2.02) conditions were not different (seeTable 4).The mean of the groups was not significantly different for the With CS and Without CS. This indicates that there was no difference in the two groups after the intervention. It is important to note that the analysis of Test 1 had indicated that the two groups were not different.

Table 4: Descriptive statistics for the Test2 for skills items

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test2S	Without CS	46	6.74	2.23	0.33
	With CS	57	6.28	2.02	0.27

(b) Independent samples t-test based on gender for Test 2S

Given that the homogeneity of variance by the Levene's test, F(1, 48) = 4.40, *p* = .04 (p < .05) was not upheld for the male learners, a test not assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(40) = -0.88 and p = .38 and d = 0.26 (small effect) . These results suggest that the male learners in the group Without CS (M = 6.65, *SD* = 2.42) and in the group With CS (*M* =6.11, *SD* = 1.81) conditions were not significantly different. There was a higher mean for the male learners Without CS. There was no difference in the male groups after intervention.

For the female learners since the homogeneity of variance by the Levene's test, F(1, 51) = 0.10, *p* = .75 (p > .05) was upheld, a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(51) = .66 and p = .51 and d = 0.18 (small effect). These results suggest that the female learners in the group Without CS (*M* = 6.83, *SD* = 2.06) and group With CS (*M* = 6.43, *SD* = 2.22) conditions were not significantly different. There was a higher mean for the Without CS group. There was a small difference in the two groups of females in Test2K for the Without CS and With CS. In both groups despite their having been no differences in the groups the groups that started with the CS (With CS) performed much better than the Without CS.

There was no difference in the female groups after intervention.

Data and analysis of skills items for the Without CS and With CS of Test 3S

(a) Independent samples t-test for Test3S

Given that the homogeneity of variance by the Levene's test, F(1, 87) = 0.56, *p* = .46 (p > .05) was upheld, a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(87) =-0.26, p = .80 (p > .05) and d = 0.06 (very small effect). These results suggest that those in the With CS (M = 6.66, *SD* =1.92) and Without CS (*M* = 6.78, *SD* = 2.27) conditions with regard to skills were the same.

(b) Independent samples t-test for Test3S based on gender

Given that the homogeneity of variance by the Levene's test, F(1, 41) = 0.25, *p* = .62 (p > .05) was upheld for the male learners, a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(41) = -0.75 and p = .46 p > 0.05 and d = 0.24 (small effect) . These results suggest that the male learners in the group With CS (M = 6.65, *SD* =1.77) and in the group Without CS (*M* = 6.19, *SD* = 2.04) conditions were significantly different.

There was no difference in the male groups after intervention

For the female learners since the homogeneity of variance by the Levene's test, F(1, 44) = 0.31, *p* = .58 (p > .05) was upheld, a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(44) = -0.95 and p = .35 and d = 0.31 (small effect). These results suggest that the female learners in the group With CS (*M* = 6.67, *SD* = 2.11) and group Without CS (*M* = 7.37, *SD* = 2.40) conditions were not significantly different.

There was no difference in the female groups after intervention.

Paired Samples t-tests

(a) Paired samples t-test for Test1S and Test2S

Group Without CS

In order to determine if there was a specific change in the performance with regard to the test on skills from the performance from Test1S to Test2S without CS a paired samples t-test was done. There was a significant difference in the scores for the Without CS Test1S (*M* = 5.86, *SD* = 1.89) and the Without CS Test2S (*M* = 6.70, *SD* = 2.20) conditions; t(42) = -2.29, *p* = .03 (*p* < .05*)* and d = 0.41 (small effect)These findings indicate that the group who did not use CS improved the performance on the skill items in the TDRV-GO test.

Group With CS

The paired samples t-test compared the performance on Test1S to Test2S for the With CS. There was no significant difference in the scores for the With CS Test1S (*M* = 6.12, *SD* = 1.79) and the With CS Test2S (*M* = 6.28, *SD* = 2.02) conditions; t(56) = -0.462, *p* = .65 (*p* >.05) and d = 0.08 (a very small effect). These findings indicate that use of computer simulations did not improve significantly the performance on the skill items of TDRV-GO test for the learners. When compared in this way, what emerges is there was a better improvement in the skills as a result of not using CS than the use of CS.

In the first week it can be summarised that CS did not have any effect on the acquisition of skills.

(b) Paired samples t-test for Test2S and Test3S

Group Without CS

In order to determine if there is a specific change in the performance with regard to Test2S to Test3S (without CS) a paired samples t-test was done. There was no significant difference in the scores for the Without CS Test2S (*M* = 6.69, *SD* = 2.18) and the With CS Test3S (*M* = 6.66, *SD* = 1.92) conditions; t(34) = 0.07, *p* = .95 (*p* >.05*)* and d = 0.015 (a very small effect).These findings indicate that use of a CS did not significantly improve the performance from Test2S to Test3S on the TDRV-GO items. There was a very small decrease in the mean from Test2S to Test3S.

Group With CS

The paired samples t-test compared the performance on Test2S to Test 3S for the With CS. There was no significant difference in the scores for the With CS Test2S (*M* = 6.17, *SD* = 1.98) and the Without CS Test3S (*M* = 6.79, *SD* = 2.29) conditions; t(52) = -1.82, *p* = .08 (*p* >.05) and d = 0.29 (a small effect). These findings indicate that the intervention did not significantly improve the performance on the skill items of TDRV-GO s for the learners from Test2S to Test3S.

(c) Paired samples t-test for Test1S and Test2S based on gender

Male group Without CS

This section considered the effect of the intervention with regard to gender.

The paired samples t-test compared the performance on Test1S to Test2S for the Without CS when it was split for male and females. There were four different pairs in all. There was no significant difference in the scores for the Without CS Test1S for males: (*M* = 6.09, *SD* = 2.02) and the Without CS Test2S males (*M* = 6.50, *SD* = 2.37) conditions; t(21) = -0.75, *p* = .47 (*p* >.05) and d = 0.19 (a small effect). These findings indicate that use of no CS for male participants did not significantly improve the performance of the male learners in the Without CS on the TDRV-GO skills items. Cohen's d = 0.19 was a small effect size.

Male group With CS

The paired samples t-test compared the performance on Test1S for the With CS and the Test2S With CS conditions when it was split for male and females. What is considered here is the analysis for the males in the With CS. There was no significant difference in the scores for the With CS Test1S for males: (*M* = 6.67, *SD* = 1.36) and the With CS Test2S males (*M* = 6.11, *SD* = 1.81) conditions; t(26) = 1.43, *p* = .17 (*p* >.05) and d = 0.35 (a small effect). These findings indicate that use of computer simulations for male participants did not improve their performance on the TDRV-GO skill items, actually the performance decreased.

Female group Without CS

The paired samples t-test compared the performance on Test1S for the Without CS and the Test2S Without CS conditions when it was split for male and females This part looks at the female in the without simulations group. There was a significant difference in the scores for the Without CS Test1S for females: (*M* = 5.62, *SD* = 1.75) and the Without CS Test2S females (*M* = 6.90, *SD* = 2.05) conditions; t(20) = -2.71, *p* = .01 (*p* < .05) and d = 0.67 (medium effect). These findings indicate that use of no CS for female participants significantly improved their performance on the TDRV-GO skills items.

Female group With CS

There was no significant difference in the scores for the With CS Test1K for females: (*M* = 5.63, *SD* = 2.00) and the With CS Test2S females (*M* = 6.43, *SD* = 2.22) conditions; t(29) = -1.52, *p* = .17 (*p* >.05) and d = 0.39 (a small effect). These findings indicate that use of computer simulations for female participants did not significantly improve their performance on the TDRV-GO skills items.

(d) Paired samples t-test for Test2S to test3S based on gender

This section will look at the effect of intervention with regard to gender for the Test2S and Test3S.

Male group Without CS

The paired samples t-test compared the performance on Test2S for the Without CS and the Test3S Without CS conditions when it was split for male and females. There were four different pairs in all. There was no significant difference in the scores for the Without CS Test2S for males: (*M* = 6.12, *SD* = 2.32) and the With CS Test3S males (*M* = 6.65, *SD* = 1.77) conditions; t(16) = -0.80, *p* = .43 (*p* >.05) and d = 0.26 (small effect). These findings indicate that use of CS for male participants did not significantly improve their performance on the TDRV-GO knowledge items for the learners, the performance increased but not significantly.

Male group With CS

The paired samples t-test compared the performance on Test2S for the With CS and the Test3S Without CS conditions when it was split for male and females. There were four different pairs in all. There was no significant difference in the scores for the With CS Test2S for males: (*M* = 5.92, *SD* = 1.55) and the Without CS Test3S males (*M* = 6.19, *SD* = 2.04) conditions; t(25) = -0.60, *p* = .55 (*p* >.05) and d = 0.15 (a small effect). These findings indicate that use of no CS for male participants did not significantly increase their performance on the TDRV-GO skills items for the learners.

Female group Without CS
The paired samples t-test compared the performance on Test2S for the Without CS and the Test3S With CS conditions when it was split for male and females. There were four different pairs in all. There was a no significant difference in the scores for the Without CS Test2S for females: (*M* = 7.22, *SD* = 1.96) and the With CS Test3S females (*M* = 6.67, *SD* = 2.11) conditions; t(17) = 1.01, *p* = .33 (*p* >.05) and d = 0.27 (small effect). These findings indicate that use of CS for female participants did not significantly improve their performance on the TDRV-GO skills items for the learners. The performance decreased. It is worth to note that the group was using CS.

Female group With CS
There was no significant difference in the scores for the With CS Test2S for females: (*M* = 6.41, *SD* = 2.33) and the Without CS Test3S females (*M* = 7.37, *SD* = 2.40) conditions; t(26) = -1.86, *p* = .08 (*p* >.05) and d = 0.41 (small effect). These findings indicate that use of no CS for female participants did not significantly improve their performance on the TDRV-GO skills items for the learners, however Test3S was higher than Test2S.

The independent Samples test for Test2S based on gender indicates a decrease in the mean marks when comparing the Without CS and With CS groups. What was favoured in this case was the Without CS except for the female participants though the difference was not significant and the effect size of 0.18 was a very small one when the independent samples t test considered Test2S for the With CS and Without CS.

When the independent samples t-test is used for Test 3S, what is found is Without CS seems to have an edge except where when With CS is considered there is a very small effect size and it was not significant. It is worth mentioning the not using of CS in the second week seemed to help the female participants also since they performed well in the With CS for the 2S to 3S, the effect size of 0.41 is greater than the 0.27 for With CS which was about using CS. With regard to skills the lack of CS seemed to be better than where simulations were used.as indicated by: the independent t-test for 2S: (a) for the case of male (b) paired samples t-test for 1S:2S; 2S:3S in the With CS group; 1S:2S female for the With CS and 2S:3S With CS female.

The instances where the CS led to better effect sizes was: In the independent samples t-test for Test 2S based on gender in particular female where d = 0.18 which is a very small effect size; the paired samples t-test 1S:2S With CS for male, d = 0.35 compared to Without CS , d = 0.19 and also a paired samples t-test for the Without CS male 2S:3S who were using CS in week 2 d = 0.26 compared to 0.19 for the With CS who were not using CS.

The effect of skills on the acquisition of skills when considering the effect sizes ranged from very small to small. It was not significant.

Summary for skills items
The effect of CS or no CS on the acquisition of a skill for grade 11 learners was determined. Gender was also considered. There was no significant difference between the effects of the groups With CS and Without CS and the effect sizes on the effect of CS was small, d = 0.25. The effect size was also a small one of 0.26 for the male learners and on the other hand the female was not significant and it was a small effect size of 0.18.

With regard to the changes as measured by paired samples tests, the use of CS did not improve the results of the learners significantly, with a very small effect size of 0.08. In contrast, for the second week, the group which used CS decreased a little but not significantly with a very small effect size of 0.015. An analysis for the gender indicates both male and female did not improve significantly with a small effect size of d = 0.19 and 0.39 respectively. The items on skills were not affected much by the use of CS.

The results in this section also indicate that the teacher centred approach can increase performance. This is exemplified in the skills area. It is more powerful than the use of CS for the acquisition of skills with regard to the samples considered.

CONCLUSION

This study has found that CS did not improve the skill of *describing relationships between variables in geometrical optics* tremendously, since the effect size was small. The finer analysis indicates that the male learners performed better than the female learners. It is important that further research could be done with other topics but the limitation of teacher centred could mean that skills may better be acquired through interactive engagement. And this could be taken on with further research.

RECOMMENDATIONS

For further research it could be better that a research where there is interactive engagement be performed to determine the acquisition of skills using computer simulations.

In the research being recommended there should also be a differentiation of the female and male learners to determine the effects.

It could be very instructive if there could be research on other physics topics to determine if the same effects would be observed. The research could consider where there could be a teacher centred and also the student centred approach aspects.

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THE STATE OF USING INNOVATIVE TEACHING FOR E-LEARNING IN SOME RURAL SCHOOLS IN LIMPOPO, SOUTH AFRICA

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Abstract–Although the use of computer technologies in schools is taken very seriously by governments and education systems around the world, schools are still battling to use these technologies in classrooms. There is no doubt that educational technologies (computers) as modern technology media are effective didactic tools for improving education attainment, but most teachers neither use these modern educational technology as teaching and learning tool nor integrate technology into their curriculum. There are various challenges at schools for not using the modern media such as computer technologies in classroom. This study investigated the use of ICT and challenges teachers have in using computer technologies as ICT at their school. The participants of this study were 57 teachers from five poor rural schools in Limpopo Province in South Africa. The data were collected using questionnaire. The information in the questionnaire included biographical data, types of media technologies teachers use as statements of challenges as perceived by teachers. The challenges that educators are faced with for not using computer technologies in classroom include: lack of computers at schools; high cost of computers, which supported by that the schools are from poor rural villages; lack of computer literacy training. There is much to be done in the Province schools to effectively use Information and Communication Technologies in the classroom. Support of principals and School Management Team at schools is highly required in order to have computers and use them in classrooms.

Keywords: Computer Technology, Challenges, Computer Literacy, ICT, South Africa

INTRODUCTION

The use of computer technologies in schools is taken very seriously by governments and education systems around the world. South Africa, like many other countries, has developed policy on the use of ICT in education to raise the ICT skills of people and move towards the information society (Trinitas, 2000). This is an indication of the importance being placed on education and training in the use of ICTs and the setting of high priorities to improve teaching and learning outcomes to prepare young people for the information economy of the 21st century. As educational institutions move towards the mainstream use of ICT in teaching and learning there appear to be some critical steps and vital ingredients needed for the successful integration of ICT into school curriculum. Although computer technologies have been in most schools for more than two decades now, educators in many schools continue to grapple with how to use them to enhance teaching and learning environments. Since the development of the first computers many educators (e.g. Bork, 1980; Carnegie Commission on Higher Education, 1977; Papert, 1980) have argued that computers should be used to support teaching and learning. These arguments have increased as computers evolved into relatively low cost technology available today. However, there is still considerable debate over how computers should be used in schools (Riel, 1998). Australia is recognised internationally as an early leader in the inclusion of, and research into, the use of computers in schools.

Any discussion about the use of computer systems in schools is built upon understandings of the connection between schools, learning and computer technology. When the potential use of computers in schools was first mooted, the predominant understanding was that students would be ‘taught’ by computers (discussed by Mevarech & Light, 1992). In a sense it was thought that the computer would ‘take over’ the teacher’s job in much the same way as a robot computer may take over a welder’s job. Collis (1989) refers to this as “a rather grim image” where “a small child sits alone with a computer” (p. 11).

Technology is developed to solve problems associated with human need. If there is no problem to solve, the technology is not developed and/or not needed. Applying this principle to educational technology would mean that educators should create and use technologies that address educational problems, of which there are many. Further, a technology will not be used by educators where there is no perceived need. Therefore, when discussing applications of computer technology in teaching and learning the question must always be asked, "What educational problem(s) needs to be addressed?" (Newhouse, 2002**).**

This question needs to be asked at all levels of decision-making, from the teacher planning a learning content lessons, to a school administrator purchasing hardware and software, to an educational system officer developing policy and strategic plans. At the teacher level the question becomes: "Am I satisfied with the educational opportunities I am able to offer students in school classrooms?" While teachers should never be completely satisfied, and they will always strive to do better, the question really is whether what they provide adequately develops the potential of the students and adequately prepares them for a productive life in society. Many educators (e.g. National Centre for Vocational Education Research, 2002) and educational commentators (e.g. Murdoch, 2001) believe that what is offered in school classrooms in developing countries, is hopelessly inadequate to match the needs of our society and the needs of individual students. Schank and Cleary (1995, p. ix) put this succinctly when they state, "Today's schools are organized around yesterday's ideas, yesterday's needs, and yesterday's resources (and they weren't even doing very well yesterday)." An increasing number of educators (e.g. Schlechty, 1997) are sure that part of the solution is to provide better technology support for teaching and learning environments. Schank and Cleary (1995) argue that we know enough about learning to support it with computer systems, using software that allows students to experience activities, at school, that have been impossible or difficult, in the past. At the school and system levels the educational-problem question becomes whether the resources available to the school are being most efficiently employed to provide the most effective educational opportunities for students. It becomes much more a question of productivity, a balance between inputs (resources) and outputs (learning outcomes). Investing in computer technology means reducing investment in other resources (e.g., books, teachers, buildings). Will using computers provide better learning outcomes than the equivalent investment in those other resources? If so, what level of investment in computers compared with other resources will provide the optimum output? Very few educators and educational commentators would advocate no investment in computers, even if only using a computer literacy rationale. A few advocate an investment that supports almost all education being conducted electronically, particularly online, often referred to as e-learning (e.g. Bonk, 2001). Most are somewhere between these extremes. This paper report on the study that investigated the state of using ICT as well as challenges of educators in using computer technologies in teaching and learning.

RELATED LITERATURE REVIEW

Challenges of using computer technology at schools

With any change come challenges and barriers to change. Computers have been in many schools for some time but several challenges have hindered wide use of them by educators in the educational process. Helping educators change is the key to fostering ICT integration and some researchers have identified educational technology as a catalyst for bringing about educational change, particularly in shifting the teacher's role from one of lecturing (sage of the stage) to facilitator of learning (guide on the side) (Hinostroza & Mellar, 2000). Although many believe that despite new cognitive approaches to learning such as constructivism, education is stuck in the behavioural paradigm of the industrial age. While some teachers cope well with large-scale change, as they enjoy risk-taking and are willing to work with new methods of learning, many teachers are reluctant to change, as they cannot see the value in changing or adopting to the new innovation. Rogers (2000) asset that, understanding where teachers are in terms of their level of ICT literacy is a necessary step in understanding the challenge that prevent and the factors that influence inclusion and integration as each step requires different support and assistance. Such challenges include the lack of funding or budget constraints, teacher training, limited time for teacher planning, lack of support and infrastructure, and lack of vision as to what can be achieved with technology, causing many educators to resist the change. Every educator looks at the integration of technology – and its challenges - from a different perspective. Rogers (2000) classifies the barriers into two categories: internal and external. Internal barriers come in the form of teacher attitudes or perceptions about technology in addition to the person's existing competencies in using these forms of technology. External factors encompass the availability and accessibility of the necessary hardware and software, the presence of technical personnel, institutional support and a staff development program that includes opportunities for skill acquisition and maintenance. For ICT to be effectively adopted into schools, planning is vital. As a part of the planning process, the philosophy, aims, goals and objectives of the school must be used as a guide for the vision, goals and objectives of the technology program (Cole, 1999) with the main focus on the educational needs and skills of the students. Over a decade ago, school technology planning was heavily driven by the technologies, and most often in the form of equipment acquisitions, but today technology plans need to centre on the teaching and learning (Rogers, 2000). Ownership and collaboration with input from key stakeholders increase the potential for successful implementation of ICT into schools. It is important to note that without the vision, appropriate skills, incentives, resources, an action plan and collegiality, change cannot occur without confusion, anxiety, resistance, frustration, or feeling like you are on a treadmill or isolated.

The degree to which teachers will facilitate the use of computers to support learning is determined by a balance of pressures or forces and the presence and size of barriers or obstacles to be overcome. The term forces indicates a resultant action and the term obstacles emphasises the removability. When combined they provide a resultant force that could be considered as a measure of the motivation and 'energy' level a teacher has towards facilitating computer support. The resultant force will determine the extent (both quantitatively and qualitatively) to which a teacher may be likely to implement computer support for learning under ideal circumstances and over a period of time. Forces are fundamentally perceptions in the 'mind' of the teacher that eventually influence actions.

However, these perceptions may be based on external entities such as administrators, parents or students, or may be based on the internal beliefs of the teacher, or a combination of both. Some factors influencing teacher perceptions may be either positive or negative such as the perception of the requirements or nature of the curriculum. For example, one teacher may perceive their curriculum to require the use of computers to provide relevance while another may perceive the opposite based on the requirements of external assessment. Obstacles are external to the teacher. They are those things that could be removed immediately by the actions of another person (although not necessarily) and as a result the teacher would facilitate a higher level of computer support for learning. For example, an obstacle may be lack of access to hardware or software. This would be removed if the school Principal bought more hardware or software. The lack of IT literacy skills by the teacher or student may be a challenge that could be removed by the purchase of easier to use software for the teacher. A lack of time to experiment could be removed by providing a teacher with more time free of teaching. It is sometimes difficult to distinguish between negative forces and obstacles with both representing barriers to increased facilitation of computer support.

Dawes (2001) argues that problems arise when teachers are expected to implement changes in what may be adverse circumstances. It can also be deduced from this view, that if the teachers are expected to effectively integrate ICTs in their practice, they must receive appropriate, thorough training and continuous development on ICT usage in the classroom. Balanskat , Blamire, & Kefala, (2006) also argue that many teachers still chose not to use ICT skills in teaching situations because of their lack of ICT skills rather than for pedagogical or didactics reasons. They also argue that despite teachers' ICT training, there is still a lack of follow-up on the utilization of newly acquired skills (p 50). Balanskat et al (2006) further assert that unsuitable teacher training programs fail to engage teachers in using ICT both during their lessons and also in the preparation of lessons beforehand.

The most commonly mentioned cause of this lack is that the training courses focus mainly on the development of ICT skills and not on the pedagogical aspects of ICT, (p 51).

On the other hand, Altum (2007) argues that the three major factors that need to be solved in teacher education entail: (i) insufficient staff in the area of ICT use in education; (ii) insufficient resources and (iii) lack of research in this field. This view is complemented by Kozma (2008) who stresses the need to develop human resources capable of responding to the demands of the information age and to nature ICT literacy and skills through education.

For effective ICT integration with teaching and learning to be implemented, teachers need not be just computer literate but be specifically well trained and equipped with the know-how of ICT usage in different subject areas within the curricula. It should follow that once teachers are highly competent in their ICT skills in teaching and learning, there will be an increase in the level and quality of ICT usage in education. In this view, BECTA (2004) argue that if training is inadequate or in appropriate, then teachers will not be appropriately prepared, and perhaps not sufficiently confident, to make full use of technology in and out the classroom. The lack of teacher competence, then, together with the associated lack of quality training for teachers, can be seen as a barrier to teachers' use of ICT.

UNESCO (2002) states that with the emerging new technologies, the teaching profession is evolving from an emphasis on teacher-centered, lecture based instruction to student-centered, interactive learning environments. Designing and implementing successful ICT-enabled teacher education programs are the key to fundamental, wide-ranging educational reforms. Teacher education institutions may either assume a leadership role in transformation of education or be left behind in the swirl of rapid technological change. For education to reap the full benefits of ICTs in learning, it is essential that pre-service and in-service teachers are able to effectively use these new tools for learning. Teacher education institutions must provide the leadership for pre- and in-service teachers and model new pedagogies and tools for learning.

It can be concluded that the existing professional development programs on ICT usage are inadequate. UNESCO (2002) assert that teacher education institutions also need to develop strategies and plans to enhance the teaching-learning process within teacher education programs and to ensure that all future teachers are well prepared to use the new tools for learning. The need for teacher training on ICT usage in their practice cannot be underestimated. All stakeholders need to be given adequate support as they adopt ICT in their daily practice, (Aceto., Delrio, & Dondi, 2006).

It can also be maintained that the training should be of high quality, new technologies for teaching and learning must be offered, educators must be involved in important context activities and teamwork among educators must be encouraged. Teachers may adopt and integrate ICT into their teaching when training programs concentrate on subject matter, values and technology.

Many studies using various research methodology has been conducted and different findings of challenges ranging from lack of computer literacy and training, lack of time; lack of appropriate pedagogies and philosophies; beliefs; lack of resources and so forth were identified. This paper report on case study which investigated the state of implementing e-learning, in particular focusing on the challenges the schools at rural areas in Limpopo Province experience.

THE PURPOSE OF THE STUDY

The study investigated the use of ICT and challenges teachers have in using computer technology at five rural schools in Limpopo province, South Africa.

METHODOLOGY

The study was a case of five schools in Limpopo Province. The participants of this study were 57 teachers from rural school in Limpopo province in South Africa. The data were collected using questionnaire. The information in the questionnaire included biographical data, types of educational technologies used, and statement of challenges in using ICT at schools.

THEORETICAL FRAMEWORK

The research was grounded on the theory of Diffusion of Innovations (Rogers, 2003). Rogers argues that diffusion research has its focus on the conditions which increase or decrease the likelihood that members of a given culture will adopt on a new idea, product, or practice. He argues that people's attitudes toward a new technology are a key element in its diffusion. ICT integration is a technological innovation in education. Rogers believes that the implementation of an innovation is just one phase of a five-stage diffusion process. Diffusion here means "the process through which an innovation spreads via communication channels over time among the members of a social system", (Rogers, Medina, Rivera, & Wiley, 2003). Rogers' theory explains how innovation is communicated to the would-be innovators in five stages, namely, knowledge, persuasion, decision, implementation, and confirmation. *Knowledge* requires exposure to the innovation and understanding how to use it. *Persuasion* refers to the development of a positive attitude toward the innovation. *Decision* refers to the commitment to its adoption. *Implementation* is putting the innovation to use, whereas *confirmation* refers to the reinforcement resulting from the desired outcomes. Rogers' diffusion of innovation theory was suitable for the study of the integration of ICT with teaching and learning in these schools as it allowed the researcher to investigate how teachers, learners and SMTs interacted with ICTs to enhance teaching and learning. The study investigated the degree of each school's exposure to ICTs and their understanding of how to use these powerful tools *(Knowledge Stage)*. Although all the five stages of Rogers' theory of diffusion are explained, this study used only three of them (Knowledge, Implementation and Decision stage). The results of challenges in using ICT for teaching and learning also showed lack of training in computer literacy as an indicator of knowledge stage according to Rogers theory of diffusion (table 3). This study also investigated the use of different ICT at schools, and the results are shown in table 2. This aspect is underpinned by Rogers' theory of Implementation, to understand the extent of educational technology implementation at schools. Although this study did not investigate ICT policy awareness and its implementation the issues of decision making by SMT at schools is implicit in the use of ICT at schools (Decision stage).

RESULTS

Table 1: Profile data of educators

Gender	Frequency	Percentage	Total	
			frequency	Percentage
M	25	43.9	57	100
F	32	56.1		
Current position	**Frequency**	**Percentage**		
Teacher	45	78.9	57	100
SMT	10	17.5		
Principal	2	3.5		
Years of service	**Frequency**	**Percentage**		
1-5	12	21.1	57	100
6-10	17	29.8		
11-15	12	3.5		
16-20	13	22.8		
21-25	9	15.8		
26 and above	4	7.0		
Age group	**Frequency**	**Percentage**		
26-29	7	12.3	57	100
30-35	3	5.3		
36-39	9	15.8		
40-45	21	36.8		
46 and above	17	29.8		

Table 1 shows that most of the participants (78.9%) were teachers in the classroom, and the rest were either School Management Team (SMT) such as head of department (17.5%), and principal (3.5%). The fact that most participants were teachers was relevant, in that computer technologies at schools are used by teachers to amplify learning and teaching for better understanding and meaning making (Newhouse, 2002). Many teachers have argued that computers should be used to support teaching and learning (Bork, 1980). There were not huge differences in years of experiences, except that more teachers (29.8%) were from the 6-10 intervals. Less than quarter (22.8% and 21.1 %) of teachers were in the interval of 16-20 and 1-5 years of experience respectively. The information in table 1 shows that less than half of participants (36.8%) of teachers were in the age interval of 40-45, while just above a quarter (29.8%) of them were in the age interval of 46 and above.

EDUCATIONAL TECHNOLOGY USAGE AT SCHOOLS

Table 2: The use of educational technologies at schools

NO	Types of technology media	Used		Not used		Missing		Total	
		Freq	%	Freq	%	Freq	%	Freq	%
1	Computers are used as teaching media at our school	8	14.0	49	86.10			57	100
2	Radios, tape recorders are used as teaching media	2	3.5	55	96.5			57	100
3	Power point and projectors integrated the teaching and learning	9	15.8	48	84.2			57	100
4	Television sets are used as learning resources	12	21.1	44	77.2	1	1.8	57	100
5	Videos are used as teaching aids to assists learners who learn by seeing	12	21.1	45	78.9			57	100
6	There is access to internet at our school	9	15.8	48	84.2			57	100

Table 2 indicate that most of participants (86%) do not use computers their schools. It is also interesting to find that almost all the types of media technologies were not used, including conventional media technologies such as television, radios, and tape recorders. The participants shows in Table 2 that they do not use the following educational technologies: (1) 96 % do not use radios, tape recorders; (2) 84.2 % do not use power point and projectors; (3) 77.2 % do not use television sets as a learning resources (4) 78.9 % do not use videos as teaching aids (5) 84.2 % do not have access to internet at school.

CHALLENGES OF USING ICT

Table 3. Teachers responses on challenges they have in using ICT

NO	Item	Agree		Disagree		Missing		Total	
		Freq	%	Freq	%	Freq	%	Freq	%
1	Our school lack literate teachers in ICT to offer CAT subject	30	52.6	24	42.1	3	5.3	57	100
2	There is a lack of computer technology in our schools	40	70.2	15	26.3	2	3.5	57	100
3	Irregular power supply hinders the use computers in schools	26	45.6	29	50.9	2	3.5	57	100
4	The cost of purchasing computers is high	36	63.2	18	31.6	3	5.3	57	100
5	There are inadequate facilities to support full use of the information and communication technology	39	68.4	16	28.1	2	3.5	57	100
6	The non-inclusion of ICT programmes in teachers training curriculum affects its adoption in schools	39	68.4	13	22.8	5	8.8	57	100
7	Teacher are very reluctant to adapt to use of ICT in teaching and learning process	17	29.8	38	66.7	2	3.5	57	100
8	Lack of fund hinders school from embracing ICT	41	71.9	14	24.6	2	3.5	57	100
9	There is fear of exposing to much information on the institution to the public	17	29.8	38	66.7	2	3.5	57	100

Table 3 illustrate that 52.6 % of participants agreed that they lack literate teachers in ICT and CAT at their schools. Over two third (70.2%) of participants agreed that they lack computer technologies at their schools. Less than half of participants agreed that irregular power supply prevent them from using computers at schools. More than half of participants (63.2%) agreed that the cost of purchasing computers are high. Most of educators (68.4%) agreed that there are inadequate facilities to support full use of ICT. More than half of educators (68.4 %) agreed that the non-inclusion of ICT programmes in teacher training curriculum affects its adoption in schools. Almost two third (66.7%) of educators disagreed that teachers are very reluctant to adapt ICT in teaching and learning process. Most educators (71.9 %) agreed that lack of funds hinders them from embracing ICT at schools. Almost two third (66.7%) disagreed that there is fear of exposure to ICT to the public.

VALIDITY OF THE STUDY

Merriam (2001,) argues that the validity of a study depends on the extent to which its results are trusted. Lincoln & Guba (1985,) maintain that the validity of the data raises the question how can an enquirer persuade his or her audience that the research findings are worth paying attention. Validity in relation to research is a judgment regarding the degree to which the components of the research reflect the theory, concept, or variable under study (Streiner & Norman, 1996). The validity of the instrument used and validity of the research design as a whole are important criteria in evaluating the worth of the results of the results conducted. The content validity of this study is confirmed by variables that are adapted from other studies which measured similar variables. External validity refers to the extent to which the results of the study can be generalized to the larger population (Polit & Hungler, 1999). The results of this study cannot be generalised to other larger population unless used in similar limited context.

DISCUSSIONS OF FINDINGS

The findings of the study as shown in table 1 confirmed that most schools still know old types of conventional media technologies which were also not used, i.e television, radios, and tape recorders. The findings of this study shows that most teachers at schools are not using modern technologies for teaching and learning. These findings are not different from the findings of Al-Zaidiyeen, Mei and Fook (2010), who investigated the levels of ICT use by rural secondary schools teachers, and found that ICT are only rarely used for educational purposes by teachers. Their findings revealed that the level of ICT use varies from teacher to teacher, and the majority of participants had very low level of ICT use for educational purposes. In another study conducted by Pelgrum and Plomp (1993) on how computers are used by teachers, they also found only a small number of teachers were using ICT as an integral part of teaching process. The findings of this study and other related studies are supported by Rogers' theory of diffusion (1995) in terms of relative advantage being prevented the ICT use by teachers. Teachers are more likely to incorporate ICT use in their classroom if they see its relevance to their instruction and are convinced that the design of education software is compatible with educational goals and the individual learning needs of students (Williams, Boone & Kinsley, 2004). New educational technologies should replace the traditional media (radio, tape recorders) in the 21st century, and shape our culture (Lin, Li, Deng and Lee, 2013). According to Mikre (2011), failure to use modern educational technologies for pedagogic purpose would further widen the knowledge gap and deepen the existing economic and social inequalities among the developed and the developing countries.

Participants of this study were requested to agree or disagree with statements which reflected challenges of using ICT at their schools, as shown in table 3. Over two third (70.2%) of participants agreed that they lack computer technologies at their schools. This is not different from other studies who found that lack of computers and software in the classroom could be a serious challenge for teachers to use ICT in the classrooms (Mumtaz, 2006; Makgato, 2012). Less than half (45.6%) of participants agreed that irregular power supply prevent them from using computers at schools. This result is in compliance with the study of Abass and Ayo (2013) who found that 78% of participants agreed that power failure at the school hinders them from using ICT effectively. More than half of participants (63.2%) agreed that the cost of purchasing computers are high. Most of educators (68.4%) agreed that there are inadequate facilities to support full use of ICT. More than half of educators (68.4 %) agreed that the non-inclusion of ICT programmes in teacher training curriculum affects its adoption in schools. The results of this are not different from that of Makgato (2012) where almost half of the respondents (52%) agreed that they did not receive training to use technology in the classroom. Several studies also found that relevant computers literacy and training is an important predictor of technology use in the classroom (Oliver, 2002; Ezziane, 2007). This is also agreeing with Newhouse (2002) who found that although computers technologies have been in most schools for more than two decades now, educators in many schools continue to grapple with how to use ICT to enhance teaching and learning environments.

Just above two third (66.7%) of educators disagreed that teachers are very reluctant to adapt ICT in teaching and learning process. Most educators (71.9 %) agreed that lack of funds hinders them from embracing ICT at schools. Lack of funding or budget constraints and support and infrastructure are common challenges for not using computer technology at schools (Newhouse, 2002). Almost two third (66.7%) disagreed that there is fear of exposure to ICT to the public.

CONCLUSION

This small scale study shed some light in the use of educational technology as well as challenges of using ICTs in the classroom. Majority of educators in this study said that they have no computers at schools to use, hence they are not using them in classrooms. It is not surprising because the schools are situated in deep rural villages. There is a need for all stakeholders to embark on a massive supply of computers at these schools. It is also clear that teachers need sufficient training and time to empower them in using computer technologies in the classroom. Although countries and research has reported on the importance of computer technologies in proving teaching and learning very few schools are using these technologies in classrooms. There is much to be done in this country schools to effectively use technologies in the classroom. Support of principals and SMT at schools is highly required in order to have computers and use them in classrooms. Since this was limited scope of investigation further research is required at a large scale to ascertain the extent of problem in using ICT in schools.

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TOWARD AN AUTHENTIC SET OF PROGRAMMING STRATEGIES FOR TEACHING-AND-LEARNING COMPUTER PROGRAMMING

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Abstract–Computer programming is a very difficult subject to teach and learn. Consequently, over the last few decades much research has taken place within the discipline of teaching-and-learning computer programming. This paper focuses on whether explicitly teaching a set of authentic computer programming strategies to first year students learning a computer programming module improves their algorithmic skills. It also aims to establish whether students are able to develop a vocabulary for programming strategy dissemination so that educators and students with such a vocabulary can discuss learning strategies. A quantitative as well as a qualitative analysis was conducted. The results indicate that explicitly teaching a set of authentic computer programming strategies, determined by expert programmers, can provide students with a mental model associated with generic algorithmic solutions. This may provide students with a baseline on which other algorithmic, pseudo code and computer programming solutions can be built.

Keywords: computer programming, computer programming strategies, explicitly teaching strategies

1. INTRODUCTION

Computer programming is a unique discipline to teach and learn, as students often enter tertiary institutions unprepared for the cognitive demands of computer programming (SpeakComputerProgramming, 2012). Unless a student has studied Information Technology (IT) as a subject at school, students enrolled for a computer programming module commence the module with no mental model or prior knowledge regarding the rigour of computer programming (Cutts, 2006). Research indicates that even if students have achieved an above-average mark in mathematics, this is not an indication that such students will achieve good results when completing a computer programming module (Fincher, 2005). Given that computer programming is demanding and students are often unprepared for such a discipline, the challenges experienced by educators and students alike are unique and may require unique solutions.

This paper describes a study in which the researcher developed a set of computer programming strategies to assist students in developing a mental model to plan and design of algorithmic solutions. The computer programming strategies were explicitly taught to students as research indicates that explicit teaching of such strategies achieves superior results over implicit instruction (deRaadt, 2008). The paper is structured as follows: Section 2 provides a background of computer programming as a discipline. Section 3 describes previous research regarding teaching a set of computer programming strategies. As teaching students computer programming strategies can achieve superior results, Section 4 introduces computer programming strategies taught at a university in Johannesburg, South Africa. Section 5, 6 and 7 describe the study, present the results and discuss critical outcomes regarding teaching computer programming strategies. Finally, the paper is finally concluded with Section 8.

2. BACKGROUND

This section describes the cognitive tasks associated with computer programming, as well as the difficulties that students face when learning to be computer programmers. It also illustrates that such difficulties arise from the pedagogical approaches used to teach computer programming, as well as the overwhelming curriculum that needs to be completed during a semester.

2.1 Computer programming

Computer programming, also known as software development, can be defined as the process of developing an algorithm to complete a particular task. The tasks are normally problems that need to be solved. The result of these tasks is the formulation of a program. A program is a detailed step-by-step set of instructions, also known as a sequence of actions, which tells the computer exactly what to do (Zelle, 2002). The process of creating a program can be broken down into a number of stages (Zelle, 2002) as these stages (numbered A to F) make it more manageable to create a program. The stages are:

A. **Formulate requirements –** the computer programmer must understand what the problem is that needs to be solved. In understanding the problem, the programmer will be able to determine accurate solutions to the problem.
B. **Determine specifications –** the computer programmer must be able to describe exactly *what* the program will do.
C. **Create the design –** the computer programmer must now describe *how* the program will work. Tools, such as algorithms, pseudo code, flowcharts and Input-Process-Output (IPO) charts are valuable sources.
D. **Implement the design –** the computer programmer translates the design that is written in pseudo code, a flowchart, and/or an IPO chart into a computer programming language, such as Java, Python or C^{++}, to name a few.
E. **Test / Debug the program –** the computer programmer must compile the program to verify if there are any syntactical errors in the program, fix them and re-compile the program. This cycle should continue until the program is error / bug-free[5]. Once the program is error free the computer programmer must then execute (run) the program to verify that it produces accurate results. If the program does not produce accurate results it means that the program contains logical errors.
F. **Maintain the program –** the computer programmer can make changes to the program to produce other results as programs evolve as users' needs change.

According to The Joint Task Force on Computing Curricula, the Association for Computing Machinery and the IEEE-Computer Society, computer programming is a prerequisite to the study of most Computer Science or Information Technology courses (ACM, 2012). These organisations (ACM, 2012) state that "*…..to effectively use computers to solve problems, students must be competent at reading and writing programs in multiple programming languages*". This means that novice computer programmers must be able to:

- Design and analyse algorithms (problem solving);
- Select appropriate paradigms (programming constructs);
- Utilise modern development tools (programming languages); and
- Utilise testing tools (integrated development environments or IDE's).

Competency in these areas, means that students have learnt the fundamental concepts and skills related to the software development (computer programming) process (ACM, 2012). For students entering university these tasks may seem daunting.

2.2 Difficulties faced by students learning computer programming

The skills expected for computer programming are complex. These skills include the ability to:

- Solve problems (Development-OECD, 2004; Mead, 2006);
- Articulate a problem into a programming solution (Garner, 2005; Lahtinen, 2005);
- Construct mechanisms and explanations (Soloway, 1986);
- Combine syntax and semantics into a valid program (Winslow, 1996);

[5] The term bug originated due to a moth that managed to find its way inside a computer

- Understand larger entities of a program instead of smaller details (Lahtinen, 2005);
- Apply fundamental computer programming concepts (Garner, 2005; Robins, 2003);
- Understand abstract concepts (Lahtinen, 2005); and
- Properly estimate their level of understanding (Lahtinen, 2005).

Many of these skills require students to think in an abstract manner, or require higher order thinking skills (HOTS). Unfortunately, students in South Africa often do not acquire such skills at primary and secondary educational level (Jansen, 2012). This means that when such students are presented with a subject, such as computer programming, they struggle to deliberate concepts in an abstract manner (Mason, 1999). For example, although students may understand how to solve a particular problem mathematically, they may not be able to articulate the problem into a programming solution by applying fundamental computer programming constructs learnt in the classroom.

2.3 Curricular and computer programming

This module often forms the foundation of Computer Science degrees or Information Technology diplomas curriculum (ACM, 2012). Since lecturers ultimately decide on curricula for computer programming modules and how such curriculum will be taught, their role in the acceptance and adoption of pedagogical approaches to teaching-and-learning computer programming cannot be disregarded.

Depending on the student's chosen career path a curriculum may consist of a variety of Computer Science or Information Technology modules. However, computer programming always forms part of such a curriculum and it is normally always covered throughout first, second and third year levels (ACM, 2012). Some degrees and diplomas focus primarily on the development of students learning-to-be computer programmers, while others combine computer programming with business management, business analysis and technical career paths, such as networking or technical support. Regardless of the combination, teaching computer programming to first year students consists of teaching a very generic set of foundational concepts (Knox-Grant, 2006). These concepts relate to memory, variables, structuring a program, decision-making, creating loops, arrays and files (Farrell, 2013).

2.4 Pedagogical approaches for computer programming

Pedagogical approaches relate to the manner in which teaching-and-learning takes place in order to facilitate desired learning outcomes (Pears, 2009). There are many pedagogical approaches to teaching-and-learning (Boyer, 2008; Pears, 2009). However, the traditional teacher-centric pedagogical approach is still the most popular (Nicolaides, 2012).

The teacher-centric approach consists of activities, such as lecturing, questioning and demonstration. The lecturer is the expert who transfers their knowledge across to students (Xiaohui, 2006). This approach is used extensively to teach not only computer programming modules, but also other disciplines of study. Although the teacher-centric approach is the most popular approach, there are other pedagogical approaches that are unique to teaching-and-learning computer programming.

Firstly, teaching a particular language, such as Java, where the structure, syntax and semantics of the programming language itself is taught (Pears, 2009). Most textbooks are structured according to the constructs of a particular programming language. For example, students may learn how to make use of variables by applying the eight primitive data types known to Java.

Secondly, teaching students' problem solving techniques applicable to computer programming is another approach. The idea is that if a student is able to solve one type of problem, that student should be able to solve other problems of a similar nature (Pears, 2009; Winslow, 1996). Very precise computer programming structures are taught within this context. For example, instead of learning how to make use of variables by applying the eight primitive data types known to Java, variables can be learnt by students developing pseudo code or flowcharts. Pseudo code is an English-like representation of the logical steps it takes to solve a problem (Farrell, 2013). Problem solving and the idea of solving problems using pseudo code is a pre-cursor to writing programs using a computer programming language.

Thirdly, teaching programming through the introduction of graphical user interface (GUI) tools, such as Scratch, Greenfoot or Alice provide a simulated computer programming environment that is user-friendly. It provides ease-of-use when trying to develop computer programs (Maloney, 2010).

Lastly in this paper, teaching students how to read, trace and debug existing programs (Miliszewska, 2007; Patton, 2004) before they embark on writing their own programs is also very effective. Tracing a computer program reveals underlying concepts to students that they most probably would not have thought of themselves. Students then learn to mimic these revolutionary ideas and make them their own.

All of the above-mentioned approaches can embrace the use of peer collaboration. Peer collaboration is the process of dividing students into groups of between five and eight, or pairs. They proceed to solve problems and develop computer programs collaboratively (Preston, 2006; Teague, 2007).

3. PREVIOUS RESEARCH

Teaching a set of computer programming plans and strategies was pioneered by Soloway (1986). A set of computer programming strategies is presented to students, based on experts' tacit knowledge. Students construct programs based on such strategies (deRaadt, 2008; Soloway, 1986). For example, a common concept that students must learn is the idea of "accumulating totals within a loop". Students can be given a computer program (a strategy) that reflects this concept and use the strategy to learn how to "accumulate totals within a loop" themselves. Once the student understands the strategy, it can be expected that the students would be able to adapt the strategy to any problem that requires the same mechanics associated with the strategy.

De Raadt (2008) extended Soloway's work by *explicitly* teaching computer programming strategies to students (deRaadt, 2008). De Raadt also studied experts in the field of computer programming and adapting their tacit knowledge into computer programming strategies. Unlike Soloway, de Raadt researched the importance of *explicitly* teaching such strategies to students. He believes that it is important for students to develop the "*correct*" mental model of a computer programming strategy. Explicitly teaching such a strategy would ensure that students do not develop their own, skewed, mental models of the strategy (deRaadt, 2008).

Consequently, this study researched and adapted both Soloway's and de Raadt's strategies for use in a computer programming module at a university in Johannesburg, South Africa.

4. DESIGNING AND INTRODUCING COMPUTER PROGRAMMING STRATEGIES INTO A COMPUTER PROGRAMMING MODULE

After much research regarding Soloway's, de Raadt's, as well as expert computer programmers within the department at the university where this study was conducted, the researcher developed, using pseudo code, the following ten computer programming strategies. These strategies were *explicitly* taught to a group of students studying a computer programming module for the first time. The strategies corresponded to the curriculum that needed to be taught in the first semester of the year.

Strategy 1:
Aim: This strategy will assist you when you need to input values and display the values to the screen

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num num1 = 0, num2 = 0
        inputValues()
        outputValues()
Stop
// the following code is the inputValues() module
inputValues()
        input "Please enter a number", num1
        input "Please enter another number", num2
endModule
// the following code is the outputValues() module
outputValues()
        output "The value for number 1 is", num1
        output "The value for number 2 is", num2
endModule
```

Strategy 2:
Aim: This strategy will assist you when you need to input values, perform a calculation and display the values / output to the screen

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num num1 = 0, num2 = 0, ans = 0
        inputValues()
        calc()
        outputValues()
Stop
// the following code is the inputValues() module
inputValues()
        input "Please enter a number", num1
        input "Please enter another number", num2
endModule

// the following code is the calc() module
calc()
        ans = num1 + num2
endModule
// the following code is the outputValues() module
outputValues()
        output "The value for number 1 is", num1
        output "The value for number 2 is", num2
        output "The answer is", ans
endModule
```

Strategy 3:
Aim: This strategy will assist you when you need to input values, perform a calculation that calculates discount (initial value decreases) and display the values / output to the screen

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num cost = 0, ans = 0
        inputValues()
        calc()
        outputValues()
Stop
// the following code is the inputValues() module
inputValues()
        input "Please enter the cost of an item to purchase", cost
endModule
// the following code is the calc() module
calc()
        ans = cost – (cost * 0.09)
endModule
// the following code is the outputValues() module
outputValues()
        output "The cost without the discount is", cost
        output "The cost with the discount is", ans
endModule
```

Strategy 4:
Aim: This strategy will assist you when you need to input values, perform a calculation that calculates a bonus (initial value increases) and display the values / output to the screen

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num salary = 0, newSalary
        inputValues()
        calc()
        outputValues()
Stop
// the following code is the inputValues() module
inputValues()
        input "Please enter your salary", salary
endModule

// the following code is the calc() module
calc()
        newSalary = salary + (salary * 0.50)
endModule
// the following code is the outputValues() module
outputValues()
        output "The salary with the bonus is", newSalary
endModule
```

Strategy 5:
Aim: This strategy will assist you when you need to input values, enter many values and display the values / output to the screen

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num myNum = 0, count = 0
        inputPrintValues()
Stop
// the following code is the inputPrintValues() module
inputPrintValues()
        count = 1
        while count <= 20                //count is the sentinel variable
                input "Please enter a number", myNum
                output "The number is", myNum
                count = count + 1
        endWhile
endModule
```

Strategy 6:
Aim: This strategy will assist you when you need to input values, enter many values, display the values / output to the screen and determine the average

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num myNum = 0, sum = 0, avg = 0, count = 0
        inputPrintValues()
        calcAvg()
Stop
// the following code is the inputPrintValues() module
inputPrintValues()
        count = 1
        while count <= 20
                input "Please enter a number", myNum
                output "The number is", myNum
                count = count + 1            //incrementing
                sum = sum + myNum  //accumulating
        endWhile
endModule
// the following code is the calcAvg() module which only takes place once all the values have been entered
calcAvg()
        avg = sum / 20
        output "The average of the numbers together is", avg
endModule
```

Strategy 7:
Aim: This strategy will assist you when you need to enter many values, determine the highest and lowest value in a group of numbers and display the values / output to the screen

```
// the following code from Start to Stop is the main () module
```

```
Start
        Declare variables:
        num myNum = 0, high = 0, low = 99999 //high must equal a very low number and high a very low number
        inputPrintValues()
        printHighLow()
Stop
// the following code is the inputPrintValues() module
inputPrintValues()
        count = 1
        while count <= 20
                input "Please enter a number", myNum
                output "The number is", myNum
                count = count + 1             //incrementing
                if myNum > high               //to determine the highest value
                        high = myNum
                endIf
                if myNum < low                //to determine the lowest value
                        low = myNum
                endIf
        endWhile
endModule
// the following code prints out the highest and the lowest value, called the printHighLow() module
printHighLow()
        output "The highest number is", high
        output "The lowest number is", low
endModule
```

Strategy 8:

Aim: This strategy will assist you when you need to input many values, using a sentinal value of 99999 to indicate the end of the input values. Each input value is placed into a category according to the following table:

INPUT VALUE	CATEGORY VALUE
0 – 5	2
6 -10	5
11 - 15	9
16 – 20	12
21 -	15

For each input, the input value is displayed as well as the category value which was chosen for the input value according to the table.

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num inputValue = 0, categoryValue
        inputValuesCategorizePrintValues()
Stop

// the following code is the inputValuesCategorizePrintValues() module
inputValuesCategorizePrintValues()
        input "Please enter a value ", inputValue      // enter the first input value
        while inputValue != 99999         // while the sentinal value is not = 99999
                if inputValue ≤ 5 then
                        categoryValue = 2      // categorize input values
                else
                        if inputValue ≤ 10
                                categoryValue = 5
                        else
                                if inputValue ≤ 15
                                        categoryValue = 9
                                else
                                        if inputValue ≤ 20
                                                categoryValue = 12
                                        else
                                                categoryValue = 15
                                        endIf
                                endIf
                        endIf
                endIf
                output " For input value of ", inputValue, " the category value is ", categoryValue
                input "Please enter a value ", inputValue      // enter next input value
        endWhile
endModule
```

Strategy 9:

Aim: This strategy will assist you when you need to declare an array of values, input values into the array and output values from the array

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num count = 0
        declareArray
        inputValuesIntoArray()
        printValuesFromArray()
Stop
//this module declares the array in memory
declareArray()
        num marks [20]
endModule
//this module enters values into the array
inputValuesIntoArray()
        count = 1
        while count <= 20
                input "Enter a mark into the array", marks [count]
                count = count + 1
        endWhile
endModule
//this module prints values from the array
printValuesFromArray()
count = 1
        while count <= 20
                print "The mark is", marks [count]
                count = count + 1
        endWhile
endModule
```

Strategy 10:

Aim: This strategy will assist you when you need to declare an array of values, input values into the array, perform a calculation on an element in an array and output values from the array

```
// the following code from Start to Stop is the main () module
Start
        Declare variables:
        num count = 0
        declareArray
        inputValuesIntoArray()
        calc()
        printValuesFromArray()
Stop
//this module declares an array in memory
declareArray()
        num marks [20]
endModule
//this module inputs values into an array
inputValuesIntoArray()
        count = 1
        while count <= 20
                input "Enter a mark into the array", marks [count]
                count = count + 1
        endWhile
endModule
//this module increments each students mark by 5 marks and puts the new value into an array
calc()
count = 1
        while count <= 20
                marks [count] = marks [count] + 5
                count = count + 1
        endWhile
endModule
//this module prints values from an array
printValuesFromArray()
count = 1
        while count <= 20
                print "The new mark is", marks [count]
                count = count + 1
        endWhile
endModule
```

These 10 computer programming strategies were explicitly taught to students during the first semester, while they were learning the fundamental constructs associated with computer programming. The constructs were used to develop algorithmic solutions in pseudo code.

5. METHODOLOGY

5.1 Participants

In the first half of 2014, 139 first year students at a university in Johannesburg, South Africa studying a computer programming module, took part in the study.

5.2 Material and procedure

Three different types of material were used. Firstly, a quantitative questionnaire comprising questions associated with the manner in which students either relate or do not relate to the relevant computer programming strategies explicitly taught to them. Table 1 illustrates the different questions that were asked. Students responded with either a “yes” or a “no” answer. Secondly, an end-of-semester assessment was analysed by the researcher by comprehensively reviewing the manner in which students answered two questions in the assessment, namely Question 4 and Question 5. Thirdly, a qualitative focus group of 10 students were interviewed relating to questions as illustrated in Table 1. The focus group interview also provided an opportunity to assess the extent to which students could discuss strategies using a vocabulary associated with computer programming.

6. RESULTS

A number of results were gained from the study.

6.1 Quantitative questionnaire result

Data was gathered to explore whether explicitly teaching computer programming strategies assisted students when they were faced with the task of developing a solution to a problem at an algorithmic level. As seen in Table 1, 11 questions were asked. The initial results indicate that as students have no prior experience of programming and, at best, demonstrate an ability to hold only fragile knowledge related to computer programming concepts, strategies do assist them in building algorithmic solutions. Eighty three point one six percent of students agreed that computer programming strategies are very helpful to them and 16.9% of students disagreed.

Table 1: Students’ response to explicit teaching of computer programming strategies

	Questions	% Yes	% No
1.	I understand that a computer programming strategy is a specific guideline (algorithm) to solve a general problem	96	4
2.	I have read and understand most of the computer programming strategies provided to me	78	22
3.	I am able to identify what a computer programming strategy does when I see it	81	19
4.	I am able to make use of the correct computer programming strategy when a problem is presented to me	76	24
5.	I found computer programming strategies useful when solving a problem	91	9
6.	I find it easy to take a strategy and change/adapt the strategy to the problem that I need to solve	67	33
7.	I find that a computer programming strategy can assist me in solving a problem faster, with more accuracy	85	15
8.	In the last semester test I made use of the strategies given to me as an appendix at the end of the question paper	86	14
9.	A computer programming strategy can improve my programming abilities because I can learn from the strategy and have better insight into the problem	92	8
10.	I feel that computer programming strategies can assist me with learning programming skills	92	8
11.	When I am reading through a problem i very quickly start getting a mental picture of which computer programming concepts are needed to solve the problem	70	30
	Average of Yes and No	**83.16%**	**16.9%**

It is interesting to note that in question 6 of Table 1, many students struggled to adapt the strategy from one problem solving context to another. This means that these students have not developed higher order thinking skills (HOTS) (King, 2000). This is problematic as higher order thinking skills relate to the ability of students to solve a problem in one context and develop a solution in another context, namely at an algorithmic level (Levy, 2011).

6.2 Assessment analysis

Students' end-of-semester assessment was analysed to determine the presence or absence of strategies. There were 2 questions in the assessment that were analysed, namely Question 4 and Question 5. Both questions required students to read and understand the problem presented to them, and then to develop an algorithm using pseudo code. Question 4 was presented to the students as follows:

Given the following problem, solve it by developing an algorithm using pseudo code. Please take note that Appendix A illustrates a number of strategies that you can make use of to assist you in solving the problem and developing the pseudo code.

The All Stars Company decided to increase the salaries of all their employees. Enter the employee number (empNbr), department code (deptCode) and current annual salary for the year (annualSal). The increase in salary depends on the employee's department code, as seen in the following table:

Department Code	*Percent Increase*
AY	*6%*
HT	*6.3%*
KL	*6.9%*
Other departments	*5.8%*

Display the employee number and new annual salary (newAnnual) of each employee. At the end of the program, display the total amount spent on the annual increases (totalAmtInc) for all employees.

Question 5 was presented to the students as follows:

Write an algorithm using pseudo code that will allow a user to enter all 20 different pets in the pet shop into an array (PetArray). The array must be able to print out a list of all the different pets in the pet shop.

Question 4 and Question 5 required different thought processes and the level of difficulty between the two questions is vastly different. Table 2 illustrates the similarities and differences between the two questions.

Table 2: Computer programming skill set required to solve problems

Computer Programming skill set	Question 4	Question 5
Level of understanding required when reading the question (easy, moderate, difficult)	Difficult	Easy
Amount of "story telling" information provided that could interfere with students thought processes	Considerable	Little
Computer programming constructs required to solve the problem	Input, processing, output, selection, looping	Input, processing, output, Looping, arrays
The degree to which the strategy needs to be adapted from one context to another	Hard	Moderate

Table 2 illustrates that depending on the computer programming skill set required, some problems are more difficult to solve than others. As illustrated in Table 3, the type of problem presented to the students determined whether the students made use of a strategy and how successful they were at implementing the strategy. For example, as illustrated in Table 3, students found it difficult to make use of a computer programming strategy for Question 4. The strategy may have been too generic and they may have found it too difficult to adapt the strategy from the one context to the other. Students required a deep level of understanding of the strategy and the problem if they wanted to answer Question 4 in the assessment.

Table 3: Presence or absence of a computer programming strategy

Question	Strategy absent	Strategy present
4	55%	45%
5	11.5%	88.5%

On the contrary, most students were able to adapt a strategy for Question 5. Although this may be that the question lacks an element of difficulty, it is still a major accomplishment because, at this stage of students programming abilities, they only possess fragile knowledge regarding fundamental programming concepts.

6.3 Qualitative focus group interview

The focus group interview provided an opportunity for students to discuss the extent to which strategies assisted them in developing algorithms in more detail. The first question that was asked to the students during the focus group interview was:

What is it that you like about using computer programming strategies?

These were some of the student's responses:

> Student 1: "well the good part of it is that it gives you the whole program and all you have to do is go through the whole thing like you just apply what you have to like you already see the picture of what you want and you just have to apply it"
> Student 2: "ok like I can say about a computer strategy if you have the strategy you know what you have to work on you just look at the program and you just put your ideas in there and see what you understand about that…"
> Student 3:"for me it helps me to see and align what strategy needs to be applied …"

The theme that emerged from the focus group interview was that computer programming strategies provides a mental model or baseline that can assist students with planning and developing a *new* algorithmic solution. It provides a starting point from which they can then plan their own algorithmic solutions. The interview also revealed that students were able to make use of a computer programming vocabulary. For example, students made use of the following vocabulary during the interview: "*I can apply*", "*align the strategy and apply*" and "*understand the problem, use the strategy to solve the problem*".

7. DISCUSSION

The purpose of the study was to explore whether explicitly teaching computer programming strategies to students with no computer programming experience assisted them in solving problems better. The results from the quantitative questionnaire, the end-of-semester assessment analysis, as well as the qualitative focus group interview consistently illustrate that explicitly teaching students computer programming strategies developed by expert computer programmers, provides students with an initial mental model of a programming solution. It also provides students with an opportunity to learn best practices of expert computer programmers so that they, in turn, may learn how to develop solutions to generic computer programming problems.

8. CONCLUSION

Determining a pedagogical approach for computer programming is a difficult task as computer programming is cognitively demanding and educators find it challenging to teach. Failure rates are high as students have fragile mental models of programming strategies. Many of them do not possess the mental capacity to meet the standard set for them. Such standards originate from a curriculum that is demanding and pedagogical approaches are often inadequate.

Explicitly teaching a set of authentic programming strategies determined by expert programmers can provide students with a correct mental model regarding an algorithmic solution. This allows students to develop a baseline on which other solutions can be built. However, it is imperative that students sufficiently understand the strategy so that it can be correctly applied and so that it can be correctly transferred to other algorithmic contexts. If explicitly taught, strategies have the ability to improve the performance of students' problem solving skills and provide a better platform on which underlying processes can be established.

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TOWARDS EFFECTIVE TEACHING AND MEANINGFUL LEARNING TO ADDRESS THE CHALLENGES OF ICT EDUCATION IN AN OPEN AND DISTANCE LEARNING CONTEXT

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Abstract–The aim of this paper was investigating research questions around using the myITLab system towards effective teaching and meaningful learning to address some of the challenges related to an Information and Communication Technology (ICT) module being offered in an Open and Distance Learning (ODL) context. Literature reviewed included objectives relating to academics', teaching assistants' and students' experiences of using myITLab towards effectively teaching and meaningfully learning ICT modules. Significant concepts related to simulators, document checkers and ODL are formulated and situated within an appropriate theoretical framework. The research design, sampling, data collection and the validity and reliability thereof, as well as the data analysis method used is described. The paper discusses results on academics', teaching assistants' and students' experiences with myITLab towards effectively teaching and meaningfully learning ICT modules. Conclusions are presented on ways in which this paper makes an original contribution towards effectively teaching and meaningfully learning ICT modules.

Keywords: Effective Teaching, Meaningful Learning, Information and Communication Technology.

1. INTRODUCTION

Universities are increasingly using Information and Communication Technologies (ICTs). Worldwide, a belief seems to persist that going online and including such technologies in programmes will ensure effective teaching and students' meaningful learning (Mitchell, Smith, Louw, Tshesane, Petersen-Waughtal & du Preez, 2007). This perception sees computer literate students as being able to use technology to enter the information world that electronic media and the Internet can deliver. They can access electronic module content and materials conveniently via the Web, research academic topics and complete assignments, tests and/or examinations. There is, however, an increasing awareness of the remarkable range in terms of readiness of students coming into universities (Cooper, 2011). On this, Dednam (2009) specified that many students do not possess sufficient knowledge about technology and competencies with regard to the computer and software skills that they will need for application while they are studying and subsequently in their jobs. Along with Kitahara, Westfall and Mankelwicz (2011), it is acknowledged that this is a significant and growing challenge at many universities. This research, however, was not intended to examine the nature and causes of such challenges.

Rather, the aim of this paper was investigating research questions around using myITLab towards effective teaching and meaningful learning to address some of the challenges related to an Information and Communication Technology (ICT) module being offered in an Open and Distance Learning (ODL) context. The research questions thus investigated were:

- How do academics and teaching assistants (TAs) effectively teach ICT modules using myITLab?
- How do students meaningfully learn ICT modules using myITLab?

Literature reviewed therefore included objectives relating to academics', teaching assistants' and students' experiences of using myITLab towards effectively teaching and meaningfully learning ICT modules. The investigation included aspects related to effectively teaching applications in an ODL context, to address students' struggles with learning these meaningfully. Academics and teaching assistants also share how working with the available features can be used to effectively teach applications to their students. Significant concepts related to simulators, document checkers and ODL are formulated and situated within an appropriate theoretical framework. The research design, sampling, data collection and the validity and reliability thereof, as well as the data analysis method used is described.

Results are presented from academics on both conventional and non-traditional educational programmes, together with discussions on multi-faceted methodologies for dealing with significant issues related to innovative, state-of-the-art hardware and software tools and assistive systems (Kitahara et al., 2011). The magnitudes of the numbers related to e-cheating and academic dishonesty in the digital age remind academics that their responsibilities related to providing the best learning environments are becoming progressively more complicated. Such changing roles of academics have interesting implications for supporting students affectively, administratively and academically. This paper thus makes a significant and original contribution regarding effective teaching and meaningful learning to address some of the challenges related to ICT modules, and especially those being offered in an ODL context.

2. LITERATURE REVIEW

Towards Meaningfully Engaging Students

The remainder of this paper begins with a literature review on research into optimising the affordances of a range of technologies for creating opportunities to increase collaboration and interaction between students and allows for feedback from teaching assistants - Cloete, de Villiers and Roodt (2009) were adamant that such technologies are crucial for increasing the effectiveness of teaching for active and meaningful online learning.

Referring to Fink, Katz (2011) agreed that when students engage in active experiences with module materials, the likelihood is higher that long-term retention will be achieved. Cooper and Cunningham (2010) commented on the importance of engaging students in meaningfully learning ICT so that they remain in the computing field and the discipline of ICT as preparation for their careers or further studies. The module discussed in this paper similarly aims to develop the computer competences of students from outside the ICT field, as well as to build comprehensive viewpoints for ICT students, who will apply these in their work area.

Towards Academics Effectively Teaching ICT Modules

Dednam (2009) underscored the importance of ensuring that ICT modules' content and standard satisfy the needs of those programs that prescribe these. Microsoft (MS) Office skills therefore remain important as the most popular element of many ICT modules (Epperson, 2010). myITLab represents a computer-assisted, online learning system, including assessment solutions, produced by Pearson Education. Huan, Shehane and Ali (2011) advised academics to choose good module software like myITLab, which provides valuable online simulations exercises for Microsoft Office that allow students to successfully accomplish an activity precisely as it is explained in the text. Academics appreciated the flexibility that myITLab offered in being capable to select specific electronic chapters from many of the publisher's different textbooks - Thompson (2012) thus described how they decided to go with no conventional textbook and, as an alternative, used only myITLab.

All students' work in myITLab can be recorded in the built-in grade book (Jenne, 2009). This provides academics with compelling, at-a-glance diagnostics, in order for them to observe how the students are performing in the form of especially comprehensive evidence regarding students' performances (Speckler, 2010). Students' assessment can thus be tracked, with myITLab enabling academics to be hands-on regarding their students' success.

Kitahara et al. (2011) employed myITLab as learning technology in a module called Computer Concepts and Applications for testing students' competence in Microsoft Office applications. Preliminary assessment operated quite satisfactory, with all students being capable of successfully completing their myITLab examinations. Perhaps due to the considerable technical conditions enforced by the myITLab software, no significant procedural difficulties were experienced, with only a small number of straightforward-to-resolve practical matters.

Similarly, Cooper (2011) agreed that the program is very accurate and virtually error-free. Those students who were unsatisfied with their myITLab results realised that it usually was due to their own errors, rather than an error from the program's side. One of the few challenges that the latter author encountered with myITLab merely involved a small number of students: When several international students failed to adequately understand the meaning of the wording of certain examination questions, the academic was capable of explaining the meaning of these questions without difficulty to assist these students' understanding.

Introductory ICT modules such as the one discussed in this paper are confronted with various challenges because of the fact that incoming students have preferences for a wide range of specific learning styles and habits for taking in and handling information (Galpin, Sanders & Chen, 2007). This module, as one aspect, discusses the influence of technology on social and ethical issues relating to ICT (Epperson, 2010), which is perceived as being challenging to teach effectively. Towards the goal of information literacy, students are taught how to locate information, incorporating elements on critical thinking and issues regarding fundamental comprehension of the computer and its influences on mankind.

Using myITLab in the modules offered by Murphy, Sharma and Rosso (2011) improved the number of students who successfully completed the activities assessed. This might be because myITLab not only helps academics to identify which students are more likely to be successful, but ultimately by developing an understanding of how to help students to succeed. This helps academics to become aware of how improved, more effective teaching could meaningfully impact students' learning.

Towards Assistants Effectively Teaching ICT Modules

As teaching assistants do not have the time to keep on learning new programs, the simple-to-use program administrator feature made myITLab a popular choice among them (Speckler, 2010). Also, because the sections are inherently standardised, teaching assistants are much happier, while myITLab keeps assessment consistently on track. Academics need not follow up with teaching assistants or watch over them. It equally makes it simpler for novice teaching assistants to swiftly settle down. They are appreciative of the fact that module sections had been set up for them. This means that irrespective of who teaches a specific section in the module, all students receive an equally high-quality learning encounter.

Towards Students Meaningfully Learning ICT Modules

myITLab provides students with learning materials, as well as hands-on practice and assessment, which can be conducted online using realistic simulations of the Microsoft Office environment and products. These visual, practical methods help students to understand skills on a deeper level (Speckler, 2010). An academic, who has been using myITLab to deliver a module online, reported that it worked well: Students seemed happy with the simulations' quality. Another academic agreed that like a good simulator, myITLab allowed students to select from a number of different options before committing to anything. Finally, these simulations contain hints to guide students towards the applicable action when they are having difficulties (Jenne, 2009). myITLab further offers project-based exercises that students could complete for learning the Office skills necessary in their module.

myITLab makes learning meaningful for students in a number of ways:

1. In an end-of-semester survey, a student's comments about the program included that (s)he liked "that I can do my homework anywhere I am, whenever I want to do it … I do feel like I have a" academic with me when using myITLab (Speckler, 2010, p. 12). Especially for an ODL context, programmed technologies are combined with ICT modules relatively easily (Murphy et al., 2011).
2. The program provides students with individualised instruction. They can only pay attention to those components, which focus on competencies where they lack proficiency - In myITLab, they are able to pick what they work through (Galpin et al., 2007)! This is in sharp contrast to the usual laboratories for first-years, which are inclined to be fairly regulated and students frequently have to finish numerous segments and submit these before progressing. Students acquainted with a certain level of a Microsoft product can proceed to the following level if

already knowing the components in the current level (Huan et al., 2011). Multimedia simulations also have hints accessible for students to observe. According to Cooper (2011), students have numerous tries for completing their training and could request a hint or even have the procedure demonstrate the acceptable response before they finish it themselves. By being adjustable for individual students' competency levels, myITLab permits students to work around the module at their own level. The latter author believes that the main advantage of the outcomes-based training provided to students in myITLab is that the assessment allows students to pace themselves. Proceeding at their own pace, those who struggle could devote as much time as they require.

3. Cooper (2011) drew attention to another advantage of myITLab: it could be implemented with just a web browser and an internet connection. Students do not have to buy MS Office to use myITLab.
4. Automated grading is quick. The program provides assessment of practical exercises so that students receive not only accurate, but also immediate feedback (Bedre, 2008). Students could sign into their profiles any time to perform numerous actions, such as watching the videos made available in the module. As an external third-party web-hosting, myITLab helps students take online examinations.

Speckler (2010) described how myITLab was instrumental for a visually-impaired student to achieve success. By using an audio myITLab text with additional information read to him, this visually-impaired student was enabled to study where elements were positioned and to specify which activities to undertake. He completed all his assignments and received top honours in a module, which even some conventional students could not successfully finish.

In ways like these, students were held responsible for their studying and were more successful in their examinations. Kitahara et al. (2011) believe that it is important to provide students with early opportunities for taking a trial examination before their summative assessment, to ensure that they are accustomed to the user experience. As students work on their grader assignments, they are, in fact, already preparing themselves for the examinations - the fact that the examinations have an identical configuration as the assessment in the module contribute to student success (Cooper, 2011).

During the examination opportunity in myITLab, hints are not accessible. Academics can obviously modify the questions in an examination, as well as setting up the examination so that a reduced number of attempts are available. They can also make it possible for students to reset the examination, and after completion, for viewing explanations for the examination questions and/or immediately receiving the result of the examination based on conditions set up by the academic.

Using project-based assessment permits students to complete an examination in any sequence they prefer, instead of having to proceed step-by-step through displaying competencies (Katz, 2011). Within such a non-linear approach to assessment, students are permitted to finish what they are best able to, ahead of returning to complete outstanding sections. Such assessment provides for integrating competencies with real-world requirements for preparing students for the actuality of operating in a non-linear world.

Students in the project described by Bigenho (2011) could situate their strategies for managing their time and needing to offset social lives, work and their study schedules, by focusing on appropriately using their time and assignments. For these students, the module had direct instruction related to computer applications through myITLab. Together with studying their textbook and assignments, they were also provided with self-regulatory tasks related to the completion of assignments.

3. THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1 Simulators and Document Checkers

Because of the problems detailed in the introductory section of this paper, universities have in recent years invested money in innovative technologies for meeting their students' needs (Cloete et al., 2009). Individual academics are seeking opportunities for enhancing their teaching effectiveness by turning to and using supplemental e-learning platforms such as myITLab, Skills Assessment Manager (SAM), SimNet and SNAP. Academics agreed that adopting systems such as myITLab to use in specific university modules engage students in the process of providing them with valuable skills (Westin, 2012), as discussed in the first part of the literature review.

These systems form part of a variety of popular training and assessment applications usually offered by academic publishers of computer applications textbooks, which include test banks, Microsoft Office simulators and document checkers (Murphy et al., 2011). Some examples of these are detailed in Table 1.

Table 5. Simulators and document checkers

Office simulators	Document checkers	Publisher
SAM	SAM Projects	Cengage Learning
MyITLab	Grader	Pearson Education
SimNet	SimGrader	McGraw-Hill Higher Education
	SNAP	EMC Corporation

These systems typically come pre-packaged with module content that is often mapped to established module textbooks offered by these publishers (Westin, 2012). Software competencies, such as using the MS Office collection of products, are a common focus of such systems intended for the university market. A lesson typically provides interactive, comprehensive exercises for the elements, functions and uses of the software, where students are expected to carry out detailed keyboard or mouse activities for completing these lessons.

These tools usually make it possible for a student to accomplish different activities in a simulated environment (Murphy et al., 2011). Thus enhancing students' learning experiences can not only be beneficial to students' ability to learn basic concepts with Microsoft Office, but also their problem-solving abilities. Thompson (2012), however, also emphasised the importance of students being capable of applying the concepts from these simulations under different circumstances. Therefore, most of these systems combine the simulator aspect with a built-in document checker for problem solving projects, which can be completed in the authentic product (Murphy et al., 2011). These authors pointed out that the addition of such application-based projects in ICT modules specifically increased students' skill levels. Academics similarly noticed the superior levels of student achievement, which live-in-the-application software presented to students in some advanced modules (Speckler, 2010).

3.2 Challenges of ICT Education in an Open and Distance Learning Context

Open and Distance Learning is defined as an educational provision system that links students to instructional resources (Huan et al., 2011). The implementation of ODL involves a process that uses such accessible resources and is growing to integrate emergent technologies. Mitchell et al. (2007) agreed that recent literature suggested that ODL and online provision are being viewed as being the same. These authors also point out that introducing technology for the provision of ODL resources can be tremendously beneficial. It is, however, essential in any such ODL modules for those designing and/or writing these to increasingly come up with new, but realistic methods of effecting ODL educational design good practice.

The statements above also supported the vision of ODL as a means for providing educational access to those students who have been deprived, by augmenting their learning opportunities. Huan et al.

(2011), however, warned that as the success of ODL has propelled universities to multiply the number of modules accessible online, particular challenges result from teaching ICT modules to students who are not together physically and follow different learning programmes: Effectively teaching ICT modules traditionally entails high levels of interactive demonstrations between academics and their students.

Especially in an ODL context, Huan et al. (2011) pointed out that drop-out and failure rates are elevated in entry-level ICT modules. Cooper (2011) introduced myITLab for improving student understanding and satisfaction, as well as reducing the high attrition rates typically experienced in such introductory ICT modules. A t-test carried out as part of a statistical analysis found a significant difference (improvement) in student satisfaction before and after the introduction of myITLab. Results in the same study indicated that students were also happier. Although student retention had been attracting ICT academics' interest for many years, it also remains true that students require to be mentored, as well as networking, to feel happy.

4. RESEARCH METHODOLOGY

A series of workshops were offered for both full-time (secondary) academics and part-time teaching assistants who would potentially be involved in teaching the module. Speckler (2010) reported that other academics could train TAs to deliver a module like this in a quality manner in around six hours. This means that less time could be spent on training TAs, which leaves more for actual teaching. In an ODL context, however, these TAs were allowed to complete their online training over a period of about six weeks. At the end of their training, TAs were required to hand in an assessment portfolio.

As part of this portfolio, they were required to complete a selection of activities in myITLab and in terms of the discussions and assignments that students in the module would eventually carry out, as well as a blog post reflecting on their experiences while learning about this module. No specific references to myITLab were made in the announcement on the portfolios.

4.1. Research Design

The research reported on in this paper used a qualitative approach (McMillan & Schumacher, 2010), with data taking on the form of words, and the researcher searching through and exploring these until a deep understanding of informants' perspectives was achieved. In line with the aim of a phenomenology research design, this allowed for reflection and analysis. This methodology directed the researcher towards collecting data on how individual TAs made sense out of their particular experiences as they were working through the module content.

4.2 Population and Sampling

The population for this study consisted of all 179 potential TAs who were originally considered for training. From this population, 114 potential TAs completed Grader and 106 simulation activities in myITLab, while 146 portfolio documents were submitted. Of the latter, a sample of 58 documents was selected.

4.3 Data Collection

All portfolio documents submitted were searched for one or more mentions of myITLab. Within those artefacts thus identified (McMillan & Schumacher, 2010), the applicable sentences and/or paragraphs were extracted.

4.4 Validity and Reliability

McMillan and Schumacher (2010) indicated triangulation between sources as critical for facilitating interpretive validity. Reliability was promoted by triangulating data and paying attention to establishing and increasing data trustworthiness. A variety of strategies were used to enhance validity, given the requirements of qualitative research designs, including the extent to which interpretations and perceptions had shared meaning between informants and the researcher. It was decided how to go about in ensuring internal validity for this study, by using multiple sources for comparing results with one another. Finally, "literal statements from participants and quotations from" their portfolios are provided (McMillan & Schumacher, 2010, p. 330).

4.5 Data Analysis

Analysis of identified data artefacts was concerned with how myITLab was used, as well as the purpose(s) that it was used for (McMillan & Schumacher, 2010): could an extract be classified as mainly describing the potential teaching assistant's experiences in terms of a student trying to meaningfully learn a new environment, or as a teaching assistant, who would need to effectively teach it to students? As a researcher in the interpretive paradigm, the author mostly preferred inductive data analysis, as this was more likely to help in identifying "the multiple realities potentially present in the data" (Maree & van der Westhuizen, 2007, p. 37). Also as an interpretivist researcher, the author therefore carried out this particular study in the 'natural' contexts of the portfolios as submitted, "to reach the best possible understanding", since the realities of TAs' experiences "cannot be understood in isolation from" the contexts in which these occurred. Finally, data were also analysed in light of literature as reviewed to consider how the results compared and/or contrasted with previously completed studies.

5. DISCUSSION OF RESULTS

Towards an Academic Effectively Teaching an ICT Module

The author chose to use myITLab in conjunction with the institutional e-learning management system, although e.g. Westin (2012) indicated that it can be used independently. Powerful program administration features provided the primary academic on this specific module with tools, which helped to generate module content, a template and sections for each teaching assistant on the module before the start of the semester - as compared to Bedre (2008), this made it possible to manage the module in terms of all users, including secondary academics and teaching assistants, as well as the marking and assessment of students registered. Similar to what was shown by Speckler (2010), after this part of the module had been set up, all other (secondary) academics, whether they are full-time or contracted TAs, whether on campus or online, were offered a complete, populated section, including e-textbook chapters, student videos, PowerPoint presentations and all assignments.

While the initial set-up in terms of the template for the module etc. took preparation time up-front on the part of the author as module leader, these sections were available for the full semester, thus alleviating potential tension and misunderstandings on the parts of both teaching assistants and full-time secondary academics, who were using the module study material. Similar to what was presented by Speckler (2010), and most importantly, the use of myITLab in this way ensured that all students received identical study materials, were graded in the same way and took similar examinations. myITLab also enabled the author to provide the assignments and examinations departments with authentic marks, which could justify success in concrete terms. The author could focus on effective teaching, while myITLab took care of organizational particulars.

Towards Assistants Effectively Teaching an ICT Module

"Learning Unit 1 is straight forward with the help of myITLab" and a teaching assistant did not "foresee any challenges". Prior to accessing myITLab, "I attempted the assignment to create the Stress Management document using my own knowledge. It piqued my interest to explore all the facilities I have seen in previous versions of Microsoft Word, but had not tried to use. Previously, my attitude was to produce a detailed document and not worry much about the formatting and assuming the readers' interest would be on the facts. But after working on the Word Grader project, I realised I could make a well-formatted document express my facts and findings clearly. I have gone on to a few of my personal documents and reports that I have produced over the years and formatted them using the new knowledge. In myITLab, the instructions in the eBook are relevant for the activities in the module materials."

"During the completion of this module I found the practical exercises on myITLab very advantageous. The fact that it has three practical (simulation) exercises and then the grader assignments adds great value to the module."

One of the TAs "felt more at home learning through videos in the myITLab environment than reading normal text. I found the interface to be very user-friendly. The intelligence of myITLab is amazing. How on earth did it manage to grade, and, of course, send results there and there? I commend the myITLab team for this. I learned additional Microsoft functionalities from myITLab training that will help me run my businesses" - These indications were similar to a student quoted by Speckler (2010, p. 6), who liked using myITLab and "learned more than I would have if we only read the book without using the program".

"The myITLab platform is intuitive and useable." This teaching assistant appreciated "the fact that the content is available in different formats. After reading the text, the videos and exercised made for good enhancements." The "hints are to my mind an excellent method of teaching in the physical absence of" an academic/teaching assistant and no physical textbook - again, as similarly indicated by students in Speckler (2010). "I have been going through the PowerPoint presentation to accompany 'GO! with Microsoft® Word 2010 2e'. This was very important, as it gave me an overview of the training. Having watched the 'PowerPoint Chapter 1 Project 1A Student Video', I have also learnt a few things about PowerPoint."

The final Learning Unit (4) brought a teaching assistant to a place where (s)he "pushed myself to complete all training and assessment". These kinds of experiences led to another TA agreeing that myITLab is the best tool for assisting students towards meaningful learning.

Towards Students Meaningfully Learning an ICT Module

As a student learning the myITLab environment, a teaching assistant "was very impressed". Another liked it, as "myITLab is a fantastic tool for practicing the MS Office applications." Accompanied by a screenshot showing Excel, a third indicated that (s)he enjoyed the myITLab exercises! "I have discovered that the GO! ICT for Development Solutions eBook in myITLab is very useful in completing the activities. The myITLab program changes the whole desktop setup into a new myITLab view".

Going through the module using myITLab especially was "a revelation. As a seasoned Microsoft Office user, I approached the exercises with a superior air, only to be stuck on the task of creating tabs (Word 2010). Just as I resigned myself to searching the help function and tediously following a menu of technically worded commands, the task was brilliantly, simply demonstrated via an interactive video clip. This will definitely prove very useful to students from different backgrounds of computer exposure."

Teaching assistants were also fascinated by how myITLab is used in addition to the institutional e-learning management system for the purpose of delivering the content of this module to students. This shows that the university have invested a lot of time, money and many hours of careful planning in making sure that this project becomes a success. The training on Microsoft Office was also provocative. "I use Microsoft Word on a daily basis, but I have learnt something I did not know from the training on myITLab regarding Microsoft Office and I think our students, including those who will be using computers for the very first time, will be excited by how the Microsoft Office training has been packaged. The instructions on myITLab are very clear and it makes it easy for one to understand the task at hand."

A teaching assistant similarly indicated that students "have the opportunity to try again if you did not understand it the first time. I also found that you receive your grade immediately, instead of having to wait for it" - this was "phenomenal" - compared to Speckler (2010, p. 6), who quoted a student indicating that the "software is fun to use 'cause I'm in control of it. I can go back over things if I forget or did not get it the first time."

There are myITLab assignments that automatically grade students and what is quite good about it is that results are available online for students to view. Using myITLab is very interesting and the online training is easy to understand and follow. myITLab provides an excellent framework to implement a noticeable variety of student tasks on MS Word and Excel. The myITLab environment finally makes it quite easy to learn yourself with the hints and demonstrations.

6. CONCLUSION

Accumulating the competencies to innovatively plot a course through the current changeable professional marketplace has never been more imperative for students. The author agrees with Galpin et al. (2007) that students should be provided with the skills most desired by stakeholders - academics should be looking at the knowledge, skills and values, which will be most valuable for students during their professional lives.

It is therefore important that universities bring all participants to the table and include them from the start in any conversations (Boisvert, Bruno, Kamali, Puopolo, Rynn & Feuerbach, 2008). Participants should include administrators, staff from various student support departments, academics, students and local business partners, who will be appointing these graduates, for gathering the numerous viewpoints regarding desired outcomes and offer the support required to realise changes. This could meaningfully alter such conversations amongst stakeholders, to ensure that effective teaching and meaningful learning in ICT modules become a concern shared between students, academics, universities and all other stakeholders (Kitahara et al., 2011).

Towards Students Meaningfully Learning ICT Modules

Especially in an ODL context, students preferred studying using an online format, since it was much more convenient. myITLab offered academics a way to overcome some of the challenges associated with ODL, like being able to 'show' students how to do things: by using myITLab, students could now access, look at and listen to module content and resources anytime when it was convenient to them, from wherever they were.

Academics were able to create custom (e)textbooks that included only the content being used, which were cheaper. The results reported in this paper showed that both academics and students were easily able to find all of the module resources needed, such as simulations, videos and demonstration documents.

Students' meaningful learning was further supported when they were able to see what they have done wrong and corrected it themselves. myITLab's visual, hands-on approach helped them to understand the skills they acquired at a deeper level, which lead to them not only succeeding in this module, but also in subsequent ones. The advantages of myITLab highlighted in this paper showed how academics could provide students with a wider range of meaningful learning experiences, with myITLab serving as an innovative technology for improving students' performance.

Towards Academics and Assistants Effectively Teaching ICT Modules

myITLab enabled academics to handle increased enrolment without losing integrity. The module described in this paper was set up to accommodate 150 sections of approximately 180 students each. It is humanly impossible to process the assignments completed via Grader in the time and with the detailed feedback provided. As had similarly been indicated by Boisvert et al. (2008), the technological tools found in myITLab were also acknowledged as an approach for not only reducing effort, increasing accuracy and better informing students of their training and subsequent actions, but also enabling academics to devote added time to student achievement and less on administrative issues. In agreement with Mitchell et al. (2007), this way focused on offering students the best educational practices, which the selected media and applicable learning environments could provide.

Speckler (2010) reported that since the release of myITLab in 2007, its adaptable technologies and high-level system methodology have supported academics across the world to appropriately provide in excess of 50 000 modules to more than 700 000 recorded users without difficulty. This same author pointed out that the success of myITLab can be attributed to the fact that all of its features, including a clean user interface and solid technical architecture, are housed together. In agreement with other academics' opinions in the research literature cited and based on results reported in this paper, the author is confident about the reliability of myITLab and how well it works. From personal experience, the author is also positive about the customer support received from the Pearson team.

Academics can now provide their students with innovative, accessible and reasonably-priced instructional offerings, thus equipping them as productive participants in the 21st century labour force (Speckler, 2010), because they can call upon the kind of technology needed to warrant that graduating students do more than just carry on - they excel (pun intended ;)

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TOWARDS MONITORING THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN INSPIRED SCIENCE, ENGINEERING AND TECHNOLOGY COMMUNITY ENGAGEMENT

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Abstract–Although Community Engagement (CE) is considered one of the core functions of higher education (HE), it is being implemented in a primarily fragmented, ad hoc manner. There is a need for transformation from the traditional, ad hoc, disjointed and unlinked CE to CE that is linked to the teaching and research of an institution, with measurable outcomes as evidence. Traditional CE is, however, currently challenged in terms of resources and the logistics of time and place. This research thus considers the use of information and communication technology (ICT) towards the enhancement of CE from traditional to virtual by means of the use of technologies within CE projects, and in so doing overcoming the identified CE challenges. The enhancement of CE implies that traditional CE is not replaced but rather enriched and supplemented by virtual CE. The primary objective of this research is to develop a model that may be used to monitor the use of ICT in CE within this process of enhancement. The secondary objectives of this research are, namely: to examine the current status of and challenges facing CE, to consider the trends in the development of ICT, and to investigate the options that would be appropriate for monitoring the use of ICT within CE. It is proposed that the increasing inclusion and use of ICT be monitored. The interpretation of the monitor data may lead to the identification of benefits of and hindrances to the use of evolving ICT within a changing community. The context of implementation of this research is the Inspired towards Science, Engineering and Technology (I-SET) community engagement project. The aim of this project is to create awareness of Science, Engineering and Technology through the fun activities of robotics.

Keywords: Monitor, ICT usage, community engagement (CE)

1. INTRODUCTION

The dimensions of scholarship are defined to include the scholarship of community engagement (also referred to as CE), the scholarship of teaching and the scholarship of research (Boyer, 1997). Digital scholarship has subsequently been defined as the transformational effect of technologies on scholarship (Pearce, Weller, Scanlon, & Kinsley, 2012). The digital contribution of technologies to the achievement of the scholarship of teaching has been considered, and an education-driven approach to the use of technologies has been proposed (Laurillard, 2002, 2008). However, although CE is considered a core function, it is mainly implemented in an ad hoc fashion, according to the White Paper for Post-School Education and Training (Department of Education, 2014). The report highlights the need for a transformation from traditional (i.e. face to face), ad hoc, disjointed and unlinked CE to CE that is linked to the teaching and research of the institution and that has measurable outcomes linked to those of the institution. The challenges of traditional CE (i.e. dwindling budgets, time constraints, a lack of academic commitment and limited community access (Labelle & Anderson-wilk, 2011)) are regarded as constraints. The motivation for the study lies in the need to consider the transformation of CE according to the changing definition of scholarship. This may require overcoming the challenges of CE for the benefit of all communities. There is also a need to align CE appropriately with the evolving development of ICT, which would lead to a re-think of CE to ensure alignment with the scholarship of teaching and learning.

This research investigates the use of ICT within CE projects, with a view to overcoming CE challenges. The transformation process entails a move from traditional to virtual CE. The enhancement of CE implies that traditional CE is not replaced but rather enriched and supplemented by means of virtual CE. The monitoring of this process will ensure that progress is visible and measured regularly. The primary objective is to propose a model to monitor the use of ICT in CE. The secondary objectives of this research are namely: to examine the challenges to CE, to consider trends in the development of ICT, and to investigate the appropriate options for monitoring the use of ICT within CE. It is proposed that the increasing inclusion of ICT needs be monitored, to ensure that interpretation of the monitor data leads to the identification of the benefits of and hindrances to the use of ICT within a changing community.

Section 2 presents the relevant literature relating to the challenges of CE, ICT trends and options for monitoring the use of ICT. Section 3 contains a description of the theoretical framework for the proposed model. In Section 4, the use of the model is discussed, with reference to the Inspired towards Science, Engineering and Technology (I-SET) CE project as an illustration of the deployment of ICT for the enhancement of CE, and the need for the proposed monitoring model. Section 5 outlines proposed future research opportunities. The conclusions that have been reached are presented in Section 6

2. LITERATURE SURVEY

2.1 Challenges of CE within digital scholarship

According to the White Paper (Department of Education, 2014), although CE is considered a core function of universities in South Africa, it is primarily implemented in an ad hoc manner. The White Paper also highlights the need for a transformation of from the traditional, ad hoc, disjointed and unlinked CE to CE that is linked to the teaching and research of the institution and that has measurable outcomes linked to those of the institution. The current CE challenges need to be considered in terms of opportunities and incentives (Labelle & Anderson-wilk, 2011). The potential benefits of utilising alternative media options to reach a wider community and of communication technology development are thus seen as factors that could act as triggers for transformation. It is suggested that a multi-dimensional view of engaged scholarship be considered, and that the impact that technology may have on engagement be measured (Labelle & Anderson-wilk, 2011). This must support the recommendation that engaged scholarship should be ‘on the desk of each academic’ (Sandmann, 2008) to ensure the transparency and awareness of engagement projects. This notion is in line with the extended definition of digital scholarship (Pearce et al., 2012). It is suggested that digital media and the relevant technology have created openness and transparency in all forms of scholarship within academia. From these references it may be deduced that digital scholarship may provide opportunities for the recommended TE of CE. The definition of scholarship of engagement is being expanded to include the digital focus of the current digital era. However, a model to monitor the digital enhancement of CE through ICT deployment is required.

CE is defined as an on-going, cyclic process rather than a one-off event in which academics and members of the community engage (Aslin & Brown, 2012). Thus, the engagement should be of reciprocal and mutual benefit to the academics and the engaged community, as well as to the wider community of project stakeholders. However, engagement is considered to be challenging work that requires institutional support and stakeholder commitment, and a radical change in the institution’s approach to CE is called for (Brukardt, Holland, Percy, & Zimpher, 2004). To ensure that the engagement needs of each project stakeholder are met, the community project as well as the demographics and expectations of all stakeholders need to be clearly and unambiguously defined. In creating capacity for engagement, measures of quality, impact and benefits must be identified, and the required infrastructure needs to be secured (Holland & Ramaley, 2008).

The literature refers to a number of general challenges of CE, including:

- **Insufficient budgets**. Allocated CE budgets have been reduced (Labelle & Anderson-wilk, 2011). It is suggested that a lack of sufficient budgets may encourage disengagement (Fitzgerald, Bruns, Sonka, Furco, & Swanson, 2012).
- **The changing preferences of communities for communication**. The engagement preferences and needs of communities change, specifically for younger generations in the community and digital communication (Labelle & Anderson-wilk, 2011).
- **The lack of metrics**. The metrics for engagement need to be identified and measured for effective CE (Holland & Ramaley, 2008).
- **Failure to apply technology for effective engagement**. The absence of engaged scholarship 'on the desks' of all (engaged) scholars – and failure to use technology to ensure effective and convincing engaged scholarship – are identified (Sandmann, 2008).

However, the following specific challenges hinder the use of ICT for CE:

- **The lack of integration**. Although isolated technologies have been deployed within CE, the lack of integration of the ICT deployed in CE has been identified as a challenge (Tan, Stockdale, & Vasa, 2011).
- **The lack of growth**. The use of ICT for the growth and expansion of CE so as to include communities that may be excluded due to financial and time constraints (and thus indirectly distance and location).
- **The lack of adaption**. As the scholarship of teaching is adapted, so too the scholarship of engagement needs to be transformed and adapted in order to meet the demands of the knowledge society, to overcome the apathy that discourages innovation, and to embrace the promises and opportunities of the digital era.

The level of community participation in the planning process needs to be considered prior to any engagement with that community (Hashagen, 2002). According to Effective Engagement Kit each CE project should include a strategy specifying the engagement objective, the identified stakeholders, and the defined level of engagement, the strategic engagement activities (including budget and communication constraints), the engagement risks, and a strategy evaluation. The changing needs for knowledge and skills compel communities to become changing, cooperative and multi-disciplinary to ensure collaborative knowledge exchange (Holland & Ramaley, 2008). However, engagement must be synchronized with the institution, should adhere to the core principles of CE, and should offer a support environment within which both the community and the institution will be able to sustain and maintain the engagement (Holland & Ramaley, 2008). These safe support environments vary, however, according to the academic goals (e.g. teaching or research), the community goals (e.g. capacity-building) and the common goals of collaboration and sustainability. Three approaches to change in higher education are proposed for planning change in CE (Holland & Ramaley, 2008). CE may also be considered in terms of the levels of public participation and empowerment (Head, 2007). The engagement with the community may be classified according to the phases of the engagement (Bringle & Hatcher, 2002). Each of these phases has implications for the practical implementation of the project. They need to be understood to ensure effective engagement, especially due to the complexity of the cultural differences that frequently form part of the equation.

Using general CE principles, institutions need to define their own framework for specific CE projects that meet the needs of their specific institution community (NICNAS, 2009). An important aspect to consider, is that the range of stakeholders needs to be identified prior to the commencement of the CE project (Newton, 2009). It is suggested that CE should be transformed in such a manner that it is not the products of the engagement that are emphasised but the impact of the engagement (Fitzgerald et al., 2012). It is evident that engagement should be transformed, albeit according to current technologies, to address long-term community needs according to approaches that have been adapted to ensure that CE is the focus of academic teaching and research, embedded within the structures of the university.

Given the significance of CE, it has to be measured and monitored in terms of scope, impact and features (Hanover Research, 2011). A lack of CE indicators has been identified, however. For CE as a process, it is also important that these metrics should be measured regularly to monitor the transformation and change of the CE process. These metrics also need to support both CE accountability and awareness of contribution of CE initiatives. The effective measurements of CE, and the tools required for this measurement, are considered to be in the formative stage, as the different approaches address a range of issues. As yet, no one approach has been identified as the best fit (Hanover Research, 2011). To overcome the challenges of measuring CE, measurements must be developed to include the measurement of the economics, change and impact (Hart, Northmore, & Gerhardt, 2009), rather than merely the activities. To support CE as a process, continuous measurement is required on specific timelines. Thus a collection of snapshots of measured metrics to show change over time is recommended, rather than a one-off data study. Measuring CE from the perspective of all stakeholders, including that of the community, is also proposed. In addition it is recommended that an initial goal be defined and the types of measurements (to address the needs of all the stakeholders) be identified (Hart et al., 2009). However, in the summary of engagement management approaches presented (Hanover Research, 2011), no mention is made of the focus of the technologies used by a CE project, nor of whether the collection of measurements is available as an information system. Engagement requires the participation of the community. CE projects must therefore encourage stages of participation on a continuum (Tamarack, 2010). Two approaches to the evaluation of CE are considered. The one focuses on the traditional stages of 'think, plan, implement and monitor', and the other on the process of thinking, planning, implementation and evaluating. The latter is an uninterrupted (on-going), real-time (immediate) process known as the developmental evaluation primer.

CE needs to be adapted and transformed to meet the needs of the community over a period of time. The deployment of ICT in a CE project to meet these general and specific challenges also needs to be monitored. The measurement of CE needs to interpretative and meaningful, contributing to the improvement of CE and identifying the hindrances to CE. It should address all stakeholder needs. The impact of CE projects over time must be visible, evident and interpretable within the community of engagement. However, it is necessary to make a distinction between ICT for CE (i.e. for enhancing CE activities) and ICT-based CE (i.e. CE activities that incorporate the deployment of ICT services). All CE projects are defined in terms of the traditional engagement between the academic and the actual community. The virtual engagement through the use of ICT should be used for the enhancement of CE and the extension of the CE enabling environment.

2.2 The extent to which ICT is used in CE

The use of ICT has become an integral part of the academic core functions of teaching, learning and research and is rapidly developing and evolving. Web 2.0 technologies have been hailed as the enabler of (learning) spaces that allow for collaboration and participation (Greenhow, Robelia, & Hughes, 2009). However, the issues of accessibility, technology use, practices and governance policies have been identified as issues that require further research. These technologies have also been used to support community development through informal learning (Mason & Rennie, 2007). It is emphasised that, initially, existing technologies should be deployed, and that the sustainability of the technology within a CE project should be supported. The three stages of a project to introduce technology to a community are highlighted (Mason & Rennie, 2007): the set-up of the technology and the enabling of the community, the training of the community, and the management of the technology for sustainability.

Although technologies are deployed in CE projects, the deployment has been disjointed and lacking in integration (Tan et al., 2011). It is recommended that a model be followed to guide the introduction and deployment of technologies within a CE project. The model presented here includes measures of function, psychology, community and user satisfaction, taking a continuum of community participation into consideration (Tan et al., 2011). One of the first principles (of the ten proposed) that should be considered prior to the deployment of any technologies in a community is to know the wants, needs and limitations of the community and of community stakeholders (Tignor, 2013). Issues that need to be considered include: the effective adoption and use of technology, patterns of technology communication, and the types of problems that may be addressed through the use of technology.

Whether technologies are deployed for teaching and learning or for CE, it is imperative that the user be aware of the relevance of the specific technology as well as the nature of engagement required (Pinkett, 2000). To this end, a theory to support community development with a view to promoting engagement efforts during the introduction of technology is presented. The digital continuum is about knowledge and skills as well as technical support, and about the user's access to both (Cohill, 2000) within any community network. Although any CE network includes the community, the project content, the services and the infrastructure, it is the communication in the community that is required for successful engagement.

The role of technology in CE is considered to be that of focusing on cost reduction, on overcoming time (and distance) constraints, and on supporting effective communication (Thorman, 2012). Theoretically, the technology deployed for engagement should connect individuals and support relationships, encourage participation and discussion, and highlight common interests. The use of Web 2.0 technologies is highlighted, however, due to the lack of integration between them (Tan et al., 2011). The integration or combination of multiple digital technologies may offer greater opportunities.

A virtual community (VC) is defined as a collection of individuals with a shared interest, whose interaction may be partially supported by technology (including mobile technologies) within a set of norms or standards (Porter, 2004). The range of activities performed by the participants and the types of interactive behaviours detected within a VC are explained in terms of a framework for information exchange (Burnett & Buerkle, 2004).

Fernback and Thompson believe that there is a need to bring people, irrespective of physical location, together through community and communication (Fernback & Thompson, 1995). They do warn that organising communities is challenging, as a virtual community (VC) needs to be built up (from members belonging to other actual communities). Brown [9] proposes a three-stage approach to building a community in terms of engagement and community. This approach includes suggestions for the facilitation of community formation in an online community environment, as well as the process required on a continuum. The diversity and cultural aspects of the community need to be included, however (Robinson, 2006). The holistic community needs to take environmental complexities into account (Ellaway, Dewhurst, & McLeod, 2006).

A VC may be considered an environment in which community can be reclaimed, albeit digitally (Driskell & Lyon, 2002). A question that is being investigated is whether VCs are able to provide two core elements of community, namely commonality and interaction, without an actual community place. A VC may be considered reinforcement rather than a replacement of community. The importance of communication, interaction and collaboration between people on the one hand and between people and computers on the other hand within communities is emphasized (Jin, 2002). An important aspect of a VC is the reliability and support of the technology required by the community to communicate. The leadership of a VC is also highlighted (Sobrero, 2008) in terms of process, innovation and development. The monitoring of progress within a VC is important, so too the dissemination of this information within the VC community (Sobrero, 2008). In considering the differences between actual and virtual communities, the internet allows for the creation of global communities, which have limited costs and are mostly accessible to all members (Evans, 2003). This creates the opportunity for user empowerment, alternative community agendas, alternative access options, and options for international collaboration. However, the author warns that access to a VC does not imply membership, and that training and support may be required. Actual and virtual community may be defined in terms of spirit, trust, interaction and commonality of interest (Rovai, 2002).

The technologies used for obtaining and disseminating information and for communication span a wide range, from individual technologies to integrated environments, and evolve over time. Trends in ICT occur according to the needs of the technology user. The ICT options that are deployed depend, to a large extent, on the trending technologies and the needs of the community.

Access to ICT does not imply effective usage of ICT, however, thus ICT needs to be monitored in terms of usage and impacts (e.g. innovation, lessons learnt and changes of practice) (Price & Kirkwood, 2010). Community informatics (CI) is a field of research and implementation that considers community and technology, as well as interaction between them. However, both community and ICT evolve, thus on-going monitoring must adapt to the needs of the community.

2.3 Monitoring the use of ICT for CE

Community and technology are the two main components in CI, despite the on-going transformation of both (de Moor, 2009). Thus, the field of CI is defined as a study of the use of ICT (including Web 2.0 social media and mobile technologies) that may be used to support and enhance communities, despite the problematic definition of community (Averweg & Leaning, 2011). The value of CI is determined by the context and is often case-driven and system-focused (de Moor, 2009). It is noted that ICT provides connection to communities, a community-oriented perspective on usage and community benefits for growth, and is considered a reflection of the current society (Goodwin, 2007). This requires evaluation for the duration of the CE, however (i.e. monitoring).

The evaluation of CI and the definition of indicators is considered in terms of democracy, social capital, empowerment of the individual, community, and opportunities for economic development to ensure that value is understood (O'Neil, 2002). The ICT evaluation guidelines that is available, however, with the warning that these provide an initial point of departure for the assessment of CI projects. Recommendations for definition or purpose, community participation, triangulation and appropriateness of quantitative data is highlighted by O'Neil (O'Neil, 2002). Also, in the course of evaluation, certain factors need to be taken into account in the process of designing and developing effective technologies for communities. These are considered in terms of the community, the group within the community and the individual within the group (Erete, 2014). These best practices are required to support social cohesion and capital within the community.

The integration of technology may also be measured, subjectively, on a continuum defined according to the five stages of introduction, adoption, adaption, infusion and invention (Zimmer, 2012). The continuum of effective use of technology (Boettner, n.d.) is defined in terms of entry, adaptation, impact and innovation, and each stage is considered in terms of its characteristics as well as aspects relating to the student, the educator and the technology. Technologies may also be considered on the technology continuum (Moore, 2012; Puentedura, 2013).

The use of technology may be measured in multiple ways (Thorman, 2012). Quantitative measures can use the number of clicks, tweets, visits, hits or invites. A factor that hinders the measurement of CE and the use of ICT is the absence of standardised metrics for assessing the impact of technology for engagement projects. This also affects the measurement of online and offline engagement and social capital (Thorman, 2012).

There is a need to identify evidence to conclusively show that that the use of technology enhances learning (Price & Kirkwood, 2010). "Enhancement" in this sense would imply that learning is improved. However, any quantitative or qualitative evidence to support this claim must be measurable. The evidence suggests, rather, that learning is supported (and enhanced) by the use of technology, thus it may be deduced that CE may also be supported (and enhanced) by the use of technology. Although the capacity of technology alone to transform learning is questioned, an evidence-based approach to the use of technology is recommended (Price & Kirkwood, 2010).

To measure the use and impact of technology on CE, it is recommended that specific metrics be created, that survey and analytic tools be adopted, that qualitative measures be included to support the analysis of the quantitative metrics, and that communities suggest measures of impact (Thorman, 2012). Robust data and evidence of enhancement usually necessitates a longitudinal study. It is recommended that HE move toward an evidence-based approach to the use of technology, according to which the interpretation of evidence would lead to changes in practice and the effective use of technology (Price & Kirkwood, 2010). For teaching and learning, frameworks are defined to benchmark the use of one or more technologies within a teaching module (Smyth, Bruce, Fotheringham, & Mainka, 2011). Such frameworks for enhancement, extension and empowerment guide the inclusion of technology within modules. A framework is presented for the analysis of evidence of technology-enhanced learning (TEL), in which evidence is considered in terms of type and impact (Price & Kirkwood, 2010). Both the learning content and the process need to be taken into account.

Although virtual communities (VC) develop by means of tools and technologies, a definition and classification of a VC is proposed (Lee, Vogel, & Limayem, 2003). It is noted, however, that the technologies required for the support of such a community is lacking. The definition proposed refers to cyberspace, the use of ICT, the communication and interaction required, and the inter-relationships between members of the community. There is agreement regarding the use of CI (Gurstein, 2000) as a concept to support the use of ICT to ensure the pursuit of community development goals. It is emphasized that an analysis of VC user needs may contribute to the use of ICT to support the VC (Lee et al., 2003). Participation by the identified stakeholders is as important in virtual as in actual communities. A digital inclusion experience to engage stakeholders is proposed (Siefer, 2014) as a framework that includes four steps: identify, meet, engage, and publish and promote.

The ICT deployed is required to meet the needs of the community. To determine whether this objective has been met, the deployment of the ICT needs to be monitored. Several criteria for this monitoring process have been suggested, e.g. the usage of a technology and the impact of the technology in a community. To identify the long-term impact of effective use, regular monitoring is required.

2.4 The attributes and metrics of monitoring

Monitoring is a continuing function that uses the systematic collection of data on specific indicators to provide management and the main stakeholders with details regarding the extent to which objectives have been achieved and progress has been made in the use of allocated funds. The process of monitoring the deployment of ICT for CE may be considered in terms of a number of contributing evaluation frameworks found in the literature. Each of the frameworks to be considered for inclusion in the proposed model may contribute either qualitative values to a description of the process in terms of qualitative profiles, or quantitative values of metrics to the measurement of the process in terms of quantitative trends. In terms of a model, the qualitative attributes describe the engagement with a community within a project. These attributes are the descriptors and the terms of reference used to profile the CE transformation process. The values of these attributes seldom (if ever) change within the duration of the project. The quantitative metrics of a CE project may be measured frequently along one or more of the frameworks proposed in the literature. The procedure required for the measurement of such identified metrics must be explained in detail.

2.4.1 Description of entities in process

A CE project may be described qualitatively in terms of the level of community participation in the pre-engagement planning process (Hashagen, 2002); academic and community goals (Holland & Ramaley, 2008); levels of public participation and empowerment (Head, 2007); phases of engagement (initial, developmental, maintenance or resolve) (Bringle & Hatcher, 2002); or dimensions of public engagement (Hart et al., 2009). The Effective Engagement Kit recommends that a CE project be described in terms of a strategy that includes objectives, stakeholders, levels of engagement, activities, risks and plan reviews (Newton, 2009). A community may be described qualitatively in terms of the identification of stakeholder and stakeholder needs (Newton, 2009). Prior to the introduction of technology in a community, a community may be described in terms of its wants, needs and limitations. Once ICT is introduced, however, a community may be described in terms of the effective use and adoption of technology, patterns of technology communication, and types of problems that may be addressed through the use of technology (Tignor, 2013). The technology may be described qualitatively in terms of the type of application (e.g. text, audio or image) (Cross, 2007). A virtual community may be described qualitatively in terms of its definition and classification (Lee et al., 2003), its attributes (i.e. purpose, place, platform, population and the implemented profit model) (Porter, 2004), or the range of activities performed by the participants and the types of interactive behaviours detected within the community.

2.4.2 Monitoring relationships

The community scales use the dimension of change (a quantitative measure) as a continuum for measuring change in the community (CSBG Monitoring and Assessment Task Force, 1999). The engagement of the community within a CE project may be monitored quantitatively in terms of measuring its impact (Fitzgerald et al., 2012), or it could be monitored according to the Carnegie Foundation classification (Driscoll, 2008), or according to a framework for the measurement of engagement (Adams & Hess, 2005). The stages of participation have been suggested that considers two approaches. The one approach focuses on the traditional stages of 'think, plan, implement and monitor', and the other on the process of thinking, planning, implementation and evaluating. The latter is an uninterrupted (on-going), real-time (immediate) process known as the developmental evaluation primer (Tamarack, 2010). ICT use in a CE project may be measured or monitored in terms of the project stages of introducing the technology to a community (the set-up of the technology and the enabling of the community, the training of the community, and the management for sustainability) (Mason & Rennie, 2007); the measures of function, psychology, community and user satisfaction, taking a continuum of community participation into consideration (Tan et al., 2011); the focus on cost reduction, on overcoming time (and distance) constraints, and on supporting effective communication (Thorman, 2012) or the usage of metrics (Thorman, 2012). There are, however, no standardised metrics for assessing the impact of technology in CE projects. This applies to measures of online engagement, offline engagement and social capital (Thorman, 2012). The use of evidence on three levels of impact (i.e. micro, meso and macro) are identified (Price & Kirkwood, 2010). The integration of technology may also be measured, subjectively, on a continuum defined according to the five stages of introduction, adoption, adaption, infusion and invention (Zimmer, 2012). Technologies may also be considered on the continuum of static to dynamic, whereby technologies are not considered in isolation, but rather as part of a whole relative to the goals and objectives for the use of the technology (Moore, 2012). Available evaluation frameworks may be deemed to be appropriate for inclusion as a basis for the proposed model for the monitoring of ICT use in a CE project.

3. A PROPOSED MODEL TO MONITOR THE USE OF ICT IN CE

3.1 Introduction

A model to monitor the usage of ICT for CE in terms of contributing processes is proposed. The model is set out in Figure 1, and discussed in Section 4.2. 4.3 and 4.4.

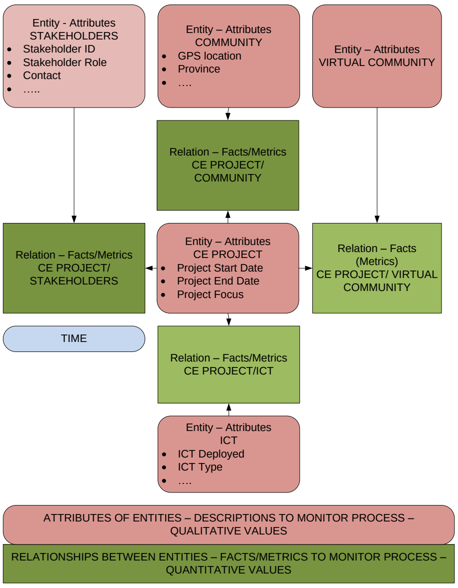

Figure 1: Diagrammatic representation of proposed model

3.2 Attributes and metrics

Each relationship may be described in terms of the values of a number of attributes and may be monitored in terms of the values of metrics that are measured regularly. The attribute values are qualitative, and provide qualitative profiles. The metric values are quantitative, and provide trend profiles. The metric values may also be used as aggregated values. It is envisaged that the interpretation of these metric values over time will lead to the identification of trends, opportunities and hindrances of CE through the use of ICT. The frequency of the measurement needs to be determined, as well as the definition of the qualitative values. For each of the metrics used to monitor the process, the data requires meaningful presentation and interpretation. The collection of metrics needs to address the requirements of all the stakeholders of a CE project. The metrics and attributes may be considered during a feasibility study.

3.3 The entities

The entities describing the use of ICT in CE are identified as:

- The community engagement project.
- The community within which the institution engages.
- The stakeholders of a project.
- The technologies are the range of technologies available.
- The virtual community created from members of actual communities.

3.4 The relationships

The relationships that contribute to the monitoring of the usage of ICT in CE are:

CE Project – ICT. This relationship is described in terms of the attributes of the technology and the CE Project. This is an example of metrics that may be used to measure the technology in CE measures of function, psychology, community and user satisfaction, taking a continuum of community participation into consideration (Tan et al., 2011). Social media analytics, or usage metrics, are also recommended (Thorman, 2012). Technology use may be measured in multiple ways, including online engagement, offline engagement and social capital. Metrics for assessment need to be identified.

CE Project – VC. This relationship is described in terms of the attributes of the CE Project and the virtual community. The traditional to virtual community process is described in terms of the attributes of the actual community and of the virtual community of the CE project. The metrics proposed to measure and monitor this dimension are metrics to determine change in a community.

This model is described in terms of the attributes of the actual community and the VC of the CE project. An example of metrics to measure VC engagement is a framework for the measurement of engagement (Adams & Hess, 2005). Community scales use the dimension of change (a quantitative measure). This is a continuum for the measurement of change within the community (CSBG Monitoring and Assessment Task Force, 1999)

Community - CE Project. The engagement of the traditional CE is described in terms of the attributes of the actual community and the CE project. An example of a metric to measure traditional CE is the Carnegie Classification (Driscoll, 2008). The impact of the engagement may be measured on the 7-part level of engagement (Fitzgerald et al., 2012). The participation may be measured in stages of participation on a continuum (Tamarack, 2010). Two approaches to the evaluation of CE are considered. The one focuses on the traditional stages of 'think, plan, implement and monitor', and the other on the process of thinking, planning, implementation and evaluating. The latter is an uninterrupted and real-time (immediate) process known as the developmental evaluation primer.

Stakeholders – CE Project This is relation that depends on the definition of relation of the stakeholder within the CE Project .

4. THE NEED AND USE OF THE MODEL WITHIN I-SET

The use of the model is discussed in the context of the I-SET CE project.

4.1 Example of need for model

The I-SET project has introduced ICT options to enhance the CE project and to increase access to the project. However, there is no integration of use and no measure of effectiveness or evaluation of use of these ICTs.

- Social Media – FaceBook was introduced to provide a 'messaging forum'. Posts are used as status information to inform all supporters of events. All event photographs are also uploaded onto the site. The I-SET Angels team that competed in Spain have their own FaceBook page, linked to I-SET page.
- Twitter was introduced. However, there are no champions on the team to drive this.
- SlideShare was introduced for the distribution of training material. This has however, not been maintained.
- UNISA College website allows for access to I-SET videos of the annual FLL challenge competition.
- VLE has been introduced to equip educators and community leaders.

4.2 Envisaged benefits of use of model

An analysis of usage data will provide on-going insights into the use ICT for CE. By increasing awareness of the process and progress of CE projects, the problem of fragmentation in CE can be overcome. It is envisaged that the use of the proposed model will also address the need of CE stakeholders for greater visibility of the CE project, which may lead to the identification of opportunities for the investment of social responsibility funds. The use of ICT allows a CE project to become accessible to a wider community, overcoming time and place constraints. Members of actual communities may engage with each other within the virtual community, which will increase the effectiveness of CE projects. These actual communities may also engage with communities that would otherwise have been excluded from traditional CE due to resource constraints and logistics.

5. FUTURE RESEARCH

An exploratory study will be conducted to determine the extent to which ICT is currently used for CE projects, especially within other science, engineering and technology CE projects. A questionnaire will be developed for this purpose. The instrument will include both qualitative and quantitative questions to ensure validity of the data. The analysis of these data will contribute to the development of the proposed model. Once the proposed model has been defined, a prototype information system will be developed. This prototype will be used and evaluated in a quasi-experiment to determine the extent to which the use of the model contributes to the use of ICT of

CE. A group of stakeholders for a sample of CE projects will participate in the quasi-experiment. It is envisaged that the results of the quasi-experiment will contribute to the improvement and enhancement of the proposed model.

6. CONCLUSION

The proposed model includes entities and relationships in the use of ICT for the enhancement of CE. Although digital scholarship may provide the means to overcome the current challenges of CE, the challenges associated with the deployment of ICT in CE will need to be addressed. The ICT trends are dynamic and span a range of alternatives. However, not all ICT is deemed appropriate for CE. The use of ICT for CE needs to be monitored in an on-going, meaningful and interpretable manner. This will contribute to the detection of hindrances and obstacles in the use of ICT for CE. The envisaged benefits also include increased awareness of the CE initiative, and engagement with a wider community, albeit virtual. Within the context of I-SET CE project, the envisaged benefits are the increase in access and engagement for communities limited and constrained by the logistics of traditional CE.

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USING A SCRIPTABLE GAME-ENGINE TO TEACH INTELLIGENT AGENT ARTIFICIAL INTELLIGENCE ACCORDING TO OBJECT-ORIENTATED TEACHING PRINCIPLES

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Abstract–This paper demonstrates the use of a scriptable game-engine using object-orientated programming (OOP) teaching techniques to teach intelligent agent. The intelligent agent approach to artificial intelligence (AI) is concerned with the intelligent behaviour of agents. The implementation intelligent agents is more a problem of software-engineering than of the AI-discipline itself. We argue that an object-orientated language is suitable to implement an intelligent agent. We discuss the features of an object-orientated scriptable game-engine and demonstrate its suitability to implement an intelligent agent. Because of the fact that the implementation is primarily a programming problem and the similarities between object-orientation, we demonstrate that the teaching methods that are used to teach OOP are conducive to teach AI. Further, because certain scriptable game-engines employ an object-orientated object model and a visual front-end, we demonstrate that it can be used as an effective teaching environment. From student interviews we discuss their perspectives on the implementation in a scriptable game-engine and the instructional design of using OOP teaching techniques.

Keywords: Intelligent agents, game-engine, object-orientated programming, AI education.

1. INTRODUCTION AND BACKGROUND

This paper aims to argue the use of a scriptable game-engine using OOP teaching techniques to teach intelligent agents within AI. We first argue that an intelligent agent can be implemented with an object-orientated framework and that the same teaching techniques used for OOP can be applied. We argue the suitability of a scriptable game-engine to implement an intelligent agent as well as its suitability for use as a teaching environment.

As a pilot study, fourth-year IT students doing a module in AI were classroom instructed in the theory of intelligent agents and given an assignment of implementing a toy problem-solving intelligent agent using a scriptable game-engine. After the project, the students were interviewed to establish their experiences from the module. From the interpretive content analysis we give recommendations that will be used as a first iteration to refine the instructional process.

In Den Heijer & Goede (2014) it was demonstrated that a single intelligent can be implemented in a scriptable game-engine. We review most of it, but recast it to a teaching environment.

2. INTELLIGENT AGENTS

We will discuss intelligent agents and the AI topics that form part of our module's outcomes. Although we discuss all the important aspects of intelligent agents, our module's scope limits us to a single non-learning agent in a known, observable, discrete and deterministic environment. The AI techniques the agent can employ are search and optimization methods.

Various definitions exist of what an intelligent agent is. We consider what we think are the two main definitions. The first definition we consider is that of Luger (2009) that an intelligent agent is a problem solver computer program that is a situated in an interactive environment. The agent is capable of flexible and autonomous action that can be directed towards predetermined goals. Multiple agents are socially organized instead of isolated and work together to achieve set goals. The second definition we consider is that of Russell & Norvig (2014), that for each possible environment observation the agent can make, it should select an action that is expected to maximise its performance measure, given the evidence provided by its observations and whatever built-in knowledge of the environment it have.

We combine the two definitions and consider the following as intelligent agent characteristics (Luger 2009:266-270, Russell & Norvig 2014:35-59):

- It's rational in that it observes the environment and performs actions on it to achieve its goals
- Autonomous - it performs its functions without outside intervention; it has control over its own actions and may keep some internal state.
- Flexible, reactive and pro-active – it perceives its environment and reacts to it. It is goal-directed using search or planning methods. It may be able to learn new actions in a changing environment.
- If other agents were to be present, they should be able socially interact and communicate to achieve the overall goal.

The environment in which the agent is situated can have the following properties (Russell & Norvig, 2014:41-47):

- The observability of the environment from the agent's viewpoint.
- Deterministic environment's state is determined by the actions of the agent alone; stochastic states are governed by some probability.
- Discrete vs. continuous environment states e.g. discrete grid positions vs. continuous position.
- Dynamic vs. static – does time pass while the agent is searching?
- Known vs. unknown – does the agent know what the outcomes of its actions will be? If not, it will have to learn them.

A very important step in design of an intelligent agent is specifying its task environment. This includes its performance measure, environment, actuators and sensors (Russell & Norvig 2014:41-47).

An agent program implements the mapping of sensor observations to actions on the environment (Russell & Norvig, 2014:47-54). The agent program can use AI techniques or tools to aid it (Russell & Norvig, 2014:53-57):

- Uninformed systematic search – states are blindly expanded and checked if they are the goal state. It's systematic, because it returns a complete path to the goal state.
- Informed systematic search – a problem specific heuristic function determines a better state to expand first (over that of uninformed search). A* search is the most popular heuristic search method.
- Local search and Optimization – when the sequence to reach goal state is not important, these techniques provide that the final goal state.
- Logic and planning – reasoning are used arrive at new actions.
- Learning – with limited initial knowledge, learning can modify the components of the agent to improve its performance.

We view that the agent can encapsulate these AI techniques or methods. Different agent designs vary only by how the agent program decides which actions the agent should take (Russell & Norvig, 2014:47-54), again encapsulating the agent's design or behaviour.

We will now focus on the object-orientated implementation of intelligent agents.

3. OBJECT-ORIENTATED IMPLEMENTATION

Object-orientated design has become the mainstream paradigm for most modern-day software applications. It represents a software system as objects that communicate with each other. The Class construct encapsulates the properties and behaviour of an object respectively with data members and member functions. Concrete objects are instantiated to from the classes, each with their own unique properties (Cohoon & Davidson, 2002).

From section 2 it would seem that the agent and its environment can simply be implemented as an agent object situated in an environment object, but some care must be taken. The intelligent agent must be autonomous, flexible, and social. Some criticisms are levelled against the object-orientated paradigm (Jennings, 2000):

- The level of abstraction of object is too fine grained, meaning the object does not form a coherent problem solver and thus an agent.
- Action activation – the object's methods are invoked passively from outside; objects do not exhibit control over their own behaviour and are thus not autonomous.
- For multiple agents, a fixed organization structure using a static inheritance hierarchy is limiting.
- Multiple agents must be distributed, operate concurrent and communicate with each other.

Agent-orientated approaches provide a methodology to implement distributed multi-agent systems. The problem is that agent-orientated techniques are not yet as mainstream as object-orientated techniques (Jennings, 2000). For our implementation we would like to stay mainstream, and use a paradigm IT graduates ought to be familiar with.

Even with these criticisms, it remains practical to use an object-orientated programming language as implementation (Wooldridge & Jennings, 1998):

- The implementation of the agent is more a problem of software engineering than one of the field of intelligent agents; mainstream software development practices need to be followed and object-orientated techniques can be used to great effect.
- For many applications, formal agent architectures can be used, but may be unnecessary.
- The agent tools i.e. searching still need to be implemented using the currently available techniques.
- Implement each agent as a coherent problem solver with the correct course grained level of abstraction.
- Look at the agent-orientated approach as an abstraction, even if implementing it in an object-orientated paradigm.

We will only address the requirement of concurrency and the criticisms of abstraction granularity and action activation. From an object-orientated view, the implementation of a single intelligent agent according to our module's scope will be as follow:

- To ensure the correct abstraction granularity, the agent will be implemented as a single coherent problem solver in a separate class structure.
- An agent program encapsulates and implements the mapping of sensor observations to actions on the environment. Conditional-action rules, search-methods or optimization can be invoked by the agent program (Russell & Norvig, 2014:47-54).
- The problem of passive action activation or invocation of the agent program may be solved with event-driven activation. There can be an external global timer, relative to which events can call modules inside the agents (Busetta et al 2000). The agent program will be invoked by a global timer and it will in turn invoke the needed observations, tools and actions.
- The agent will be situated in a separate environment class will be used to implement various scenarios for the agent (as suggested by Russell & Norvig, 2014:46).
- The agent must still be able run concurrently if its environment is dynamic, meaning the passage of time in the environment must continue while the agent is searching for a solution (Russell & Norvig, 2014:45). Coroutines can be used as a solution (Kahn & MacQueen, 1977).

Because the implementation is can object-orientated, we will focus on objected-orientated teaching techniques. We will select a suitable teaching environment for object-orientated programming.

4. SCRIPTABLE GAME-ENGINE IMPLEMENTATION

Before discussing the game-engine implementation, some background on games and game-engines will first be discussed. Various definitions exist of what a game is, but the most convenient description is a type of play-activity, conducted in a pretended reality, in which the player must try to achieve some non-trivial goal within a set of rules (Adams 2010:3). In a video game context, this pretended reality or game world can contain an 'artificial intelligence' opponent (Adams, 2010:124).

Game-engines allow developers to reuse large portions of the core components. The core components include an input system, rendering system, collision detection system and audio system (Gregory, 2009:11,29). With a runtime scripting system, custom game objects with new behaviours can be implemented (Gregory, 2009:802). The core systems of the engine are driven by a game loop. With each discrete step of the game loop, all the systems are notified with events to calculate, communicate and update their states. The renderer then draws the frame to the screen (Gregory, 2009:10). With each frame, each object's update event runs its own piece of code and the renderer draws the object's visual representation to the screen (Gregory, 2009:757).

Asynchronous coroutines are used for object methods than may span more than one game-loop; this allows for the methods to be invoked in one frame and only return its solution in another, without holding up the entire game-loop (Gregory, 2009:800).

The game-engine has a front-end game world editor that allows the game world to be populated with static and dynamic objects. The editor also allows objects' initial properties and behaviours to be set (Gregory, 2009:701).

In the previous section we reviewed that a single intelligent agent can be effectively implemented in an object-orientated programming language. Our main requirement for a game-engine to implement an intelligent agent will thus be a game-engine whose object model support full object-orientation, event-driven activation and coroutines. In our opinion, the two most popular scriptable game-engines are the Unreal® Engine and Unity. Both use high-level object-orientated scripting languages. Their object models allow for fully custom behaviour and properties, fully defined by class constructs (Goldstone, 2011:40, Busby et al, 2010:18).

Addressing each point from the object-orientated implementation from the previous section, the implementation in a scriptable game-engine will be as follow:

- A single agent class script is used to encapsulate the agent as a single problem solver. The agent's data members included its states and a reference to the environment class.
- The agent program member in the agent class implements the main behaviour of the agent and invokes all the needed actions and AI tools such as searching. The AI tools and actions are member functions of the agent class.
- The agent program itself is invoked with each frame update event from the main game loop.
- The environment is represented as a separate class. The agent class is situated in the environment class.
- Methods that span more than one frame are implemented as coroutines. The agent keeps track of all its actions by using an internal state variable. The search method is invoked as a coroutine; the agent program continues running in Idle mode until the search returns a solution.

We have established the suitability of a scriptable game-engine to implement an agent; we now need to look if it is a suitable teaching platform. Before the advent of the module we ourselves informally reviewed the Java and C++ implementations given by the online repository of the prescribed study material (AIMA Online Code Repository, 2014). Initially, the main advantage for us was the game-editor's existing GUI. Having to deal with building a GUI or applet is very characteristic, time intensive and not common to object-orientation in general. For students to build a GUI will be distracting from the important issues of the program structure (Kölling & Rosenberg, 2001). Another advantage for us is the strong C# object model, which we feel will allow them to transfer their knowledge to a mainstream integrated development environment (IDE) such as Visual Studio. Students had an object-orientated programming module that formed part of their IT course.

Our game-engine of choice was the Unity game-engine. To customize object's behaviour it uses C# or Java as a scripting language in its scripting editor named Monodevelop. Monodevelop offers auto-complete and changes to the scripts are automatically transferred to the Unity editor. The game-world editor offers all the tools needed to design your scene and preview it (Goldstone, 2011:17,28). Public data members of custom script-defined objects can be edited in the Inspector window, providing the means to interact and experiment with game-objects (Goldstone, 2011:113).

5. INSTRUCTIONAL DESIGN

Our artificial intelligence module is an optional module for honours IT graduates. The outcomes of the module state that students must not only be able to select a suitable agent design, but also implement it. We have preliminary selected a scriptable game-engine that will be able to implement an intelligent agent according to our modules outcomes and provide a suitable teaching language and environment.

We adopt much of the guidelines provided by Kölling & Rosenberg (2001) for teaching object-orientation as a starting point for our instructional design. The following instructional sequence is suggested for novice programmers:

1. Objects are explained first. Without writing any code, classes and objects are explained.
2. Students 'fill in the blanks', by adding or making small modifications to existing code.
3. Let them implement or change existing methods.
4. Add new methods.
5. Add new classes.
6. Develop a project from scratch.

For the pilot study, the students are classroom instructed in the theory of intelligent agents and its characteristics according to the 'object's first' guideline from step 1 above. We explain the agent object situated in the environment object:

- Class abstractions represent the program's components – the agent class is an abstraction or template of the agent's components and the same applies for the environment class.
- Concrete script objects are instantiated from classes – if we were using multiple agents, multiple agent objects can be instantiated in a single environment object. Each agent object will have its own unique variables or state.
- Script Objects have methods that can be invoked – the agent object's main method is its agent program method that implements the behaviour of the agent. It invokes all the needed actions and AI tools after observing the environment object. The agent program itself is invoked with each update event if it is situated in a dynamic, real-time environment. For the game-engine this update event is called at each frame update.
- The AI tools and actions are sub-methods of the agent class, invoked from the agent program method. These may include observe, search and action methods. The action method, when invoked by the agent program method, will change some state variable in the environment object.
- Methods may have parameters and may return results. In the case of the search method, the parameters can control the search behaviour. The search method itself returns the path it found.
- The different environment properties are explained as data members of the environment object – in the case of a discreet (vs. continuous) environment, the state of the environment will be represented by an integer index number instead of a floating-point number.
- How the agent program implements different agents design suited to specific types of problems.

These are all demonstrated to the students though direct interaction before they were given any assignments.

The Unity GUI is explained to them by letting them create an empty agent and environment class with a visual 3D representation. Note that because we are dealing with IT graduates and limited time, we jump to step 5 of adding classes of the suggested instructional sequence of Kölling & Rosenberg (2001):

- The Unity game-editor GUI is explained (Figure 2).
- The game-engine's object-model is explained.
- The Monodevelop scripting editor is explained.
- To help visualize the program structure, the agent and environment are represented by 3D game-objects in the game world(Figure 2). The agent and environment game-object is instantiated respectively from the agent class and environment class, although the classes contains no functionality yet.
- The input/output of game-editor GUI is explained, especially using the object Inspector of Unity Figure 3).

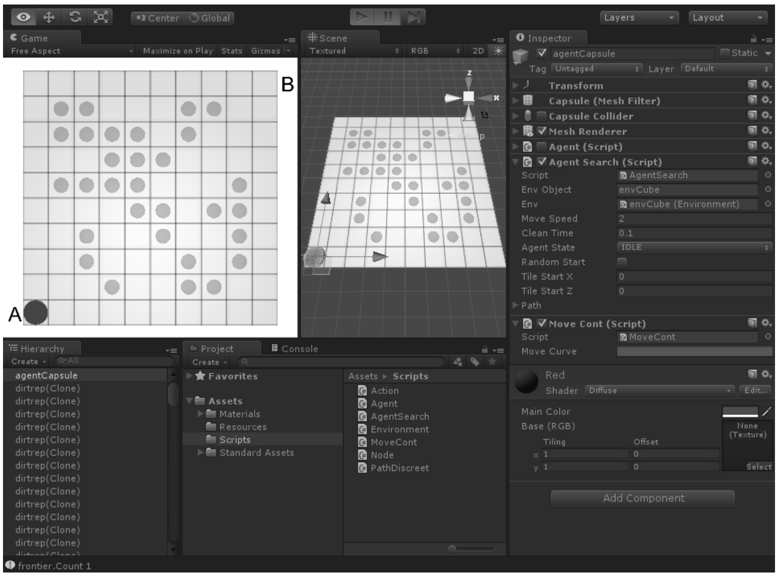

Figure 1: Unity editor

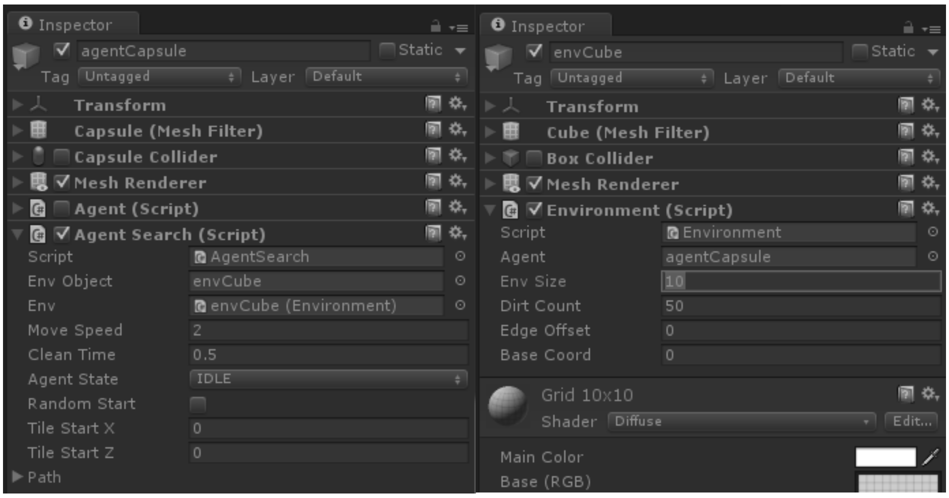

Figure 2: Inspector windows of the agent and environment game-objects

On to step 6 of developing a project from scratch (Kölling & Rosenberg, 2001), the students are given a large project to implement in Unity. We divide it into credit-bearing weeklong milestones for the following reasons:

- The object-orientated implementation allows for complete classes or methods to be easily incorporated into a milestone.
- Difficult topics milestones can be allocated more time to complete.
- Because milestones are credit-bearing, it forces students who procrastinate to complete their work.
- The complete milestone are given to the student after it is evaluated, letting them built upon a complete standardized implementation, even if they could not complete it.
- It allows more time for the lecturer to prepare and more flexibility to focus on difficult topics.

For the pilot project the students must implement a vacuum cleaner toy-problem. The vacuum agent is situated in a rectangular 10mx10m grid environment with 50 random dirty tiles. Figure 4 shows a screen-capture of the editor's preview window. In between milestones there are direct contact-sessions e.g. to explain systematic search methods. They were only given vague guidelines and encouraged to consult online code-repositories and manuals. The project is divided into milestones as follow:

- The vacuum agent the vacuum agent should only be able to find the closest dirt tile and clean it. Implement the agent class' data members including its state, a reference to the environment object, initial location, speed and time to clean one tile. Implement the agent's methods including its Move, Clean and Find-Closest. Use a representative 3d model.
- Implement the environment class' data members including the dirty tile locations and size of the environment.
  Implement the environment's methods including a method to generate random dirt, check if a tile is dirty and update the locations after the vacuum cleaned it. Use a representative 3d model of the tile environment as well as the dirty tiles.
- The students are tasked with compiling a report, including the task-environment and their results of the vacuum's performance as the time to clean 50 tiles. They present their results as a demonstration to the entire class.
- With the agent and environment object fully functioning, the students must expand their vacuum agent's abilities using A* search. The vacuum cleaner must move from corner A to B. It must find the shortest path to B, trying to avoid dirty tiles. If a dirty tile happens to be part of the shortest path, if must clean it when it crosses over it. Dirty tiles take longer to traverse, since they must be cleaned. Systematic search methods are explained to the students.
  The A* search method must return a complete path towards the goal, so as a milestone, the Move method of the agent must be expanded to follow a path instead of just going to one location. It is tested by providing the vacuum with an arbitrary path to move along.
- The A* graph-search method within the agent class generates a node tree (Russell & Norvig:77-96). The students must implement a Node abstract data-type and a Node-Tree structure that any systematic search method can use.
- The A* graph-search method must be implemented by using the existing node-tree structure. It must be invoked as a coroutine so that the agent program continues running in Idle mode until the search returns a solution. This solution path is used by the Move method as a parameter.
- Again, they had to compile a report and present their results.

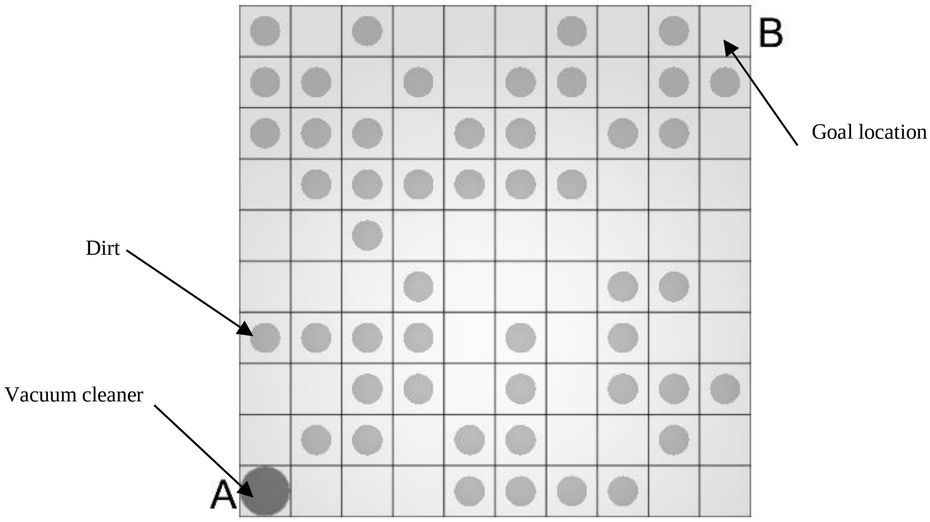

Figure 3: Initial 50 randomly generated dirty tiles

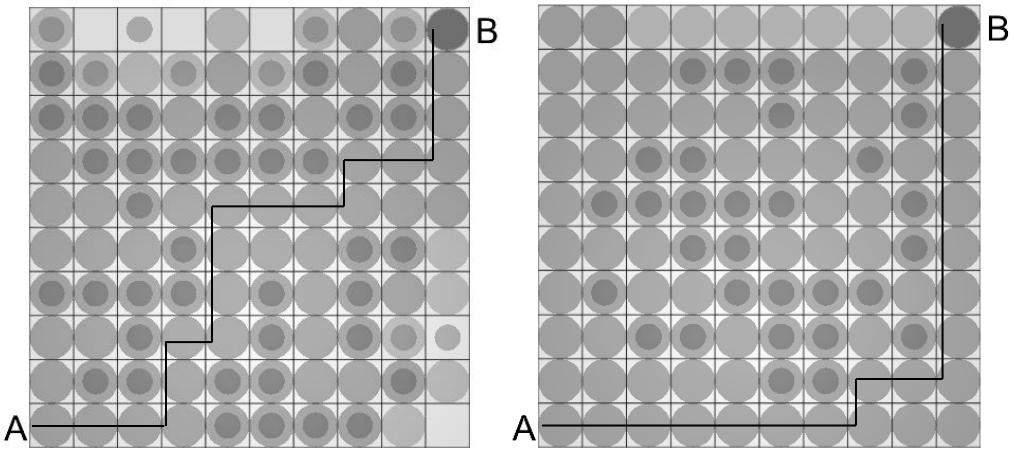

Figure 4: Vacuum cleaner at goal state for different dirt distributions

After each complete milestone, it was demonstrated to the students and the theory explained again. They were given the opportunity to ask questions. The completed standardized milestone was given to them to build upon. In our experience, topics that the students found difficult (such as the quite technical implementation of systematic search), which was initially only one milestone, can be expanded to more milestones. After the assignment and the completion of the intelligent agent part of our AI module, the students were interviewed.

6. RESULTS FROM INTERVIEWS AND DISCUSSION

We are in the fortunate position that we were able to introduce this intermediate module in Artificial Intelligence to our 4th Year IT students in a class of only three students. This is an elective module and since it is new, only three of the thirty students selected it. This will of course change in the future as students get a better understanding of the module through word of mouth. In this section we report on the perspectives of the three students. Because of this small sample reaching data saturation is highly unlikely, yet we can still achieve a clear understanding of their perceptions. The interviews were done using general and specific open-ended questions in a written interview. Various Likert-type scale questions were also asked. From the interpretive content analysis we give recommendations that will be used as a first iteration to refine the instructional process to teach AI. We interviewed the students to establish their perceptions on the following main fields as we have discussed thus far:

1. Using object-orientation to represent an agent-environment and its search tools (including the influence of their prior OOP experience). This was discussed in sections 2 and 3.
2. Their perceptions on the instructional design of the module, including the objects-first and milestone approach of section 5.
3. The success in understanding of the intelligent agent topic.

We now individually discuss the three fields:

1. Using object-orientation to represent an agent-environment and its search tools:

As explained in section 0, a key factor in our motivation for using OOP for the implementation of intelligent agents is the current programming skills of the students and the need to use a mainstream implementation. We first had to establish their understanding of object-orientation. We asked them a number of technical questions on OOP and their explanations were clear. One of the students completed his first Three-year degree at another institution and he reported that he had to catch up on basic theory of object-orientation. We asked them how difficult OOP is and all three reported that it is of medium difficulty. All of them reported to have had previous C# programming experience.

We asked the students to explain intelligent agent concepts after it was recast to an object-orientated paradigm. We asked them open ended questions to assess their knowledge on the theory of intelligent agents. The students demonstrated a clear understanding. One wrote: "Because the intelligent agent is an object, it can therefore be programmed accordingly. The agent needs an environment which also is an object and both of these can have states and behavior." They were asked if the agent class (with its embedded tools such as search) and its environment class (with its drawing methods) were a suitable representation and all strongly agreed. We therefore conclude that the students perceive object-orientation as a suitable representation and that they have a clear understanding of implementing intelligent agents using object-orientation.

2. Instructional design: Objects-first and milestone method:

Corresponding to the instructional sequence of 'object's first' in section 5, we want to understand if the students found it helpful that the agent-environment and tools first be recast to object and explained that way. From the responses about the object representation (field 1 above), they provided clear explanations and showed a clear understanding of the agent abstraction by explaining it in terms of objects.

To understand the perceptions of the students on breaking the large assignment down into milestones, they were asked if they prefer the milestones to a receiving one large assignment and all three preferred the milestone method. One referred to the distribution of effort as motivation for its preference. The other two students highlighted the advantage of receiving code after each milestone in order to be able to achieve the next milestone. We also asked explicitly if object-orientation (separate agent and environment objects, separate search method) and the milestone divisions work well together and all agreed that it did. We conclude that the objects-first and milestone method was successful from the perspective of the students. We conclude that all three students had a positive learning experience.

3. Success in terms of their understanding of intelligent agents:

Overall we wanted to establish if we could use object-orientation in a scriptable game engine to teach intelligent agents. We share here the answers of all three students. 1. "Using the example of the vacuum cleaner helped a lot to understand the application of an intelligent agent in a real world scenario. By programming the sensors of the agent as well as the actuators and rules for an agent helped understanding the ins and outs of how an intelligent agent works and what it is." 2. "A very good implementation and practical use of an agent and made it clear what an agent should do and how it should be done. The assignment gave me a lot of knowledge and gave me motivation when I saw the final milestone in a graphical sense." and

3. "The Assignment helped a lot in understanding how and intelligent agent and its environment work. Because we programmed the agent and saw how it affected and reacted to its environment made it easier to understand than just reading and explaining it". We conclude that the students were successful in their understanding of intelligent agents.

7. CONCLUSION AND FUTURE WORK

Although we only had three students we saw this as an opportunity to understand their experience of the module. Recasting the theory of intelligent agents to the more familiar object-orientation helped them better understand the theory. The students were able to use the Unity scriptable game-engine that allowed them to do an object-orientated implementation that fitted into their prior understanding. It was demonstrated that they had a successful learning experience from the instructional design of objects-first and the Unity milestone assignments.

The perspectives of the students provided invaluable feedback and confirmation for us to continue using a scriptable game-engine in our module and focusing on the OOP implementation. Future work will be pursued by implementing the other AI topics that forms part of our current module, including Local Search methods and Perceptron neural networks.

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USING TECHNOLOGY TOWARDS EFFECTIVE TEACHING AND MEANINGFUL LEARNING IN AN OPEN AND DISTANCE LEARNING COMPUTING CONTEXT

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Abstract–The purpose of this paper relates to exploring academics' technology use towards effective teaching and meaningful learning in an Open and Distance Learning (ODL) Computing context. Literature was studied on academics' technology use towards effective teaching and meaningful learning in an ODL Computing context. An appropriate theoretical and conceptual framework presents main arguments centring on formulating and situating significant concepts, including those related to ODL, throughput and other measures of academic efficiency. The research design, sampling, data collection instrument and the validity and reliability thereof, as well as the data analysis method used, are described. The paper discusses results related to academics' use of technology towards effective teaching and meaningful learning in an ODL Computing context. Conclusions are finally presented on the way in which this paper makes a contribution to fields related to academics' use of technology towards effective teaching and meaningful learning in an ODL Computing context.

Keywords: Technology, Effective Teaching, Meaningful Learning, ODL context.

1. INTRODUCTION

1.1 Problem Statement and Rationale

The constant pressure that is being put on Higher Education Institutions (HEIs) to increase their throughput rates, in order to attract funding from the national government, is a contributing factor to the research interest of this paper - this was specifically mentioned by Pityana (2009) when he referred to trends, progress and challenges relating to Open and Distance Learning (ODL) contexts in the developing world. Improving success and throughput rates is a priority of the national government (Sondlo & Subtozky, 2010). As the national government is the main funding agency for HEIs, there is therefore a need to explore all avenues that could lead to throughput improvement in every educational programme. Botha (2010) explained how each individual academic has a role to play in student throughput - if academics work towards increasing pass rates in their respective modules, this would eventually lead to increased throughput in the programmes of study.

1.2 Aim and Objectives of the Study

The study reported on in this paper represents a single site study of the School of Computing (SoC) in the College of Science, Engineering and Technology at the University of South Africa (UNISA). This higher education institution offers open and distance learning, which draws its student population from all over the world. *my*UNISA is an online technology that offers a range of functions aimed at maximising the collaboration between academics and students.

This study aims at developing a deeper understanding of the various uses of especially online technology, and specifically *my*Unisa, in addressing academic challenges to improving students' academic performance. Academics' commitment to this endeavour is essential, as pointed out by researchers like Cant and Bothma (2010), that the extent and effectiveness of technology usage lies with the academics. The intention is to direct efforts towards improving throughput rate. As affirmed by Botha (2010), the cost of lack of throughput is very high for the learning institution, as well as the students.

The aim of the research reported on in this paper therefore relates to exploring academics' use of technology towards effective teaching and meaningful learning, specifically in the School of Computing at the University of South Africa, which presents an ODL context. In order to work towards achieving this aim, the following objectives will be used as focus for the research reported on in this paper, to indicate quantitatively:

- what the pass rates for selected SoC modules in a specified timeframe looked like; and
- how much academics used various myUNISA technologies in the selected modules.

An indication will also be provided on how qualitative data, relating to how academics use various technologies towards effective teaching and meaningful learning in their modules, and specifically in an ODL Computing context, is being collected.

1.3 Research questions

The research reported on in this paper focuses on the following primary research question:

- How do academics in the SoC use technology towards effective teaching and meaningful learning in an ODL Computing context?

The secondary questions that will assist in delving into the primary research question include:

- What do the gross survival rates look like for selected SoC modules in a specified timeframe?
- How much did academics use various *my*UNISA technologies in the selected modules?
- What are academics' perceptions about the use of *my*UNISA technology?

1.4 Contribution of the Study

The contribution of this study towards the field of effective teaching and meaningful learning is to establish, from academics' perspectives, how especially online technology as a model of support and collaboration could escalate throughput rates in an ODL Computing context. Similar to Mbatha and Naidoo (2010), the results of this research could be used to promote the use of myUnisa technology within the SoC, which may ultimately lead to increased throughput rates in the study programmes offered.

An introduction to the problem statement and rationale of the investigation, the aim and objectives of the study, together with applicable research questions, and the contribution of the study have now been provided. Next, related literature that was studied on academics' technology use towards effective teaching and meaningful learning in an ODL Computing context, are presented to provide an overview of existing research from previous studies, and gaps are identified. An appropriate theoretical and conceptual framework presents main arguments centring on formulating and situating significant concepts, including those related to ODL, throughput and other measures of academic efficiency.

The following section will focus on the research methodology, design, sampling and data collection instruments used. It will also contain an outline of the reliability and validity of the data collection instruments, as well as a description of the data analysis method used. The paper proceeds to discussing the results of the study related to academics' use of technology towards effective teaching and meaningful learning in an ODL Computing context. An analysis of the results will also be provided. A summary of the research results is provided at the start of the conclusion section of the paper. Conclusions are also presented on the way in which this paper makes a contribution to fields related to academics' use of technology towards effective teaching and meaningful learning in an ODL Computing context. Recommendations with regard to further research will also be made.

2. LITERATURE REVIEW

The paper will now proceed to a review of the literature on research into how academics use technology towards effective teaching and meaningful learning, in order to thus increase throughput rates, in some cases in Open and Distance Learning contexts.

Based on the experience of managing a tutorial system in Adult Basic Education Training in the UNISA ODL context, Quan-Baffour (2005) pointed out that many students, especially those from South Africa, are based in rural areas where the number of resources is lacking. Ferreira and Venter

(2011) quantified similar challenges, as many students do not have access to electronic devices for online communication. The latter authors confirmed that myUNISA, as a web-based system, is meant to improve academic interaction, communication between UNISA staff and students and to expand engagement among students. Based on student feedback, Ferreira and Venter (2011) considered barriers to meaningful learning in an ODL context.

Related literature, which in each case presented opportunities for further investigation, included:

- An investigation reported on by Ergul (2004) found no significant relationship between student characteristics such as age and gender and academic performance in an Open and Distance Learning context - this was, however, for application on students at Anadolu University. In their research, Fan and Lee (2007) stated that the quality of students on entry will affect their study outcomes, with their research results showing that background characteristics of students are significant factors affecting their completion of a module.
- While Davis and Venter (2010) looked at drivers of student performance in an Open and Distance Learning context, their students were postgraduate ones in a business module. Improving throughput is a major challenge for higher education institutions, and as recognized by Davis and Venter (2010), one of the drivers towards improving throughput is to improve student performance. Through the academics' efforts to improve performance in their respective modules, overall throughput rates can be enhanced.
- Even though Hörne and Naudé (2002) did carry out a study investigating suggestions for increasing the throughput rate of distance learning students in the School of Computing, the more than a decade since the publication of their study is likely to have seen large changes in technology use. Their focus was also limited to students of a single second year Computer Science module in the SoC.

2.1 *my*Unisa and the benefits of technology

*my*Unisa is an online learning management system which, as described by Mabunda (2010), provides association and support for learning and teaching - the latter author investigated the challenges and implications of using technology to assist with effective teaching and meaningful learning at Open and Distance Learning HEIs. The *my*Unisa system initially ran on the Sakai framework version 2.0.1 (Sithebe & Myburgh, 2006).

Various studies reiterate the importance of student support, specifically in ODL institutions, to enhance overall student performance (Nichols, 2010; Maathuis-Smith et al., 2010). Van Eeden and Dewar (2010) refer to the use of technology in an ODL institution to facilitate support and interaction among students. Their view was also supported by Van Rooyen (2010) in her research about the use of instant messaging application. As it is believed that the system is underutilised, it is recommended (Van der Merwe, 2010) that both academics and support staff will have to acquire new skills to reap the full benefits of online teaching and learning.

According to Mabunda (2010), it is generally accepted that technologies can assist towards effective teaching and meaningful learning. Based on the Korean experience of technology innovations and the development of distance education, Jung (2000) believes that it is instructional design, and not technology, that is at the centre of quality distance education. As pointed out by Bower (2001), however, distance education technologies create a major change in the way instruction is delivered - such technologies are capable of creating an anywhere-and-anytime learning environment (Yukselturk & Bulut, 2007), as well as acting as predictors of student success in e.g. online modules. Risenga (2010) qualifies this notion in his research study by affirming that in typical ODL contexts, students who are not able to meet their academics heavily depend on the communication technology available when attributing their success or failure.

Problems related to geographical distances are minimised through the use of modern technology, because distance students have several means to interact with academics/tutors and their peers (So and Brush, 2008). Therefore, technology orientation is a necessity in increasing students' distance learning receptivity (Zhang, 2005). Also, an online environment may level the playing field where shy or timid students can also participate (Patterson, 2009).

Moody (2004) suggests that lack of technology background may be one of the barriers to learning for a distance education student.

3. THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1 Open and Distance Learning

Subotzky and Prinsloo (2011) presented a socio-critical model and framework for understanding, predicting and enhancing student success, developed at UNISA for an Open and Distance Learning context.

According to Raza (2008), distance education encompasses learning that is not bound by space and time. Breetzke (2007) elaborated that distance education is envisaged as a means whereby previously disadvantaged members of society of all ages can enrol either directly or remotely at a higher education institution at reduced cost. In addition, Pretorius, Prinsloo and Uys (2009) state that distance education has the ability to cross borders, whether national or international. Ng (2008), however, stressed that distance education requires students to consistently regulate their learning processes - this is considered important for students' progress in such contexts.

Cook (as cited in Loh & Smyth, 2010) refers to the social facilitation theory, which states that there is a tendency that people often perform better in the presence of others than alone - distance education does not conform to this theory. In a distance education context, Dennen and Wieland (2007) affirmed that facilitating group discourse is vital, as students should truly engage with each other to gain insight that might not have been possible on their own.

The study reported on in this paper is specifically focused on open and distance learning, which entails the acquisition of knowledge through an education system that offers increased accessibility and flexibility, as compared to traditional on-campus learning. Most ODL definitions stress some special ideals coherently identified with ODL programmes that allow for greater learning flexibility (Jordan, 2009). ODL is viewed as suitable especially for more mature students, due to the convenience, flexibility and self-pacing offered (Yukselturk & Bulut, 2007)

Apart from time and space (or geographical distance), the other key elements of ODL prominent in definitions are academics, students and technology. ODL incorporating forms of active e-learning or online learning is described as an excellent method of reaching the adult learner who desires a high degree of flexibility (El-Bakry & Mastorakis, 2009). When comparing ODL with conventional distance education contexts, where student engagement is limited, Mbatha and Naidoo (2010) postulate that in an ODL context, the transactional distance is minimised and students engage with their peers by forming a learning community.

3.2 Student Throughput Rates and Other Measures of Academic Efficiency

Within the ODL context presented by UNISA, a number of studies have been carried out on student throughput, dropout and retention rates (Botha, 2010; Dreyer, 2010, Subtozky & Prinsloo, 2011; Risenga, 2010). Welsch (as cited in Dreyer, 2010) refers to throughput as the number of students originally enrolled, who complete their whole programme successfully. From the viewpoint of Martins (2007), distance higher education institutions struggle with the problem of student failures and low throughput rates even more than residential higher education institutions. As revealed by the research carried out by Subotzky and Prinsloo (2011), graduation rates of ODL institutions were found to be disturbingly poor. Therefore, as indicated by Sondlo and Subotzky (2010) and Pityana (2009), pressure is put on ODL institutions to increase their throughput - for example, Botha (2010) therefore investigated the role of individual academics in student throughput. Based on academics' perspectives on the learning-technology conundrum, Cant and Bothma (2010) also developed a view of how technology could be used to support collaboration, in order to escalate throughput rates.

In the study reported on in this paper, throughput explicitly refers to qualification completion, but there is a contradiction, as cited by Nichols (2010): there are significant numbers of non-traditional students in ODL, who may only be interested in module completion. Wigforss (2002) elaborated that pass and overall throughput rates are thus lowered, because many such students who drop out stay registered, but won't be included in the performance statistics.

According to Raza (2008), pass rate refers to module or programme assessment, specifically the number of students out of the total entry, or those who sat an examination, who actually passed. Moody (2004) and Wigforss (2002) asked why pass rates were so low and attrition rates so high in distance education modules, such as those at Lund Net University. Such questions led to Tyler-Smith (2006) therefore reviewing factors that contribute to early attrition, dropout, withdrawal and non-completion rates among adult, first-time e-learners undertaking e-learning programmes.

In a similar context, that of the Asian Association of open higher education institutions, Fan and Lee (2007) examined factors and practices for improving student completion rates, by comparing two distance learning modules. Maathuis-Smith et al. (2010) also investigated how higher completion rates and retention could be obtained in an ODL context, with a case study of the strategies employed by their Information and Library Studies Faculty.

Retention rate is calculated from the total number of students enrolled in a module or programme at the beginning of the enrolment period (Maathius-Smith et al., 2010). In order to remove cost barriers when students want to contact their academics, the latter authors asserted that the Open Polytechnic of New Zealand introduced a free telephone number. Determining student retention is a very difficult exercise, but as stated by Allen (2006), student retention and degree completion issues are hot topics among academic administrators. Student retention is very crucial and researchers like Subotzky and Prinsloo (2011) emphasize that enhancing retention is a priority in improving overall success.

Another viewpoint was offered by Nichols (2010), who contemplated student perceptions of support services and the influence of a deliberate and targeted intervention, with the appointment of academic support coordinators in an effort to improve student retention and success in their distance education context. Students also need to be committed to completion with perseverance and academically integrate with peers and their respective institutions in order to secure retention (Tyler-Smith, 2006).

In a case study on dropout in a South African ODL context, Dreyer (2010) refers to dropout students as those who enrolled, but failed to complete their qualification. There are academic and non-academic reasons causing students to withdraw from modules (Maathuis-Smith et al., 2010). These authors singled out the transition to higher education as one of the major problems which may require students to have special assistance with study skills suited for distance education. Tait (2003) affirms that if adequate student support is provided, students gain confidence and their self-esteem is reinforced, resulting in remarkable study progress, which may effectively contribute to reduction in the dropout rate. Another reason for dropout from studying by students was supplied by Tyler-Smith (2006): due to the fact that most distance learning students are already working, they tend to think about growth on the job and register at institutions, only to withdraw after achieving what they think they want.

Woodley (as cited in Nichols, 2010) enlightens the issue that a dropout rate is likely to be determined by both the nature of the student and the characteristics of the higher education institution. Furthermore, students' reasons for dropout are complex and numerous, with personal reasons being more significant than other reasons (Nichols, 2010).

4. RESEARCH METHODOLOGY

4.1 Research Design

Although the study uses a mixed research design, the primary research methodology reported on in this paper is quantitative. Using an interpretive qualitative methodology approach, information is further being gathered from the explanations and views of academics. The choice of this research methodology was based on the need to explore academics' views in order to gain the required understanding of their responses.

4.2 Population and Sampling

The target population is comprised of around 80 academic staff members, which includes all categories from junior lecturers to full professors. These academics are entrusted with students' academic performance. They set both assignments and examinations as a means of assessment. Academics interact with students through emails, telephone calls and one-on-one interaction with some of those students who are able to come to academics' offices. Discussion forums using the online collaboration through *my*UNISA can also be used by academics to support their students. It is on this basis that academics are thought to have insight on use of the available technology towards effective teaching and meaningful learning, especially in an ODL Computing context. Therefore, academics' perceptions about their students' performance abilities are of much value to this research.

The sample of modules being used for the study includes 30 modules that have comparative performance data for six years from 2005 to 2010. The study is limited to undergraduate modules. Therefore, the sample for the study includes the academics that were involved in teaching these 30 modules. Some of the limitations expected in terms of the sample selected include:

- The differing academics' experience with a module, as the situation could be that they may not be offering the same modules every year; and
- Variations in students' performance due to the level of the module offered (Raza, 2008).

4.3 Data Collection Instruments

The primary data that will be reported on in this research paper consist of quantitative data for the 30 modules mentioned above, including the gross survival rates for students in each of the modules for the period indicated, as well as how many times different *my*UNISA technologies were used (in total) per module during 2010.

More detailed information identifying the academics that used various *my*UNISA, the technologies they used and the frequency of use are available, providing quantitative data for discussion with academics. An interview protocol was developed, listing questions to be used during qualitative semi-structured interviews and providing adequate space for recording responses, as well as notes taken while conducting the interviews. It is specifically intended to investigate how academics use *my*UNISA to interact with students and how they encourage their students to interact with their peers using this technology.

A questionnaire linked to the research questions was also designed to explore participants' responses to the issues of *my*UNISA technology usage to improve both pass and throughput rates in their School of Computing modules - it is also distributed and completed during the interview with selected academics.

Qualitative data is thus being gathered and organised on the protocol described. The researcher engages with participants during the process of data collection. In summary, the combination of quantitative data and instruments were thus aimed at trying to find out how the academics use *my*UNISA technology towards effective teaching and meaningful learning in an ODL Computing context.

4.4 Validity and Reliability of Data Collection Instrument and Data Analysis

The research strategies implemented allow for e.g. academics' perceptions being analysed through data triangulation across inquiry techniques and provide the mechanisms for mutual support between qualitative data obtained from the interviews and questionnaires and quantitative data gathered, to consolidate research results. This enables researchers to verify the degree to which assumptions based on qualitative information are reinforced by quantitative perspectives, or the other way around. One such assumption is that academics have information relating to students' performance (or non-performance) in their specific modules.

McMillan and Schumacher (2010) indicated triangulation design strategies as being critical for assisting in the facilitation of increased interpretive validity. Reliability was therefore ensured by triangulating data and paying attention to establishing and increasing data trustworthiness.

In agreement with McMillan and Schumacher (2010), the first author had the qualitative data analysed independently by another more experienced researcher (the second author), who had not been involved in obtaining most of the data - this provided another method for enhancing validity. Then, once agreement had been reached on the descriptive data collected, results could be compared and integrated to obtain a full representation of how academics use technology towards effective teaching and meaningful learning, especially in an ODL Computing context.

A variety of strategies was used to enhance validity, since the research design combined qualitative and quantitative data, including the extent to which interpretations and perceptions had shared meaning between our participants and the researchers. As suggested by McMillan and Schumacher (2010), it was therefore decided how to ensure that the data collected was valid, for example by obtaining advice from an expert researcher on the questions used to ensure internal validity in terms of causal inferences, and by obtaining detailed descriptions of participants and their ODL working contexts for the facilitation of external validation and generalizability. McMillan and Schumacher (2010) agreed that validity in quantitative research includes issues of reliability.

The acquired qualitative data is being compared to the quantitative data of previous years from this higher education institution detailed in this paper - this comparison is beginning to show the effect of using *my*UNISA technology towards effective teaching and meaningful learning in an ODL Computing context. Similarities and differences between academics' responses are identified during data analysis. An analysis of responses is also compared to information obtained in the literature review.

5. DISCUSSION OF RESULTS

Table 1 shows the percentages in terms of gross survival rates for the 30 modules that serve as basis for the study reported on in this paper across the years as indicated. Please note that the module codes indicated are not the actual codes, but coded 'pseudonyms', with COS indicating Computer Science and INF Informatics, while the number indicates whether it is a first, second or third year module. Also shown is the average per module across the years indicated, as well as the number of times that academics assigned to each module used various technologies on *my*UNISA. The 2010 and average percentages, as well as the *my*UNISA use, had been ranked, with e.g. 'INF3E' ranked number one for 2010, as the 80% was the highest rate.

An analysis in terms of the Pearson correlation between the percentages for 2010 and the average is a high 0.815, while the correlation between the rankings of these same columns is slightly lower at 0.782. This analysis has the implications that the gross survival rates across the time period under investigation are fairly consistent; the relative ranking of various modules, however, show more variance.

Since the range for the number of times that *my*UNISA technology had been used (0 to 103) is similar to that of the gross survival rate percentages (0 to 100), Pearson correlations were also completed across these variables – all correlation values obtained in this regard were negative.

Pearson correlation between the percentages for 2010 and the average is a high -0.815, while the correlation between the rankings of these same columns is slightly lower at -0.782.

Table 6. Gross survival rates and myUNISA for selected modules

	Gross survival rate (Percentages)										
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**Ranking**	**Average**	**Ranking**	***my*UNISA**	**Ranking**
INF3E	70	65	61	56	63	80	1	66	4	23	9
COS3C	76	70	71	74	70	78	2	73	2	5	25
INF1A	60	42	57	53	77	77	3	61	8	9	19
COS2E	53	52	64	62	55	72	4	59	11	20	10
IAD3A	41	55	39	17	21	71	5	41	23	4	26
INF3J	77	74	70	73	78	70	6	74	1	6	21
INF3D	59	62	58	62	70	70	7	63	6	15	14
COS3F	66	73	58	49	59	69	8	62	7	0	
INF1B	59	49	45	45	61	68	9	55	12	0	
INF3F	56	63	64	47	66	65	10	60	10	6	23
COS1W	45	46	43	39	59	64	11	49	14	74	6
COS2X	41	52	47	45	47	63	12	49	13	90	4
COS3Y	65	61	61	51	64	60	13	60	9	6	22
INF3G	40	44	53	57	38	60	14	49	17	103	1
INF3H	72	76	71	72	73	59	15	70	3	18	12
COS2C	71	71	54	71	59	58	16	64	5	13	17
COS2D	39	41	48	39	56	57	17	47	19	7	20
MNI2A	53	39	51	44	57	49	18	49	16	6	24
COS1S	38	44	32	34	42	47	19	40	24	98	2
COS3A	44	32	27	37	47	44	20	38	25	15	16
COS3B	55	56	37	32	36	44	21	43	20	0	
COS2V	40	41	46	38	46	43	22	42	21	18	13
IAD3B	16	45	51	54	43	43	23	42	22	40	7
COS3D	52	55	29	69	46	43	24	49	15	15	15
COS1V	33	29	23	29	39	40	25	32	28	20	11
COS2A	41	36	31	56	25	32	26	37	27	12	18
IAD2B	43	53	52	62	43	31	27	47	18	96	3
IAD2A	17	46	42	44	46	29	28	38	26	24	8
COS2F	22	12	15	17	25	24	29	19	30	0	
COS1U	33	32	32	18	18	19	30	25	29	82	5

6. CONCLUSION

Apart from the rationale around the problem as explained in the introductory section, the merits of the study reported on in this paper and the relevance for this conference was further justified with regard to the frequent changes related to technology that academics have to contend with, as detailed in the literature study. The implications that the changing roles of computing academics have for supporting students affectively, administratively and academically were also investigated.

This paper included discussions on results indicating quantitatively what the pass rates for selected SoC modules in a specified timeframe looked like, and how much academics used various myUNISA technologies in the selected modules. Similar to certain aspects of the article by Mbatha and Naidoo

(2010), the results of the research reported here could make a significant and original contribution regarding emerging trends in, and the promotion and development of knowledge in fields related to, academics' use of technology towards effective teaching and meaningful learning in an Open and Distance Learning Computing context.

In terms of further research in this regard, an indication was also provided on how qualitative data, relating to how academics use various technologies towards effective teaching and meaningful learning in their modules, and specifically in an ODL Computing context, is being collected. The information thus being gathered is revealing whether there is improved student performance in modules offered by academics that frequently use myUNISA …

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A MULTIFACETED THEORETICAL FRAMEWORK THAT INFORMS HIV/AIDS KNOWLEDGE BASE FACTORS CONTRIBUTING TO HIGH PREVALENCE RATES

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Abstract–South Africa was estimated to have about 5.6 million of the global HIV/AIDS infections of 35.3 million people in 2011, the highest prevalence in the world. Three models, namely The Theory of Planned Behaviour (TPB), The Information Motivation Behaviour Skill Model (IMB) and The Social Ecology Theory (SET) have been used separately as models to carry out HIV/AIDS interventions in South Africa. These models were narrow in their perspectives and the interventions had short- lived effects. A multifaceted theoretical framework that informs HIV/AIDS knowledge based on factors contributing to high prevalence rates will be developed to effectively describe HIV/AIDS behaviour and prevention. Grade 11 students will participate in the study.

Key words: Framework, HIV/AIDS behaviour, intention, knowledge and social ecology.

1.1 INTRODUCTION

1.1.1 Background to the study

South Africa was estimated to have about 5.6 million (WHO, 2013) of the global infections of 35.3 million people (UNAIDS, 2013) in 2011, the highest HIV/AIDS prevalence in the world (Ijumba, 2011).

Reports from 2002-2010 showed that HIV/AIDS prevalence in ages of 2-14, 20-24 and 15-24 decreased in South Africa (Global AIDS response progress report, 2012). Gauteng province had the fourth highest in prevalence in the period between 2009 to 2010 in the age group 15-49 (Global AIDS response progress report, 2012).

Antiretroviral therapy (ART) prolonged life expectancy by 5 years in South Africa, nevertheless, HIV/AIDS causes untimely death of many adolescents (Smith, 2012; Zuma, 2009). Gauteng and Kwa-Zulu-Natal have the highest HIV/AIDS related deaths (Anso, 2013). There is a need to develop an HIV/AIDS knowledge based on factors that contribute to high prevalence resulting in deaths in order to develop a practical model that can inform the development of interventions to reduce HIV/AIDS infection and deaths.

These three models, The Theory of Planned Behaviour (TBP), The Information Motivation Behaviour Skill Model (IMB) and The Social Ecology Theory (SET) have been used separately as models to carry out HIV/AIDS interventions in South Africa. The three models were narrow in their perspectives and the results of the interventions were short- lived. TPB relies on intentions, IMB on knowledge and SET on social systems that influence behaviour to reduce HIV/AIDS. Intentions may change with time, knowledge may not equal behaviour and perceived social norms differ from actual social norms. It is hoped that the model developed during this study will provide a guiding, holistic framework in developing future interventions.

These three models will be integrated into a framework in order to address other determinants of HIV/AIDS infection besides behavior and to fill the gap of the narrow perspective and short lived effects of each model based intervention. While a number of studies have separately used the above models to understand HIV/AIDS behavioural prevention, no study has attempted to develop a framework that combines all three.

Kelly, Mkhwanazi, Mkhwash, Rapiti and Mashale (2012) argued that research on HIV infection focus more on behaviour (and related theories) and pay little attention to the socio ecology of HIV as determinant of HIV infection and environmental factors that contribute to susceptibility of HIV-infection. Ndebele, Kasese-Hara & Greyling (2012) attest to the above argument by stating that if the IMB intervention strategy has to decrease HIV/AIDS infection amongst adolescent it should consider all aspects of the adolescent's life. It is hoped that the new model will explain other determinants of HIV/AIDS infection that have not been recognized by the above mentioned three models.

Assumptions based on cognitive behavioural theories suggest that informed and well-motivated individuals will avoid risk but the behaviour is influenced by wider socioeconomic, cultural and environmental factors (Global HIV Prevention Working Group, 2008). A valid program that affects social norms, institutions and cognitive behavioural interventions is needed, "although to date social and ethnographic research studies have not been sufficiently used to inform behavioural intentions" (Global HIV Prevention Working Group, 2008, p.6). A valid framework would be used to develop the programmes.

1.1.2 Rationale for the study

The HIV pandemic is a global challenge that world nations have been grappling with to find a solution over three decades. Gauteng and Kwa-Zulu-Natal has the highest HIV/AIDS related deaths (Anso, 2013). The HIV/AIDS prevalence of Gauteng province needs to be reduced by a framework that will be used to develop effective interventions.

Interventions were implemented in South Africa separately using TPB, IMB and SET (Jemmott, Heeren, Ngwane, Hewitt, Jemmot, Shell & O'Leary, 2007; Ndebele *et al.,* 2012; Page, Ebersohn & Rogan, 2006). These interventions were narrow in perspective (Global HIV Prevention Working Group, 2008). A holistic framework will be broader in perspective. The IMB model upholds that an informed, well-motivated person with HIV/AIDS preventive behavioural skills will carry out the behavior, but this model sustains behavioural change for a short period (Global HIV Prevention Working Group, 2008). There may be other criteria besides knowledge and motivational skills that will enhance HIV/AIDS preventive behaviour amongst adolescents in order to reduce exposure to HIV/AIDS infections. Adolescents may lack the intent, motivational skills or the volitional control to carry out HIV/AIDS preventive behaviour after acquiring the skills. TPB states that intention and perceived behaviourial control influences behaviour (Ajzen, 1991). Intentions are the desire to carry out a behaviour (Ajzen, 1991; Ajzen & Madden, 1986). TPB was employed to find out what the extent of condom use of Xhosa speaking people of South Africa is (Jemmott *et al*., 2007). Part of the sampled population had weak intentions, others had beliefs which prevented them from using condoms and some lacked skills to use condoms effectively (Jemmott *et al*., 2007). It was advocated by Jemmott and others that the adolescents should be taught that condom use does not prohibit sexual enjoyment, and adolescents should be taught how to use condoms effectively (Jemmott *et al*., 2007). Intentions alone is not enough reason why a person takes a decision to adopt HIV preventive behaviour such as condom use that will reduce HIV/AIDS infection. The SET was criticised because behaviour change is influence by social norms (DiClemente, Salazar, & Crosby, 2006). Perceived social norms differ from actual social norm (DiClemente *et al.,* 2006). Adolescent that lacks knowledge on factors contributing to HIV/AIDS high prevalence rates may be influenced by myths, superstitions and ill-conceived social norms especially by their peers, therefore, the behaviour change such adolescents may adopt will increase HIV/AIDS infections.

Behavioural interventions reduce adolescent sexual risk behaviours for a short period (DiClemente *et al.,* 2006). Interventions that use multiple theoretical frameworks may have long lasting effects.

Behaviour interventions model rely on individual-level models (DiClemente *et al.,* 2006). Ndebele *et al*. (2012), carried out an intervention using the IMB model and said that the IMB model should consider the social, structural, cultural and environmental factors of the adolescents life in order to be effective in reducing HIV/AIDS infection. Kelly *et al*. (2012) identified that research attributes the factors that contribute to high HIV/AIDS prevalence in South Africa to behaviour and pay little attention to the social ecology of HIV that contributes to HIV infection. Research failed to combine programmes that address individual, interpersonal and social determinants of HIV infection (Kelly *et* *al*., 2012). It is hoped that the combination of these three models into a single framework will provide a holistic explanation of other determinants of HIV/AIDS infection.

Are these intervention models reliable to combat HIV? The study will develop a multifaceted theoretical framework using TPB, IMB and SET in order to inform HIV/AIDS knowledge base on factors contributing to high prevalence rates in Gauteng province.

1.2 RESEARCH QUESTIONS

The main research question is:

How can the development of a multifaceted theoretical framework inform HIV/AIDS knowledge base on factors contributing to high prevalence rates?

The sub-questions that will support the main question are:

I. To what extent does The Theory of Planned Behaviour effectively explain factors that show an association to the spread of HIV/AIDS among learners in Gauteng province?
II. To what extent does The Information Motivation Behavioural Model effectively explains factors that show an association to the spread of HIV/AIDS among learners in Gauteng province?
III. To what extent does The Social Ecology Theory effectively explain factors that show an association to the spread of HIV/AIDS among learners in Gauteng province?
IV. What other factors, not integrated into The Theory of Planned Behaviour, The Information Motivation Behavioural Model and The Social Ecology Theory, show an association to the spread of HIV/AIDS among learners in Gauteng province?

1.2.1 Assumptions about intervention models and behaviour

The researcher holds the following assumptions:

a) HIV/AIDS behavioural interventions are believed to produce short term positive behaviour.
b) Current HIV/AIDS interventions focus on personal factors such as behavioural intentions, knowledge, and motivation but not on socioeconomic and cultural factors that affect behaviour change.
c) There is more focus on behaviour as the determinant of HIV/AIDS infections and less on structural, social, cultural, economic and environmental factors that contribute to susceptibility of HIV/AIDS infection.
d) There is no single best intervention that relies solely on TPB, IMB and SET based models.

1.3 PURPOSE OF THE STUDY

The study will develop a multifaceted theoretical framework using TPB, IMB and SET in order to inform HIV/AIDS knowledge base on factors contributing to high prevalence rates in Gauteng province.

2.1 LITERATURE REVIEW

2.1.1 Theoretical approach to the study: a conceptual framework

The Theory of Planned Behaviour, The Information Motivation Behaviourial Model and The Social Ecology Theory will be used to formulate a conceptual framework that will be used to answer the research question. The researcher will investigate how the intervention is able to explain the knowledge base on factors that contribute to the spread of HIV/AIDS infection on grade 11 learners' under the following sections: i) The Theory of Planned Behaviour, ii) The Information Motivation Behavioural Skill Model and iii) The Social Ecology Theory.

2.1 .2 The Theory of Planned Behaviour

The Theory of Planned Behaviour is similar to The Theory of Reasoned Action but extends the latter by incorporating behavioural control. That is behaviour that people do not have complete control over or decision to carry out. The Theory of Reasoned Action describes the intention to engage in HIV/AIDS risk behaviour (Ajzen & Madden, 1986). When adolescents adopt HIV/AIDS risk free behaviour it will reduce HIV/AIDS infection. According to the TRA behaviour intentions would be influenced by personal and social motivation (Ajzen, 1991; Ajzen & Madden, 1986). TPB sees intention as a desire to practice a specific behaviour (Ajzen, 1991; Ajzen & Maddenm 1986). Attitudes, subjective norms and behavioural control influence the intention to carry out behaviour (Ajzen, 2011; 2002; 1991). Attitudes show how you review the behaviour (Ajzen, 2011; 1991) and subjective norms are the perceived societal pressures that may promote or prevent carrying out the behaviour (Ajzen, 2002). Perceived behavioural control asks if the resources, opportunities and behavioural skills to perform the behaviour are present (Ajzen, 2002; 1991). Behavioural intentions can be actualised if the behaviour is under volitional control (Ajzen, 1991). Perceived behavioural control shows perceptions of how simple or complicated it will be to carry out the behaviour (Ajzen, 1991). It is difficult to measure actual behavioural control before observing the behaviour (Ajzen & Madden, 1986). Perceived behavioural control is compared to Bandura's self-efficacy (Ajzen, 2002; 1991). Perceived self-efficacy is beliefs about one's ability to have control over one's level of performance and events that influence their lives (Ajzen, 2002; 1991). Intentions may change with time. Attitude, subjective norms and Perceived behavioural control may be judged to be right but perceived self efficacy may differ from the actual self efficacy preventing behaviour to reduce HIV/AIDS.

Beliefs affect behaviour (Ajzen, 2002), that is, beliefs about ones ability to perform the behaviour and beliefs about other people's feelings concerning the behaviour. Behavioural beliefs are beliefs concerning the outcomes of the behaviour, normative beliefs are beliefs concerning the expected norm and control beliefs are reasons that will drive or hinder you to carry out that behaviour (Ajzen (2002). TPB undermines information, and states that information is not a true determinant of behaviour (Fisher, Fisher, Bryan, & Misovich, 2002). Information alone is not adequate to encourage HIV/AIDS-prevention behaviour (Fisher & Fisher, 1992). Lack of information may hinder the performance of HIV/AIDS preventive behaviour as information may enhance adolescents adopting behaviour that will reduce HIV/AIDS infections.

Research carried out amongst Xhosa speaking adolescents South Africans using the TPB model reveals that basic measures to enhance the behavioural intention to use condoms will include knowledge and skills (Jemmott *et al.,* 2007). The gap created by omitting knowledge and skills in TPB will be filled by integrating the three models into a framework.

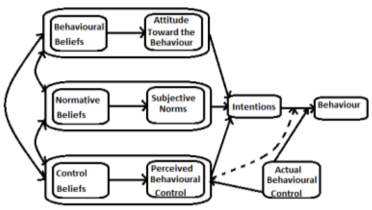

Figure 2.1: Theory of Planned Behaviour (adopted from Ajzen, 2006)

Jemmott and others drew upon TPB to identify the determinants of condoms use intention among Xhosa adolescence in Mdantsane Township of South Africa (Jemmott *et al*., 2007). They found that attitudes and perceived behavioural control showed intention to use condoms but subjective norms did not (Jemmott *et al*., 2007). Adolescents with a positive attitude towards condom use and self efficacy had firmer intentions than those with weak attitudes (Jemmott *et al*., 2007). There were diverse consequences of condoms use on sexual pleasure, ability to bargain for condom use and correct use of condoms (Jemmott *et al*., 2007). Adolescents with weak intentions needed knowledge to change their beliefs that condom use is pleasurable, and to develop condom negotiation and use skills (Jemmott *et al*., 2007). The omission of information in TPB implies that intentions, subjective norms and perceived behavioural control may not be adequate to promote use of condoms to reduce HIV/AIDS infection.

TPB was employed by Mausbach*,* Semple, Strathdee and Patterson (2009), to predict safer sex intentions and protected sex in a sample of heterosexual HIV-negative drug users. The sampled group showed safe sex intentions (Mausbach *et al*., 2009). Safe sex intentions may change with time and a combination of the three models into a single framework will address the changes that occur in intention with time.

2.1.3 Information Motivation Behaviour Skill Model

The Information Motivation Behavioural Model is a model for motivating and reviewing HIV/AIDS-risk behavioural change among different populations (Fisher & Fisher, 1992). The IMB model was proposed by Fisher and Fisher (1992) after reviewing (HIV/AIDS)-risk-reduction literature on interventions targeting risky sexual behaviour and the use of intravenous drugs.

The IMB model states that, HIV/AIDS risk can be reduced by information about how HIV/AIDS can be transmitted and prevented, motivation to reduce risk, and behavioural skill to perform specific action to reduce risk (Fisher & Fisher, 1992).

The IMB model is based on health behavioural theory that HIV/AIDS knowledge, attitudes and intentions influence performance of HIV prevention behaviour (Ndebele *et al.,* 2012). HIV/AIDS prevention is based on information on HIV transmission and on how to practice preventive behaviours (Fisher & Fisher, 1992). This statement contradicts TPB that information is not a true determinant of behaviour (Fisher *et al.,* 2002). Although information alone may not determine behaviour, the absence of information may hinder the practice of behaviour as seen with the adolescents that lacked condom use skill (section 2.1.2). The motivation to practice behavioural intention in IMB takes it root from the theory of reasoned action by Ajzen's that personal and social motivation would influence intentions to practice safe behaviour (Singh, 2003; Ajzen & Madden, 1986).

According to IMB, three factors determine reduction of exposure to HIV/AIDS (Fisher & Fisher, 1992):

a) Information.
b) Motivation.
c) Behavioural skills.

Different populations need specific HIV/AIDS prevention information and specific motivation to perform specific behavioural skills (Fisher & Fisher, 1992). Empirically, information alone showed little impact on behaviour, information is not sufficient to motivate HIV/AIDS-preventative behaviour (Fisher & Fisher, 1992). The new framework may result in a comprehensive practical model to reduce HIV/AIDS infection amongst adolescents when used to developed interventions. The importance of information in reducing HIV/AIDS prevalence rate amongst adolescents cannot be over emphasised.

The IMB model incorporates three steps, the first step involves elicitation research that is, initial research to discover the target population, the second step involves empirically targeted intervention and the third stage is evaluation research (Fisher & Fisher, 1992). The incorporation of these three stages into the new framework will increase effectiveness.

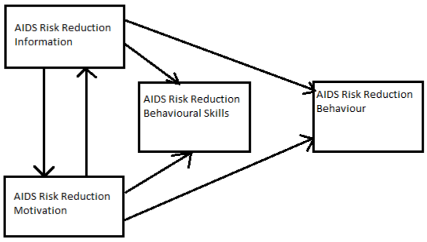

Figure 2.2: Application of Information Motivation Behavioural Skill (IMB) Model (adopted from Fisher, and Fisher, 1992).

IMB model interventions have been used in USA, South Africa (Ndebele *et al.,* 2012; Kalichman, Simbayi, Cain, Jooste, Skinner & Cherry, 2006), and in India (Singh, 2003). As was mentioned earlier the IMB model intervention has been used to study health related risk behaviours among various populations (Ndebele *et al.,* 2012; Fisher *et al.,* 2002). The IMB model has been used for intervention of risk behaviour of HIV in a classroom intervention, peer-based intervention and a combination of the two (Ndebele *et al.,* 2012; Singh, 2003; Fisher *et al*., 2002; Fisher & Fisher, 1992). The IMB model has been employed to investigate changing HIV/AIDS risk behaviour among university students in India (Singh, 2003). There was positive change in information but HIV education focuses on information while it neglects other aspects of behaviour change (Singh, 2003). Information alone is not sufficient to change complicated behaviour (Singh, 2003). Information will be a force for the adolescents to use for the fight against exposure to HIV/AIDS infection.

The IMB model was used by Fisher *et al.* (2002), to investigate HIV risk behaviour in inner city high school youth, the intervention was performed in three different groups. The groups were class-room based, peer-based and a combination of class-room based and peer-based. The authors found that class-room based intervention did sustain HIV prevention behavioural changes but peer-based intervention did not. Class-room based intervention was taught by the class teachers. Peer-based intervention taught by the peers was ineffective in sustaining HIV pretention behavioural changes (Fisher *et al*., 2002). Adolescents are influenced by peer pressure, but the study of Fisher and others proved that intervention taught by peers was ineffective so peer pressure influence should be used with caution.

Ndebele *et al*. (2012) conducted research using the IMB model as a framework on HIV-risk behaviour among adolescents in high schools in South Africa. Their research was based in Alexandra Township where they explored the effects of an IMB model-based intervention on the behaviour of grade 11 learners (Ndebele *et al*., 2012). They observed that the intervention facilitated behavioural change although the change was attributed to effect size and proximity of schools (Ndebele *et al*., 2012). The behaviour of learners was influenced by socio-cultural factors, which was not incorporated in the IMB model (Ndebele *et al*., 2012). The availability of information is not sufficient for behavioural change as other factors contribute to influence behaviour and reduce the incidence of HIV/AIDS infection. This study will integrate the three models into a framework to address other factors that contribute to HIV/AIDS prevalence that may be identified. IMB is limited because it does not take the socio-economic and environmental conditions of the learner into consideration for example the societal environment and the school community of the learner. This was echoed by Kelly *et al*. (2012), that models used to determine HIV/AIDS epidemiology in South Africa pay little attention to the socio ecology of HIV and has not built a programme that targets individual interpersonal, community and social determinants of HIV infection. The multifaceted theoretical framework will address the issue of social, economic and environmental factors that influence the spread of HIV/AIDS infection.

2.1.4 Social Ecology Theory

Bronfenbrenner developed the ecology of human development model. He argued that understanding human development requires observation of behaviour and an examination of the interaction between structures and the persons in these structures (Bronfenbrenner, 1977).

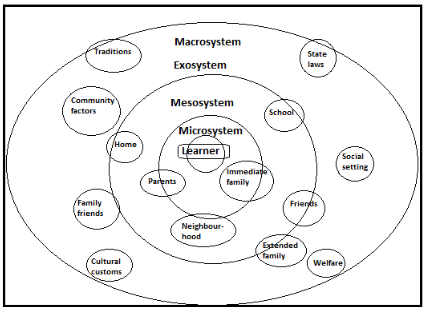

Figure 2.3: Application of The Social Ecology Theory to school learners' (adopted from Page, Ebersohn & Rogan, 2006).

SET focuses on a complete bidirectional relationship between a person and his environment as in an ecosystem (Bronfenbrenner, 1979). The five systems identified are the microsystem, exosystem, mesosystem, macrosystem and the chronosystem (Bronfenbrenner, 1994). The microsystem is immediate environment of the child such as the home, classroom and testing room (Bonfenbrenner, 1979; 1977). The mesosystem a system of microsystems includes the interactions amongst family, school and peer group (Bonfenbrenner, 1979; 1977). The exosystem is an extension of the mesosystem (formal and informal social structures) such as work, neighbourhood, mass media and government agencies (Bonfenbrenner, 1977). The macrosystem is a model in the culture such as a blueprint for schools (Bonfenbrenner, 1977, p. 515)

The chronosystem are the changes that occur with time (Bonfenbrenner, 1994), such as changes in life structures, socioeconomic, place of residence, employment status. Ecology theory incorporated time into the interaction of individuals with the environment (Renn and Arnold 2003). The context of time and changes in intention that occur with time was excluded in the TPB but will be incorporated in the new model.

Bronfenbrenner's SET can be used to study human development, human behaviour and to evaluate interventions (Bronfenbrenner, 1994; 1979; 1977; Page *et al.,* 2006)**.** Ndebele and her colleagues identified Alexandra as an impoverished community (Ndebele *et al.,* 2012, p.37) and said for maximum effect of the IMB based intervention to prevent HIV risk behaviour among adolescents, the structural and socio-cultural context of the adolescents should be measured. The behaviour and life of the learner beyond the school has to be investigated. The immediate school and other environments of the child affect the behaviour of the learner that may reduce HIV/AIDS infection.

Bronfenbrenner's SET was adapted as a framework to evaluate the effect of school based HIV/AIDS Biology intervention on the knowledge and attitude of Grade 11 learners (Page *et al.,* 2006). The researchers found that learners' knowledge and beliefs improved significantly (Page *et al.,* 2006). The macrosystem prevented or contributed to the spread of HIV. The exosystem shows major factors that contributed to the spread of HIV/AIDS. The mesosystem affects learner adopting safe HIV behaviour or risk behaviour. The microsystem reveals that learners could talk to their parents about sex and HIV/AIDS (Page *et al.,* 2006). Page and others evaluated the effects of the Biology intervention on learners but did not measure the changes in behaviour (Page *et al.,* 2006). This study will seek to explore the solution of this limitation using SET**.**

Keyon (2013) used SET to investigate the association of HIV prevalence and concurrence of sexual partnership in South Africa's language groups. Economic differences did not influence HIV spread amongst racial groups, although he suggested it is important to explain HIV prevalence differences between black South African language groups (Keyon, 2013). Three risk factors strongly associated with increase in prevalence of HIV/AIDS were multiple partners per year, point of concurrency and low condom use (Keyon, 2013). Prevalence rates vary between South African language and racial groups (Keyon, 2013). High prevalence occur with concurrency in sexual partnerships in South Africa's most affected language group (the black language group) and proposed interventions to promote having one partner at a time (Keyon, 2013).

2.2 METHOD

This study will develop a framework from a pragmatic worldview and mixed research method. Pragmatics focuses on what works, the study will focus on a more explanatory framework that can be used to develop intervention to reduce HIV/AIDS infection.

The mixed method combines quantitative and qualitative methods of investigation (Creswell, 2009; Onwuegbuzie & Collins, 2007; Johnson, Onwuegbuzie & Turner, 2007). The mixed method will overcome the limitations of either the quantitative or qualitative method (Creswell, 2009; Onwuegbuzie, & Collins, 2007). The mixed method of investigation was chosen in order to answer the research question which has sub questions directed towards getting precise and in- depth data. Substantial data will be collected, the researcher is willing to collect sufficient data.

The results of the study will be generalised and the mixed method will increase the reliability (Creswell, 2009). The study will employ an explanatory sequential design which collects and analyses the quantitative data, and seeks an explanation from the qualitative methods (Creswell, 2012; Morgan & Sklar, 2012). This design will help the researcher to focus on collecting and analysing either quantitative or qualitative data at a time.

The study will be a case study, which is the knowledge base on factors contributing to high HIV/AIDS prevalence rates in Gauteng province.

2.2.1 Research instruments

Three questionnaires, interviews and documentation will be used. The questionnaires for sub questions 1 to 3 will be developed and adopted (e.g. Ajzen, 2006; Fisher & Fisher, 1992; Page *et al.,* 2006). For questions related to TPB, the researcher will adopt the work of Ajzen's to develop the questionnaire (Ajzen, 2006), for IMB a modified version of the 'Teen health survey' developed for IMB will be adopted (Fisher & Fisher, 1992) and for SET, the researcher will adopt the work of Page *et al.,* (2006) to develop questionnaire to assess the learners. Ajzen's work explains how to construct a TPB questionnaire, Fisher and Fisher's questionnaire was developed for IMB and Page and others adopted the SET as a framework for their research. The TPB, the IMB and the SET are the three models that will be integrated into a framework in this study. Semi structured interview questions will be developed and documentation will be used to answer sub question 4.

Three hundred grade 11 learners will be purposively sampled from three schools. This is a proposal, no data has been collected, and an input will be appreciated.

Table 2.2: Overview of method

1.	Instrument development: Formulated & adopted		
2.	Pilot test questionnaires/interviews:	Content/face validity	
		Understanding	
		Time	
		Reliability	
	Phase 1-3, TPB, IMB & SET (Grade 11n=30)		
	Phase 4.1-4.2, QUAL		
3.	Analyze pilot data		
4.	Modify questionnaires & procedure		
5.	Purposive sample	(Grade 11 n= 300)	
6.	Phase 1-3 collect data QUAN	week 1	2 months
		week 3	
		week 5	
	Phase 4.1-4.2 collect data QUAL	week 7	1 month
		week 8	
	Analyze Phases 1-3 data:	week 1 – 9 (QUAN)	
	Repeat cycle as in Delphi method if data is not saturated		
		week 10	2 months
	Retest Phase 1-3	week 12	
		week 14	
	Retest Phase 4.1-4.2,	week 16 (QUAL)	
	Analyze data:	week 10 (QUAN & QUAL)	

2.2 Instrument validity and reliability

Internal validity shows control of external factors so as not to influence the result while external validity refers to the ability to generalize the results (Seabi, 2012).

Credibility of data explains whether results are realistic to participants and readers (Di Fabio & Maree, 2012). Trustworthiness shows how honestly data is collected, stored and classified (Di Fabio & Maree, 2012). For internal validity, to ensure there is no selection bias a pre-test will be done to certify no pre-test differences between the groups (Seabi, 2012). Attrition is when participants withdraw from a study, the researcher will use a large sample of 300 learners (Seabi, 2012) so that participants withdrawal will not pose a challenge to the research. For external validity and ecological validity, the researcher will do a test re-test to ensure generalisation. For population validity the researcher will carry out pre test measurement to show that there are no differences between the sample and the population (Seabi, 2012). The data will be validated through member checking (Creswell, 2012). Validity of data shows how true the findings and interpretations are (Creswell, 2012). Five learners will be randomly chosen to do member checking to read the result and report if it is a representation of truth.

Reliability shows how consistent and stable the scores from the test instruments are, test reliability will be conducted by testing and re-testing (Creswell 2013). A Cronbach alpha scale above 0.7 will be considered as indicative of reliability.

2.2.3 Data processing

Quantitative data will be captured from questionnaires into Excel and analysed through inferential statistics, including multivariate analysis using *SPSS*. Qualitative data will also be calculated, through thematic analysis and frequencies using *ATLAS TI*.

The findings will be disseminated by thesis, conferences and research articles.

2.2.4 Ethics

The researcher will obtain permission from University of Pretoria, the Gauteng Department of Education, the school authorities, the guardians and learners.

3.1 CONCLUSION

Gauteng province of South Africa has high HIV/AIDS prevalence rate. HIV/AIDS interventions based separately on these three models The Theory of Planned Behaviour, The Information Motivation Behavioural Model and The Social Ecology Theory was carried out in South Africa (Jemmott et al., 2007; Ndebele et al., 2012; Page et al., 2006). Literature studies showed the limitations of narrow perspective and those interventions based on these models had short-lived effects on HIV/AIDS infection (Global HIV Prevention Working Group, 2008; DiClemente et al., 2006). No single study has combined these three models into a single framework. A South African model that combines these three models will be developed for the fight against HIV/AIDS.

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ATTITUDES OF POSTGRADUATE EDUCATION STUDENTS TOWARDS QUANTITATIVE RESEARCH MATTERS

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Abstract–Postgraduate students often experience quantitative matters anxiety, usually related to a combination of an underlying mathematical fear and their lecturers' style of learning facilitation. This research aims to determine whether the attitudes toward quantitative matters of a group of postgraduate education students changed over time. Pre- and post-course attitudes towards quantitative matters of 130 postgraduate education (honours and coursework masters) students, enrolled for two courses facilitated by the same lecturer at the University of Johannesburg in 2013, were measured. The internationally recognised *Survey of attitudes toward statistics* instrument of Candace Schau (2003) was, with her support, converted into a *Survey of attitudes towards quantitative matters* (SATQ), maintaining its integrity. By using descriptive and inferential statistics (a paired t-test), it is demonstrated that participants' post-course attitudes show significant improvement from their pre-course stance. Multiple reasons for this attitudinal change over time may exist and demand further investigation.

Keywords: Attitudes towards quantitative matters; Measurement of attitudes; Postgraduate student attitudes; Attitudes towards statistics; Change in attitudes over time.

1. BACKGROUND CONTEXT AND PURPOSE

The majority of postgraduate students (as many as 80% in some of the studies) experience anxiety and even fear of being introduced to and expecting to gain competence in respect of quantitative research matters and methods (Coetzee & Van der Merwe, 2010; Garfield, Hogg, Schau & Whittinghill, 2002; Mills, 2004; Mulhern & Wylie, 2004; Onwuegbuzie, 2004; Schau, Stevens, Dauphinee & Del Vecchio, 1995).

Students' attitudes toward, and feelings, beliefs and perceptions about quantitative research, and its statistical and mathematical foundations, may curb meaningful learning and as a result, teaching quantitative research can and does become a major pedagogic challenge (Onwuegbuzie & Daley, 1999). Many students express and project negative attitudes upon entering quantitative research courses, viewing them (and especially their statistical and mathematical roots) as "…learning and survival tasks that cause a great deal of stress" (Schau, 2003, p. 5). In response to this, increasingly more postgraduate educators believe that students' initial attitudes toward quantitative research matters should be detected (Gal, Ginsburg, & Schau, 1997). Coetzee and Van der Merwe (2010) conducted such an inquiry at a South African higher education institution, involving 111 undergraduate and 124 postgraduate students in Industrial and Organisational Psychology. They confirm the reliability and validity their instrument, a reputable attitudes toward statistics questionnaire, known as the SATS-36 (Schau, 2003) for their South African sample. They (2010, p. 8) afterwards recommend that "future research could further investigate how student's attitudes towards statistics develop or change over time", by using the pre- and post-measurement versions of their questionnaire.

This paper reports on the pre- and post-course attitudes of a group of postgraduate (honours and coursework masters) students towards quantitative research matters. A converted version of the abovementioned SATS-36 survey has been used to determine quantitative matters attitudes of these students, as explained later in the paper. The research question that is addressed is: Do the attitudes toward quantitative matters of a group of postgraduate education students, who participated in a quantitative research course at a South African higher education institution change over time? The overarching goal of the research project (of which this paper forms part), is to devise strategies, which postgraduate educators and/or supervisors can use to positively influence students' attitudes towards the quantitative research domain.

2. LITERATURE PERSPECTIVES: MEASURING STUDENT ATTITUDES TOWARDS STATISTICS AND QUANTITATIVE MATTERS

2.1 Societal demand for quantitative literacy

One only has to be a regular television news watcher to become aware of the large volume of quantitative interpretations that are made on a daily basis (sometimes inappropriately, we may add). People at all levels and in a range of fields are increasingly expected to interpret quantitative information in a variety of formats; analyse and represent data, and take decisions based on these analyses and interpretations. News anchors, presenters, and journalists, for example, need a refined appreciation of quantitative matters to enable them to develop an informed understanding of the events they report on. Likewise, business people in a wide scope of corporate fields also have to deal with planning, scheduling, budgeting, and decision making based on quantitative matters (Rocconi, Lambert, McCormick & Sarraf, 2013).

More than two decades ago, the USA Secretary's Commission on Achieving Necessary Skills (SCANS, 1991, p. iii) expanded the traditional '3 R's' basic requirement for employment (i.e. **r**eading, '**r**iting and '**r**ithmetic), by emphasising five "foundational competencies…needed for a solid job performance". These competencies entail the productive use of resources, interpersonal skills, information, systems and technology, and an underlying golden thread of **quantitative literacy** (QL) prominently features in all five. Steen (2002, p. 8−9) defines QL as the "quantitative reasoning capabilities required of citizens in today's information age" and underscores the view of the University of Yale Mathematician, Roger Howe: "Business would be 'ecstatic' if graduates were quantitatively literate".

The demands imposed by modern society and employers on the higher education sector (and other educational providers) regarding quantitative matters empowerment are growing (compare Madison & Steen, 2007; Steen, 2001). Quantitative literacy is a non-negotiable requirement to flourish in the modern world, a world inundated by numbers and data.

2.2 Student attitudes towards statistics and quantitative matters

Attitudes play a vital role in social psychology. In spite of this role, however, there are a variety of definitions of attitudes with no accepted consensus. Researchers on attitudes have consensus that the defining characteristic of an attitude is its evaluative aspect. Ajzen (1989, p. 241) sees an attitude as "…an individual's disposition to respond favourably or unfavorably to … any … discriminable aspect of the individual's world".

In a national study, involving almost 700 senior undergraduate students in England and Wales, exploring student attitudes toward teaching and learning quantitative methods, Williams (2007, p. 6) reveals that almost half of the participants portray a lack of confidence in respect of quantitative matters. More than 40% had a particularly "bad experience" of mathematics while at school. A similar number consider themselves as "not good at maths" and just over half disclose their fretfulness about the learning of statistics. Williams (2007, p. 11) concludes his report by expressing a concern about clear evidence of an "anti-quantitative mindset" detected among the students. Two out of every three participants prefer "…writing essays to data analysis" and the majority were cynical about quantitative methods, preferring a qualitative strategy.

Many students display strong negative attitudes when they are confronted with quantitative matters or expected to gain competence in respect of quantitative research courses (Schau, Stevens, Dauphinee & Del Vecchio, 1995). Onwuegbuzie & Daley (1999) discover that students typically relate quantitative matters or courses to their underlying mathematical and/or statistical roots, subsequently labelling them as overpowering endurance endeavours, which constantly generate huge pressure and anxiety. Emmioglu, Capa-Aydin and Cobanoglu (2011) confirm these negative student attitudes toward (and almost a fear of) statistics. However, students' attitudes and expectations are vital determinants of their quantitative growth and statistical learning.

Schutz, Drogosz, White and Distefano (1998) positively relate students' performance in statistics to their previous experience of statistics and also of mathematics. Several further studies (Bradstreet, 1996; Dempster & McCorry, 2009; Schau, 2003) acknowledge significant relationships between student attitudes toward quantitative and statistical matters and their eventual achievement in such courses. It is fair to conclude that student attitudes towards statistics and quantitative matters are indeed important, especially when such students will be involved in a quantitative research or statistics course.

2.3 Measuring attitudes towards statistics

Schau, Stevens, Dauphinee & Del Vecchio (1995) describe attitudes towards statistics as multidimensional, comprising *affective* (emotions, feelings and personal motivation), *cognitive* (beliefs about abilities and competencies) and *behavioural* (study and learning activities and strategies) components. The easiest and probably also most common strategy to measure attitudes towards statistics is a Likert Scale-type survey. Sorge (2001) makes mention of three surveys in the 1980s, which were the first to assess attitudes toward statistics. They were the *Statistics Attitude Survey* (SAS, Roberts and Bilderback, 1980), the *Attitudes Toward Statistics* (ATS, Wise, 1985) and the *Statistical Anxiety Rating Scale* (STARS, Cruise, Cash & Bolton, 1985).

Schau et al. (1995) then designed the Survey of Attitudes Toward Statistics (also known as the SATS-28, a 28 item Likert scale-type questionnaire), intended to measure attitudes toward statistics based on four components namely *affect* (positive and negative feelings towards statistics), *cognitive competence* (knowledge and skills of statistical matters), *value* (the usefulness and relevance of statistics in one's personal and professional life) and *difficulty* (attitudes about the complexity of statistics). The SATS-28 was hence extended to a 36-item version (the SATS-36), adding two additional components, namely, *interest* (individual interest in statistics) and *effort* (work needed to master statistics). The SATS-36 is probably still the most recognised instrument used for measuring attitudes towards statistics.

2.4 Theoretical framework underlying this study

Schau (2003) emphasises that students' attitudes are an important determinant of academic achievement and persistence. Expectancy-value models of behaviour (Eccles & Wigfield, 1995) are especially popular and expedient in mathematics and statistics education, which form the foundation of quantitative research.

Eccles and her co-researchers (1995) see attitudes as multi-dimensional constructs that are composed of related components or factors, which are also distinct. Their three **expectancy-value factors** represent the theoretical framework underlying this research, and are neatly described by Schau (2003, p. 7−8):

- *expectations of success*: students' beliefs about their ability to successfully master statistics (quantitative matters in the context of this study)
- *task difficulty*: students' perceptions of the complexity and the nature of challenges offered by statistics (quantitative matters) and
- *value*: students' perceptions of the worth and value that statistics (quantitative matters) might add to their current repertoire of competencies, their professional domain and their lives in general.

Most studies, which aspire to focus on and measure persons' attitudes towards statistics or quantitative matters, would utilise the expectancy-value model of Eccles and Wigfield (1995) as a theoretical framework. This study is no different.

3. RESEARCH DESIGN, PARTICIPANTS AND DATA COLLECTION

3.1 Research paradigm

The inquiry primarily attempts to determine the attitudes toward quantitative matters of a group of postgraduate students, before and after their participation in a quantitative research course. The investigation adopted a quantitative approach, based on the assumption that the variable of interest (the attitudes of postgraduate students towards quantitative matters) can be measured and quantified. The research paradigm is therefore *post positivist* (Heppner & Heppner, 2004; Taylor & Medina, 2013), which presumes that an external reality exists independently from the researchers, and that this reality cannot be known fully.

3.2 Participants

The participants were students who, in 2013, enrolled for the Introduction to quantitative research module (lasting one semester, or approximately 16 weeks) on an honours (n=118) and master's (n=12) level respectively, in the Faculty of Education at the University of Johannesburg. These modules don't require a mathematics or statistics prerequisite. Table 1 below displays elements of the participants' demographic profile. The majority are female (73%), black (71%) and indigenous language speaking (65%). They are fairly evenly divided in respect of age, with just more than half (52%) who are younger than 40 years. It is noteworthy that only two out of every five (42%) participants passed Mathematics (Core or Higher Grade) as a subject in Grade 12.

Table 1: Demographic profile of the participants

Profile element		Hons	Masters	N=	%
Gender (n=130)	Female	89	6	95	73.1
	Male	29	6	35	26.9
Ethnic group (n=130)	Asian, incl. Indian	5	0	5	3.8
	Black	89	3	92	70.8
	Coloured	6	1	7	5.4
	White	18	8	26	20.0
Home language (n=130)	Afrikaans	11	9	20	15.4
	English	18	3	21	16.2
	European/Chinese	4	0	4	3.1
	African/Indigenous	85	0	85	65.3
Age in years (n=128)	29 years or younger	31	3	34	26.6
	30 to 39 years	30	2	32	25.0
	40 to 49 years	49	5	54	42.2
	50 years and older	6	2	8	6.3
Mathematics at School (Gr 12) (n=130)	Math HG or Core	43	12	55	42.3
	Math SG or Literacy	33	0	33	25.4
	Didn't enrol for Math	42	0	42	32.3

3.3 Data collection instrument

The internationally acclaimed *Survey of attitudes toward Statistic*s (SATS-36) instrument of Candace Schau (2003) forms the basis of the data collection instrument used in this study. The SATS-36 has proven to yield good internal consistency and validity measures (compare Dauphinee, Schau & Stevens, 1997; Hilton, Schau & Olsen, 2004; Schau, Stevens, Dauphinee & Del Vecchio, 1995). Use of the SATS-36 in the USA has been widespread over a number of years (Schau & Emmioglu, 2012), and it has also been used with European samples (Tempelaar, Gijselaers & Van der Loeff, 2006). Only one formal record (Coetzee & Van der Merwe, 2010) could be found of its usage with a South African sample. The South African researchers (2010, p. 6) conclude that the SATS-36 "…appears to be valid and reliable for a sample of South African students, but should be validated with other South African samples also."

The SATS-36 was hence (in collaboration with Schau, February 2013) converted into the so-called *Survey of attitudes towards quantitative matters* (the SATQ), while maintaining its original 36 items and six attitudinal components. The formulation of its 36 items was adapted to reflect typical South African terminology and a broader quantitative matters- instead of a specific statistical stance. However, the nature (positively or negatively formulated) and intention of each item was carefully preserved.

The SATQ questionnaire collects data via a 7-point Likert scale (**1** = *strongly disagree*; **4** = *neither disagree nor agree*; **7** = *strongly agree*). It ascertains student attitudes in respect of six underlying components, namely:

- *Affect* (positive and negative feelings concerning quantitative matters, consisting of six items, for example 'I am scared by quantitative aspects')
- *cognitive competence* (attitudes in respect of one's own perceived quantitative abilities, consisting of six items, for example 'I can learn quantitative matters')
- *value* (attitudes about the usefulness, relevance and worth of quantitative matters in their lives, consisting of nine items, for example 'Quantitative skills will make me more employable')
- *difficulty* (attitudes about the perceived complexity of quantitative matters, consisting of seven items, for example 'Quantitative matters are complicated')
- *interest* (level of individual interest in quantitative research themes, consisting of four items, for example 'I want to be able to communicate quantitative information to others') and
- *effort* (alleged amount of work needed to learn quantitative matters, also consisting of four items, for example 'I plan to work hard in the course').

The questionnaire consists of three sections. *Section A* contains demographical items. This include gender, ethnical group, home language, age, first (undergraduate) degree and whether mathematics was one of the respondents' subjects, and if so at what level in Grade 12 at school. *Section B* presents the 36 Likert scale-type statements on quantitative matters (as outlined above). *Section C* features five questions, which participants were expected to answer via a 7-point Likert scale-response. The questions collected respondents' views on the nature of their performance in their last mathematics course (at school), their general mathematical competency, to what extent they might be using quantitative matters in their job domain, their level of confidence in mastering the content of the 'Introduction to quantitative research' course and how likely it is that they would have chosen a quantitative research course as part of their postgraduate studies, if the choice had been theirs.

3.4 Data collection and ethical measures

The *pre-course* survey was launched during the first contact session of the 'Introduction to quantitative research' course, in which the students participated. After the goal of the research, the nature of the data collection instrument and their rights and responsibilities as respondents have been explained to them, individual written consent was obtained from all participants to safeguard the confidentiality of collected data and the anonymity of each participant.

In the case of the B.Ed. Honours group, pre-course data were collected in the second week of July 2013 (their course was offered during the second semester), while data in respect of the Master's coursework students were collected in the last week of February 2013 (their course was offered during the first semester). The *post-course* survey, which only contained the 36 items in Section B and three of the items in Section C, was conducted during the last contact session of each course, which was at the beginning of November 2013 (for the B.Ed. Honours group) and in the third week of June 2013 (for the M.Ed. coursework group).

3.5 Scoring, data capturing and analyses

About half of the items (17 of the 36) in Section B of the questionnaire are 'positively' and the other 19 'negatively' articulated. Responses on negatively-phrased items are reversed before scoring. Higher scores on items reveal a more positive attitude, and vice versa in respect of a negative attitude. A respondent's score in respect of an attitudinal component, is the mean of the scores on all items that represent that specific component. Means vary across items and a participant must have responded to all items in a component in order to have generated a component score. Higher scores relate to a positive attitude in respect of five of the six components. The exception is *Difficulty*, in which a higher score relates to a belief that an aspect is simpler (easier), while a lower score represents the opposite (an aspect is harder).

In order to investigate the development of attitudes over time, only responses of participants who fully completed both the pre-course and the post-course survey were utilised. Collected data were initially captured in a Microsoft Excel worksheet and thereafter uploaded as a worksheet on the Statistical Package for the Social Sciences (SPSS, version 22). Biographical and Likert scale-type data were initially analysed via the frequencies, cross-tabulations and other descriptive statistics options of SPSS. Thereafter inferential statistics, aimed at the possible detection of significant differences between means and variability indicators of the six components of the SATQ were performed, using Student's t-test and a one-way analysis of variance (ANOVA).

3.6 Validity and reliability measures

South African researchers, Coetzee & Van der Merwe (2010) provide strong evidence for the validity and reliability (internal consistency) of the SATS-36 survey. A six-factor structure emerged from their confirmatory factor analysis, representing the six underlying attitudinal components of the questionnaire. Five of the components (*Difficulty* being the exclusion) exhibited acceptable levels of internal consistency, with Cronbach's alpha coefficients ranging from 0.80 to 0.85. Schau and Emmioglu (2012) recommend 0.70 as an acceptable lower level for Alpha. Their 0.66 alpha value for the *Difficulty* component (Coetzee & Van der Merwe, 2010) is comparable with other studies (compare Dauphinee *et al*., 1997; Hilton *et al*., 2004; Schau *et al*., 1995), whose coefficients range between 0.64 and 0.81. The SATS-36 survey therefore seems a reliable and valid measure of students' attitude toward statistics. The question was whether the SATQ survey could generate similar results.

The newly designed SATQ questionnaire was piloted during the first week of February 2013 involving five dissertation-based Master's students in the Faculty of Education. These postgraduate students were not participants in the study, but they gave valuable feedback in respect of the nature of the questionnaire, the wording of items and the allotted time, which hugely contributed to sight validity.

Cronbach's alpha coefficients were hence calculated for the six SATQ components in respect of both pre- and post-course data. The twelve coefficients are portrayed in Table 2 below. It is interesting to note that in total nine of the 36 items were removed from all further analyses, in striving to optimise the reliability of the data. The coefficients in table 2 confirm that the participants' pre-course and post-course responses to the remaining 27 SATQ items have acceptable to very high internal consistency.

Table 2: Cronbach's alpha values for pre- and post-course attitude components

Attitude component	Pre-course	Post-course
Affect (4 items)❶	.931	.804
Cognitive (5 items)❷	.952	.779
Value (6 items)❸	.948	.793
Difficulty (4 items)❹	.906	.815
Interest (4 items)	.806	.781
Effort (4 items)	.770	.745

❶ The original Cronbach's alpha value was .874 for all six **Affect** items, but after the stepwise removal of items 3 and 4, the alpha for the remaining four items increased to .931

❷ The original Cronbach's alpha value was .950 for all six **Cognitive** items, but after the stepwise removal of items 32, the alpha for the remaining five items marginally increased to .952

❸ The original Cronbach's alpha value was .905 for all nine **Value** items, but after the stepwise removal of items 9, 10 and 17, the alpha for the remaining six items increased to .948

❹ The original Cronbach's alpha value was .814 for all seven Difficulty items, but after the stepwise removal of items 6, 8 and 22, the alpha for the remaining four items increased to .906

4. EMPIRICAL FINDINGS

4.1 Participants' attitudes towards quantitative matters

Descriptive statistics were used to describe the pre-course and post-course attitudes of the participants towards quantitative matters. These descriptive statistics are presented in Table 3 below.

Table 3: Descriptive statistics of students' attitudes towards quantitative matters: Pre- versus post-course scores

Component	Mean (Pre)	Mean (Post)	Median (Pre)	Median (Post)	Std Dev (Pre)	Std Dev (Post)
AFFECT (4 items)	3.884	5.939	3.778	6.000	.951	.541
COGNITIVE (5 items)	4.217	5.957	4.219	6.000	1.159	.547
VALUE (6 items)	5.177	6.035	5.175	6.000	.986	.505
DIFFICULTY (4 items)	2.944	4.500	2.857	4.571	.846	.592
INTEREST (4 items)	4.899	6.042	5.000	6.000	.964	.582
EFFORT (4 items)	6.486	6.773	6.750	7.000	.506	.335

In respect of the **pre-course** scores, students exhibited a high level of willingness to work hard in order to learn about quantitative matters (their mean score on the *Effort* component is between 6 and 7, with the median score even closer to 7). They also value the worth, usefulness and relevance of quantitative matters in their lives and professions (their mean and median score on the *Value* component are above 5), while they have a moderately positive interest in learning about quantitative matters (their mean score on the *Interest* component is almost and the median score is exactly 5). They were more neutral in their feelings and emotions about quantitative matters (their mean and median scores on the *Affect* component are both slightly less than 4). They also displayed a relatively neutral to slim positive attitude in respect of their own perceived competence in handling quantitative matters (their mean and median scores on the *Cognitive* component are both just more than 4). They do have a definite belief that quantitative matters are difficult, as illustrated by their relatively low mean score on the *Difficulty* component, which is below 3, with their median score even a bit lower.

However, a remarkable change in their attitudes towards quantitative matters becomes evident by an interrogation of their **post-course** scores. In thinking back about their experiences during the Quantitative Research course, they belief that they did put in a huge effort in order to become more competent in respect of quantitative matters (their mean score on the *Effort* component is now almost 7, while the median score is 7). Both the value that they now attach to and their renewed interest in quantitative matters are highly positive (their mean scores on the *Value* and *Interest* components are above 6). Gone are their former neutral feelings and emotions towards matters of a quantitative nature, as well as their rather unconvincing belief in their own quantitative proficiency (both mean scores on the *Affect* and *Cognitive* components are just below 6, with both median scores on 6). Their former perception that quantitative matters are indeed difficult, has also been reversed to a large extent, as exemplified by their 4.5 mean and median scores on the *Difficulty* component.

The attitude gains in respect of all six components are substantial and their statistical significance finally needed to be explored.

4.2 Testing for significant differences between pre- and post-course attitudes

A paired-samples t-test, including Pearson's product moment correlation coefficients, was conducted on the six pairs of pre- and post-course attitude scores. Tables 4, 5, and 6 below summarise the respective paired samples t-test statistics, correlations and test findings.

Table 4: PAIRED SAMPLE STATISTICS

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1 AFFECT	Pre-course	3.884	130	.951	.083
	Post-course	5.939	130	.541	.047
Pair 2 COGNITIVE	Pre-Course	4.217	130	1.159	1.005
	Post-Course	5.957	130	.547	.047
Pair 3 VALUE	Pre-course	5.177	130	.986	.855
	Post-course	6.035	130	.505	.438
Pair 4 DIFFICULTY	Pre-course	2.944	130	.846	.073
	Post-course	4.500	130	.592	.051
Pair 5 INTEREST	Pre-course	4.899	130	.964	.084
	Post-course	6.042	130	.582	.050
Pair 6 EFFORT	Pre-course	6.486	130	.506	.044
	Post-course	6.773	130	.335	.029

Table 5: PAIRED SAMPLE CORRELATIONS

		N	Correlation	Sig.
Pair 1	**AFFECT** (Pre- & post-course)	130	.626	.000
Pair 2	**COGNITIVE** (Pre- & post-course)	130	.498	.000
Pair 3	**VALUE** (Pre- & post-course)	130	.460	.000
Pair 4	**DIFFICULTY** (Pre- & post-course)	130	.739	.000
Pair 5	**INTEREST** (Pre- & post-course)	130	.783	.000
Pair 6	**EFFORT** (Pre- & post-course)	130	.402	.000

Table 6: PAIRED SAMPLE TEST DIFFERENCES

				99% Conf Interval of the Difference				
	Mean	**Std. Deviation**	**Std Error Mean**	**Lower**	**Upper**	**t**	**Df**	**Sig. (2-tailed)**
Pair 1: AFFECT (Pre & Post)	-2.055	.744	.064	-2.223	-1.886	-31.859	129	.000
Pair 2: COGNITIVE (Pre & Post)	-1.740	1.006	.087	-1.968	-1.512	-19.953	129	.000
Pair 3: VALUE (Pre & Post)	-.859	.877	.076	-1.057	-.660	-11.297	129	.000
Pair 4: DIFFICULTY (Pre & Post)	-1.556	.571	.050	-1.685	-1.426	-31.421	129	.000
Pair 5: INTEREST (Pre & Post)	-1.143	.624	.054	-1.285	-1.002	-21.132	129	.000
Pair 6: EFFORT (Pre & Post)	-.287	.481	.042	-.396	-.178	-6.876	129	.000

The paired-samples t-test and Pearson's correlational findings confirmed that students':

- pre-course **Affect** attitudes differ significantly (*M* = 3.884, *SD* = .951), from their post-course Affect attitudes (*M* = 5.939, *SD* = .541), *t* (129) = -31.859, *p* < .001, *d* = -2.656
- pre-course **Cognitive** attitudes differ significantly (*M* = 4.217, *SD* = 1.159), from their post-course Cognitive attitudes (*M* = 5.957, *SD* = .547), *t* (129) = -19.953, *p* < .001, *d* = -1.920
- pre-course **Value** attitudes differ significantly (*M* = 5.177, *SD* = .956), from their post-course Value attitudes (*M* = 6.035, *SD* = .505), *t* (129) = -11.297, *p* < .001, *d* = -1.095
- pre-course **Difficulty** attitudes differ significantly (*M* = 2.944, *SD* = .846), from their post-course Difficulty attitudes (*M* = 4.500, *SD* = .592), *t* (129) = -31.421, *p* < .001, *d* = -2.131
- pre-course **Interest** attitudes differ significantly (*M* = 4.899, *SD* = .964), from their post-course Interest attitudes (*M* = 6.042, *SD* = .582), *t* (129) = -21.132, *p* < .001, *d* = -1.435 and

- pre-course **Effort** attitudes differ significantly (*M* = 6.486, *SD* = .506), from their post-course Effort attitudes (*M* = 6.773, *SD* = .335), *t* (129) = -6.876, *p* < .001, *d* = -.669.

The six Cohen's d effect size values in addition suggested a very high practical significance of all findings, with the findings in respect of the Effort component considered as of high significance.

4.3 Empirical synthesis

Based upon students' significantly (statistically and practically) increased attitudes towards quantitative matters across all six components, the reason(s) underlying this substantial attitudinal change over time, with reference to the Quantitative Research course for which they were enrolled, need further empirical investigation.

5. CONCLUSION

This paper reported on the pre- and post-course attitudes of a group of postgraduate (honours and coursework masters) students towards quantitative research matters. The internationally recognised *Survey of attitudes toward statistics* instrument of Candace Schau (2003), detecting attitudes in respect of six components, was converted into a *Survey of attitudes towards quantitative matters* (SATQ). The researchers were keen to determine whether and if affirmative, to what extent the attitudes toward quantitative matters of these students (who participated in a quantitative research course at a South African higher education institution) change over time. The new SATQ instrument was thus used for the very first time in the South African higher education context.

It was found that students' attitudes towards quantitative matters significantly (both statistically and practically) increased over a period of approximately 16 weeks, across all six components of the SATQ questionnaire. An inquiry into possible reason(s) underlying this phenomenon lies beyond the ambit of this paper. However, in aspiring to make progress towards the overarching goal of the more comprehensive research project, of which this investigation forms part, further research is necessary and also appropriate. Such research may pertinently contribute towards the crafting of strategies, which postgraduate educators and/or supervisors could use to positively influence students' attitudes towards the quantitative research domain. Informally collected postgraduate study trends in the South African higher education domain, currently seem to indicate that the majority of student attitudes in this respect can at the very best be described as lukewarm to (overwhelmingly) negative.

The credibility and predictive value of the SATQ, as a self-rating attitudinal questionnaire has not been formally ascertained within the South African context. Further research, which makes use of the instrument is therefore strongly encouraged. This study (and the larger project) aspire to contribute to the most vital influence on postgraduate students' study progress and their eventual achievement, namely their attitudes.

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DEVELOPING SKILLS OF ENTERING FIRST YEAR SCIENCE STUDENTS: FOCUSED FIRST YEAR SEMINAR

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Abstract–Concern at the failure rate of first year Science, Health Sciences and Engineering students is challenging first year lectures to interrogate the knowledge and skills gap of entering students. Underprepared students have entered higher education for centuries but the problems in transition from school to university seem to be increasing from year to year. Every cohort enter universities with high expectations and good school results and then they are confronted with challenges of transition, new content and an uninviting environment. The Faculty of Science has been presenting an academic First Year Orientation seminar since 2005 and refined the format of the current programme which is a two week (six hours per day) credit-bearing module, the First Year Seminar (FYS). The programme consists of a 10 hour Language course, a 6 hour Laboratory skills and 10 hour Problem Solving skills for 10 hours. These modules are presented by dedicated academics and support staff in the faculty, and student mentors (senior students) take responsibility to get to know the students better as they work with them on a daily basis. This study reports on research conducted to determine the influence and success of the FYS on the academic preparation of first-year students in 2014. The data set contains school results, biographical and personality profiles, results from a survey completed after the FYS and perceptions after interviews with students, mentors and lecturers. Appropriate inferential statistics were employed in the analysis of the survey response and interviews as indicators of the value added by the FYS. The results will indicate how the FYS enhanced the existing knowledge and skills of entering first year students in order to place diverse students on an equal platform when official lectures and practical sessions commence during the semester.

Keywords: First Year Transition, First Year Experience**,** First Year Seminar**,** Academic Achievement in Science programmes

1. INTRODUCTION

The international trend of dedicating specific emphasis to first year students entering higher education (HE) has become more relevant in the South African (SA) context. In 2009 the first, First Year Experience (FYE) conference was held in Stellenbosch, South Africa (Leibowitz, Van der Merwe & Van Schalkwyk, 2009, p.3) and since then first year programmes and academic progress have been discussed on all SA campuses. Underprepared students have entered HE through the ages but the difficulty in transition from school to university seems to be increasing from year to year. The failure rate of first year Science, Engineering, Technology and Health Sciences (SETH) students is a matter of concern and is pertinent for relevant departments and also the economy of any country. In the past 20 years South African HE has increased enrolments by 80% (RSA, 2012, p.37). Many students who would have been excluded from university studies, specifically in Sciences are now being accepted and students from various academic backgrounds are entering the Higher Education institutions (HEIs) in pursuit of qualifications (Tait & Godfrey, 2001).

Granting more opportunities for more students' impacts on enrolment but also has a tremendous effect on the academic throughput rate, more so in Science programmes (CHE, 2013, p.13). More non-traditional students enter higher education (Giancola, Munz & Trares, 2008) and typically this massification decreases the success rate of students at risk The insufficient prior educational experience, unsatisfactory school performance and a first-generation status are but some of the characteristics identified by Cavote & Kopera-Frye (2007), Olive & Russ (2010) and Bowl (2001) to explain the lack of information and poor-preparation by their schools for the expectations of Higher Education (HE).

Universities with high numbers of non-traditional students will be challenged to retain these students in the system (Laing & Robinson, 2003) in order to complete their degrees. Academics have been investigating "dropping-out" over decades (Bunting, 2004; Slotnick, Pelton, Fuller, & Tabor, 1993; Kimbrough & Wearver, 1999) and it seems that dropping-out can be attributed to the economic and social pressures experienced by these students. Higher education has accepted that schools are not going to prepare students better and are confronted to develop strategies and even formal programmes (Kift 2008) to prepare Science students adequately and academically and increase their level of confidence, enabling them to cope with their first year studies in Science. This paper thus focuses on the measurement of the First Year Seminar designed by the Faculty of Science, UJ. Its purpose is to determine the influence of a nine day intervention in laboratory, language or problem solving skills.

2. STUDENT TRANSITION

Student transition from school to HE has been investigated and interrogated at length (Briggs, Clark & Hall, 2012; Jacobs & Jacobs, 2013; Bowles, Dobson, Fisher & McPhail, 2011, and Kift, 2009 among others) and presents significant challenges to all parties concerned. The enormous step or "gap" (Sappa & Bonica, 2008) is between two institutions, the school on one side and the university on the other side with the entering first year student caught in between. Winterson & Russ (2009) encourage both institutions to make the transition process easier but given the SA school context the schools are challenged with shortages of qualified teachers, lack of facilities and resources (Jacobs, 2010) so that they are less concerned with what happens after school.

Briggs, *et al* (2012) argue that students entering HE make a personal investment using their cultural capital which was accumulated through their prior education at school. Academics have been aware of the problems of transition and support students' needs not just in classes and laboratories but also assist with the significant social shift for the students.

2.1 Adapting of First year students

The problems with adaptation are amplified in environments where the first year student is a first generation university student; older than all other first year students; or where the student is from an ethnic group that is under-represented in the population of students at university. Briggs *et al*. (2012) elaborate on the importance for these students to create a new identity for themselves as a HE student. Students entering HE struggle to envision their life at university and cannot accurately predict their future experiences at university (Smith & Hopkins, 2005; Longden, 2006; Joint Information Systems Committee (JISC), 2007). The research that focuses on student aspirations, expectations and decision-making by Peel, (2000), Sander, Stevenson, King & Coates (2000) and Tranter (2003) indicates the discrepancy between what the students aspire to as pre-transfer students and the reality of what their experience will be in their first year of studies. James (2000) and Hillman (2005) agree that students may even withdraw (drop-out) due to their lack of knowledge and uninformed decision-making relating to their choice of studies and/or institution. The clear link between the experiences of first years and retention rates has been investigated by Yorke & Longden (2008) and they found some of the most prevalent reasons for students leaving university prior to obtaining a degree is poor decision making regarding their choice of studies, leading to a decrease in their commitment towards completing the degree; and finance. Most of the students exiting university before the completion of their degrees seem to be first years (Ertl; Hayward; Wright; Edwards; Lunt; Mills, & Yu, 2008).

2.2 Tracking students in SA

In the CHE report (2013, 52) it is stated that "(T)he current higher education system is not producing sufficient graduates to meet national needs in respect of economic and social development…" The report indicates that only 35% of students graduate within five years and an estimated 55% will never graduate. Given the 899 120 intake in 2011 almost 500 000 students will drop out without any qualification. Can SA afford this?

Bundy (2006, p.12) found that substantial growth in the participation of Black students and academic staff in higher education since 1996. Whereas only 12% of the SA HE population comprised of Black students in 1993 (NCHE, 1996, p.64), it increased sharply to 59% in 1999, 65% in 2002, and 79% in 2010 (CHE, 2013, p.39). The growth in Black student participation also introduced complications with retention and progress. Bundy (2006, p.12) notes that "…access gains also prove less healthy when measured against student success levels". A 'wasteful' number of enrolled students fail to complete their studies, there is a decline in retention rates, and dropout rates are as high as one out of five".

There are no grounds to expect these patterns to change in the near future, since they have remained unchanged since the cohort intake of the year 2000; and looking at the current educational system as a whole, the conditions will not change unless we implement systems that will be able to support and bridge the gap experienced and faced by these students. It is against this backdrop that the University of Johannesburg has implemented the First Year Programme to accommodate the underprepared students entering the institution.

3. FIRST YEAR PROGRAMMES

Internationally, the transition of students to HE has been a well-established research field since the 1970s (Akerlind, 2005, p.1) and is actively pursued in South African HEIs over the last decade. Dedicated First year experience (FYE) centres are common in the USA and these centres serve to ease student transition into university curricula and standards such as the Centre for Academic Enhancement (University of Georgia). They are also increasing in European, Asian, UK and Australian HE (Meyers & Ryan, 2008). Furthermore, HEIs offer formalised orientation (induction) programmes for transitional students (Kift, 2008).

Adaptation and socialisation can be encouraged by adequate support systems provided by university staff (Briggs *et al.,* 2012). First Year programmes have been providing first year students with a support system that focuses on making the adjustment to university life easier as well as providing them with valuable workshops in improving their prior knowledge in the subject fields of Mathematics and related science fields. The First year seminar (FYS) should place emphasis on time management and study skills and include opportunities for students to participate in social activities and engage with peers and faculty members according to Landis (2005). Students are admitted to universities before having been afforded the time to become acquainted with the institution. Experts such as Astin (1999, p.518), Tinto (2008, p.14) and Eiselen (2006, p.91) listed institutional factors that enhance student academic success:

The student should:

- be socially and academically integrated;
- identify with peer groups (although Science students often feel alienated);
- be integrated into the institutional culture; and
- be an involved student.

Pascarella & Terenzini (2005) and Keupp & Barefoot (2005) reiterate that participation of first years in these seminars has a tremendous positive effect on their ability to make the adjustment from school to university as well as retaining the students until they enter their second year of studies. A positive attribute of the FYS is that the workshops take place in smaller groups and students are grouped according to their specific fields of study which assists in building relationships amongst their fellow students and peers. Buote, Pancer, Pratt, Adams, Birnie-Lefcovitch, Polivy, & Wintre (2007) suggest that the first year students need to engage with one another in order to build friendships that will help them to adjust to life at university as well as the pressure of academic demands on them. Research indicates that the result of collaborative learning is better learner involvement, increasing their performance as well as increasing their productivity (Nunamaker *et al*., 1997; Alavi, 1994).

The purpose of a first year seminar is to boost the social and academic integration of first year students (Pascarella & Terenzini, 2005). This is accomplished by organised workshops introducing the students to various topics in their study field as well as tools on how to achieve your academic goals. Furthermore these seminars include sessions that introduce the students to various facilities on campus and support services that are made available to these students to make the adjustment to university easier. It is very important that close relationships are established, during the FYS, between the students and faculty staff (Pascarella &Terezini, 2005).

Many students in their first year of study feel alone and isolated at university, even though they are surrounded by thousands of other fellow students studying at the same institution. Tinto (2008) points out that students who attended rural schools and had to leave home to attend university usually do not have family and friends to rely on for support and fully rely on the guidance and support offered by faculty staff and senior students. Harvey & Drew (2006, p. iii) emphasise that first year students will acclimatise must faster to their new university environment if they feel that they belong there. Students in this first stage of transition need to develop their own student identity (Huon & Sankey, 2002) and learn to behave like university students (Fazey & Fazey, 2001). Otherwise, they will feel confused and lose their personal identity (Scanlon *et al*., 2005), resulting in terminating their studies.

First year students are often over confident (Oliver, 2008), and lack the ability to determine the difference between what they know and are able to achieve (Rowlands *et al*, 2008). A suggestion from Goldfinch & Hughes (2007) is that the confidence of students should be directed into suitable learning opportunities where their learning skills are constantly being developed. Furthermore, Kimmins & Stagg (2009), emphasise that this will ultimately lead to a dichotomy in the method required by the lecturers, due to the fact that first year students demonstrate a high, unsupported level of confidence in "what they think they know" regarding their academic skills but shows a lower level of confidence when it comes to applying these academic skills towards solving mathematical problems or writing a scientific report.

The first year seminar allows students to become aware and recognise the level of their personal academic skills allows for guided support and assists them to develop their skills (Kimmins & Stagg, 2009). First year seminars create a safe environment where these students can find the required support and provide them with relevant learning opportunities that are focused on developing the skills required for the various disciplines in Science. Erickson, Peters, & Strommer, (2006); Evans, Forney, & Guido-DiBrito, (1998); Pascarella & Terenzini, (1991, 2005) and Skipper, (2005), summarised that FYS programmes have the capacity to create an environment where students can develop their critical thinking skills needed for their intellectual growth.

3.1 Science FYS at UJ

The University of Johannesburg (UJ): Faculty of Science acknowledges the under-preparedness of first year students and uses the first two weeks to assist the students with the transition. The programmes are structured well so that the lecturers can start teaching content when the semester commences. During the first year seminar the workshops in laboratory skills, mathematical problem solving and academic literacy for science can both provide content knowledge and increase their confidence. The first year modules are taken by students in Science, Science, Health Science and Engineering and therefore these students were all invited to register for the FYS.

The FYS will ensure that these students (mostly underprepared) will have a well planned introduction to the various aspects of being a Science student. The programme included:

- Five (2 hour) sessions focusing on Academic literacy (language). Bowl (2001) emphasises the fact that non-traditional students may struggle to write scientific reports and essays. These sessions serve as opportunities for the students to learn how to improve their reading and writing skills with specific focus on Science modules.

- Five (2 hour) sessions focusing on solving mathematical problems with special focus on bridging the gap in content knowledge from school to university; in other words students will perform fundamental Mathematics and Numeracy to increase their proficiency to a level we would enable them to enter Higher Education.
- Three (2 hour) sessions introductory laboratory sessions, where students are introduced to Chemistry, Physics and Biology laboratories and are familiarised with various items of laboratory equipment used for different experiments. Many of the students entering the Faculty of Science come from rural schools where they have never been introduced to laboratory work. The sessions focus on allowing the students to perform basic laboratory techniques and acquire skills to identify equipment, enhance accuracy and also safety in laboratories.

Other extremely valuable sessions presented throughout the seminar are a discussion on timetable and time management. According to Ballinger (2002), students often struggle with managing their own timetable as well as meeting deadlines for assignments. We distribute the timetable booklet and get them acquainted to use the book and dates provided to keep them informed about their assessments, etc. The students are also informed about assessment at university, tests, practicals and exams that they will write and topics such as "What is required to pass?" is discussed during the session. Carefully selected staff from each discipline will present a session where they discuss study skills in various disciplines (Mathematics, Physics, Life Sciences, Chemistry, and Geography). Winterson & Russ (2009) point out that students have to become accustomed to various learning styles, referencing techniques as well as note-taking used at university. Due to the fact that research and the writing of academic essays and reports forms such an integral part of Science the first year students also attend a session where they meet with the Faculty Librarian. During this session she takes them on a tour through the library and then they sit and proceed with completing a short essay on a theme where they have to use the Internet, Journal, Textbook and database.

The first year students are also encouraged to get to know the campus as soon as possible and before the formal lectures start. This is done by facilitating an "*amazing race game*" where students in smaller programme groups receive a map of the campus and they should visit points of interest, take a photo of that place, and the first group back receives a small prize. This allows them to get to know the campus in a fun and exciting way as well as working together with their fellow students.

4. RESEARCH

4.1 Research methodology

4.1.1 Participants and sampling

Purposive sampling was used when, during the beginning and the end of the 2014 FYS (organised by the Faculty's First Year Experience), all participants (first year students were requested to complete a test (with 25 questions) prior to starting with the FYS. A total number of 865 students completed the test on the day of arrival. After nine days of FYS they were again requested to complete the same assessment and 716 completed the test. Of these 568 students participated in the pre- and post-FYS test and these were used in the analysis. In Table 1 a demographic analysis of the participants are provided.

Table 1: Demographic Analysis of Participants

Variable		N	%
Gender	F	209	38.6
	M	333	61.4
Ethnic Group	African	424	78.2
	Coloured	16	3.0
	Indian	31	5.7
	White	71	13.1
Home Language	African	393	72.5
	English	118	21.8
	Other	31	5.7
Province	Eastern Cape	7	1.3
	Free State	6	1.1
	Gauteng	334	61.6
	Kwazulu Natal	22	4.1
	Limpopo	111	20.5
	Mpumalanga	35	6.5
	Northwest	13	2.4
	Northern Cape	1	0.2
	Western Cape	3	0.6
	Other	10	1.8
Programme	Diploma	1	0.2
	Engineering	108	19.9
	IT	144	26.6
	Life & Env Sc	158	29.2
	Math Sciences	55	10.1
	Phys Sciences	76	14.0

Based on the demographic analysis of the first year group that participated in the pre/post survey, consisting of 542 students. As expected there were more males (61.4%) as Sciences and especially Engineering are male dominated. The average student in the FYS would be African (78.2%) from Gauteng province (61.6%) and the largest group was studying Life and Environmental Sciences (29.2%) or Information Technology 26.6%).

4.1.2 Data collection instrument

The 25 question multiple choice test forms part of the First Year Seminar aimed at determining the content knowledge they have regarding Laboratory Skills, Language and Problem Solving (similar to Quantitative Literacy). There were 10 questions on biographical detail and five on each in the three sections (constructs). Respondents were requested to complete the test upon arrival on the first day. After a nine day programme (see detail above) the students were requested to complete the same test as a post-test on the last day but some students did not participate in this opportunity.

4.1.3 Quantitative data analysis

To compare the students' pre- and post-FYS results, paired-samples t-test, including Pearson's product moment correlation coefficients, was conducted on the three pairs of constructs, for students who submitted for both tests. The SPSS statistical package was used to conduct the analyses.

4.1.4 Reliability and validity of the collected data

This was the first year that we did a pre-test on all three constructs. Previous years the teams responsible for the three different sections (Lab skills, Language and Problem Solving) had students complete a base-line test in the first session. This investigation served as a pilot study and the reliability will only be tested in 2015 when the adapted test will be used again.

The specialist lecturers in the three divisions checked the questions to confirm suitability. The lecturers validated each item for content and are comprehensive enough to test knowledge of students entering science programmes. Items were selected from previous base-line tests and thus have sight-validity as well.

4.2 Research findings

A paired-samples t-test, including Pearson's product moment correlation coefficients, was conducted on the three pairs of pre-FYS and post-FYS assessment results. Tables 1, 2, and 3 below summarise the respective paired samples of t-test statistics, correlations and test findings.

Table 2: Paired Sample Statistics

		Mean	N	SD	Std error mean
Pair 1	Pre Lab Skills	72.24	539	19.510	.840
	Post Lab Skills	75.99	539	19.210	.827
Pair 2	Pre Language	49.02	501	19.961	.892
	Post Language	70.34	501	19.414	.867
Pair 3	Pre-Problem Solving	45.08	516	17.833	.787
	Pre-Problem Solving	66.51	516	14.355	.632

Table 3: Paired Sample Correlations

		N	Correlation	Sig.
Pair 1	Pre-Lab Skills & Post-Lab Skills	539	.435	.000
Pair 2	Pre-Language & Post Language	501	.320	.000
Pair 3	Pre-Probl Solv & Post-Probl Solv	516	.228	.000

Table 4: Paired Sample Test Differences

	Mean	SD	Std error mean	99% conf. interval of the difference		t	Df	Sig. (2-tailed)
				Lower	Upper			
Pair 1 Pre-Lab Skills Post-Lab Skills	-3.748	20.588	.887	-6.040	-1.455	-4.226	538	.000
Pair 2 Pre-Language Post-Language	-21.317	22.958	1.026	-23.969	-18.665	-20.784	500	.000
Pair 3 Pre-Problem Solving / Post- Problem Solving	-21.434	20.219	.890	-23.735	19.133	-24.081	515	.000

The paired-samples t-test and Pearson's correlational findings confirmed that the students' Lab skills post FYS assessment results differ significantly (M = 75.99, SD = 19.210) from marks in the post FYS assessment (M = 72.24, SD = 19.510), t (538) = -4.226, $p < 0.001$, d = -0.194. This was also the case in respect of Post FYS Language skills (M = 70.34, SD = 19.414) in comparison to their Pre FYS Language (M = 49.02, SD = 19.961), t (500) = -20.784, $p < 0.001$, d = -1.083. In the case of Post FYS Problem Solving skills (M = 66.51, SD = 14.355) in comparison to their Pre FYS Problem Solving skills (M = 45.08, SD = 17.833), t (515) = -24.081, $p < 0.001$, d = -1.332.

The analysis of mean performance of students in all three categories in both tests determined a statistically significant difference ($p < 0.001$) between the pairs showing the difference between the groups based on the treatment in this research the FYS programme. The effect size indicates the effectiveness of the programme and was calculated using Cohen's d effect size values above (e.g. d = -1.332). The difference between PRE and POST measurements are standardised and then compared to 0.

Cohen provides the standard interpretation as .8 (large or 8/10 of a standard deviation unit); .5 (moderate or 1/2 of a standard deviation) and .2 (small or 1/5 of a standard deviation).

The effect size calculated by Cohen's d in this research are –0.194 (Lab skills); -1.083 (Language skills) and -1.332 (Problem Solving)). According to Cohen's standard interpretation the Language and Problem Solving suggested a very high practical significance (more than .8) and small practical significance with regard to the Lab Skills findings (less than .2). This indicates the effectiveness of the FYS programme.

4.4 Empirical synthesis

The empirical investigation generated the following noteworthy findings:

- **Language**: The academic literacy module served the students well and they perceived it as valuable. Lecturers report that they can determine from the lab reports which students did not attend the FYS.
- **Problem solving**: The value added by getting them to start thinking after six weeks of holiday cannot really be quantified but students reported this was a meaningful experience.
- **Laboratory skills**: Data above indicate that students had a good idea of what is expected, yet these are the sessions which they enjoyed the most and got to know each other – thus very valuable.

5. DISCUSSION

This study reaches the conclusion that there is a clear difference between the students that attended the FYS and those who don't. Participation in the FYS can significantly increase the student's ability to make a successful transition to university, enabling them to complete their qualification.

The objective of the FYS is not only to help them adjust but to increase peer and faculty interaction and to give the students an opportunity to engage with their lecturers in a less formal setup. The findings suggest that the workshops focusing on mathematical problem solving and academic literacy enhances student development and assists in bridging the gap due to the lack of good teaching practices at school. More research will have to be done to understand the impact of FYS on students entering HE. The current study will assist the staff involved to make the necessary changes to the programme in order for the first years to make a great success of their academic careers at UJ.

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EXPLORING THE TEXTBOOK COMPETENCE OF EDUCATORS AS AN ENABLING INPUT IN THE DELIVERY OF QUALITY BASIC EDUCATION IN SOUTH AFRICA

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Abstract–This paper provides preliminary feedback on a study exploring the textbook competence of teachers as an enabling input in the delivery of quality basic education in South Africa. A framework for understanding quality education (UNESCO, 2005), served as the conceptual context for the study. Adopting a design-based research approach, and using a training intervention (workshop) to develop the textbook competence of participants, a research site was established to explore educator perceptions regarding the importance, quality and use of textbooks in the delivery of quality education. Data was collected using questionnaires, interviews, workshop activities and artefact (textbook) analysis.The study revealed that the development of the textbook competence of teachers is not supported by teacher education and training programmes, resulting in an under-preparedness of teachers to effectively use textbooks in the delivery of quality education. Recommendation: For teacher education institutions to implement relevant programmes to enhance the textbook competence of educators.

Keywords: Quality textbooks, textbook utilisation, teacher training

1. INTRODUCTION

Little is known about the quality of textbooks and the way textbooks are used in the delivery of education in schools in South Africa, yet more than R2.4 billion was spent on textbooks in 663 subjects [7 533 titles] in 2012, to be used in 25 000 schools, by 360 000 teachers and 12 million learners. The United Nations Educational Scientific and Cultural Organisation (UNESCO, 2005) identified textbooks as an enabling* input in the delivery of quality education asserting that a cause and effect relationship exist between enabling inputs (cause) and learner performance (effect) [*enable means making it happen]. With quality education not 'happening', indicated to be the situation for a major portion of the learner population (NPC, 2012), the inevitable result is poor learner performance (e.g. poor matric results, and low levels of literacy and numeracy). It is therefore an imperative that the possibility of substandard textbooks and textbooks not being used effectively as a contributing factor to poor learner performance be investigated.

This study aims to gain a better understanding of the constructs 'the quality of textbooks' and 'the way textbooks are used by teachers and learners', and the effect of both these constructs as enabling inputs on the delivery of quality basic education. The study is undertaken in macro educational context where the doubtful quality of textbooks [which invariably impacts on the subject specific knowledge of teachers, (RSA, 2011)] and the inability of teachers to use textbooks effectively may hamper their effectiveness to deliver quality teaching.

Due to its potential to develop research-based solutions for complex problems in educational practice a design-based research approach was selected for the study. A training intervention was designed and used as a research site. The purpose of the intervention was to develop an understanding of the importance and the quality of textbooks and the way textbooks can be used by teachers and learners as an enabling input in the delivery of quality education. In the process the textbook competence of teachers were addressed. Textbook competence refers to a norms and standards requirement for teachers [as specified by the Department of Basic Education (RSA, 2000)] that requires from teachers to be able to :

- evaluate the quality of textbooks and develop supplementary material as required?
- apply different methods of using textbooks in delivering quality education

A book, The Textbook Factor in Quality Education [226 pages] (Visser, 2014), developed for this purpose, served as basic resource material for the content presented during the workshop. Questionnaires, interviews, workshop activities and artefact (textbook) analysis were used to ascertain educator perceptions (understanding) of the quality and utilisation of textbooks in their area of involvement in education.

2. CONCEPTUAL FRAMEWORK

International awareness of the role, importance, the quality and use of textbooks as an enabling input in the delivery of quality education developed slowly, sporadically and intermittently over time.

When the United Nations (UN) General Assembly in December 1948 (UN, 1949) accepted the Universal Declaration of Human rights, resolving that everyone has the right to education, quality education was not part of the agenda. The focus was on ensuring access to education to the children of the world. The right to education, qualified in terms of the right to quality education, was only formally recognised 42 years later when the World Declaration on Education for All (EFA) was adopted by a UNESCO World Conference on Education in Jomtein, Thailand in 1990 (UNESCO, 2000). In the preamble to the conference declaration reference was specifically made to the problem of quality in education:

> Acknowledging that, overall, the current provision of education is seriously deficient and that it must be made more relevant and qualitatively improved . . .

Following the Jomtein declaration, educators came to realise that perceptions around quality in education differ considerably. The need to promote understanding of the concept quality in education caused UNESCO to publish a comprehensive report, Education for All: the Quality Imperative (UNESCO, 2005).

The report suggests that in order to define quality in education a dialogue is required which aims to establish, inter alia . . . (ibid:35)

- A framework for the analysis of quality in education that enables its different dimensions to be specified;

A diagrammatical depiction of the key dimensions (or factors) that would impact on quality in education was provided (UNESCO, 2005:36); refer adapted systems diagram, **Figure 1**. The framework depicts four key dimensions which influence the core processes of teaching and learning and thus quality in education. The diagram specifically identifies teaching and learning materials (e.g. textbooks) and teaching methods (e.g. using textbooks) as enabling inputs in the delivery of quality education.

In 2006, another UNESCO publication Textbooks and Quality Learning for All: Some lessons Learned from International Experience (Braslavsky, 2006) brought many of the problems associated with the development of quality textbooks and the need to use textbooks effectively in supporting the delivery of quality teaching and learning to the attention of the international educator community.

Concurrently with initiatives by the international educator community to improve the quality of education an International Association for Research on Textbook and Educational Media (IARTEM) was established to promote the development of quality textbooks. This association initiated and is involved in developing an international standard for classroom teaching and learning materials (IARTEM, 2013; Horsley, 2013)

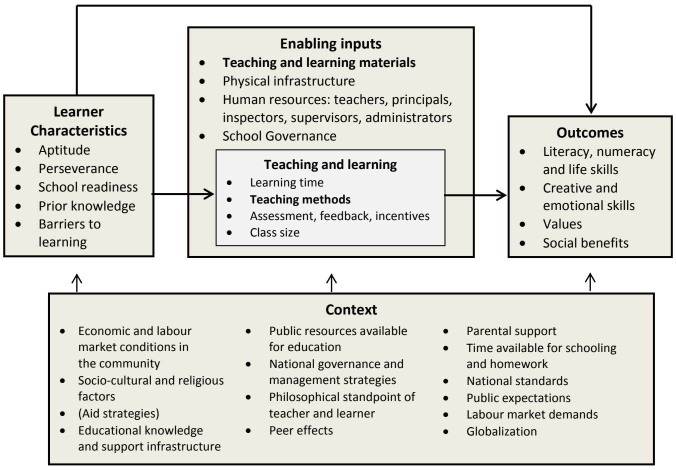

Figure 1: A Framework for Understanding Education Quality (UNESCO, 2005)

Initiatives by individual countries to promote quality textbooks brought about the establishment of a number of dedicated textbook development institutes that are actively involved in ongoing textbook research and other strategies and processes to improve the quality of textbooks, institutions such as:

- Georg Eckert Institute for International Textbook Research (Germany),
- Japan Textbook Research Centre,
- Korean Educational Development Institute
- The Ontario Institute for Studies in Education (Canada)
- International Association for Research on Textbooks and Learning Materials (Norway)
- Teaching Resources and Textbook Research Unit (Australia)
- Textbook Resources Centre (Taiwan)

It is not co-incidental that many countries recognised for the quality of their education systems (as indicated by the performance of their learners on international benchmark tests, such as TIMSS, PIRLS, PESA) are actively involved in research on the quality and utilisation of textbooks, e.g. Japan, Korea, Finland, Canada, etc. The converse has also been indicated: countries characterised by poor education systems do little or no research on textbooks, e.g. Saudi, Yemen, Morocco, South Africa, etc. (Visser, 2009).

Research on textbooks is almost non-existent in South Africa. According to the National Electronic Thesis and Dissertation (NETD) data base of the National Research Foundation (NRF, 2013) only 23 studies since 1979 (n = 56 582) dealt with textbooks in education (Keywords: education + textbooks). Most of these studies dealt with textbooks in a specific subject context (18), for instance history (6). In this regard the metaphor used by Dede (2004:107) seems to be particularly appropriate. He tells the apocryphal story ". . . of the drunk looking for his lost keys under the street light where he can see, rather than in the dark alley where they were dropped." This analogy, applied to education research, I interpret to mean that researchers often look for answers to educational problems in the familiar areas with which they are comfortable, rather than in the often messy and unfamiliar environments in which basic school education is provided. The subject area of this study – the quality and use of textbooks – often feels like the 'dark alley' in Dede's metaphor.

Another reason for the limited research on textbooks is because it is mostly not considered an independent (or separate) area of research: According to Johnsen (2001) no theoretical systems have been established for textbook analysis as a field of research with status as a separate discipline. Wikman and Horsley (2013) maintain that the likely reason why there is almost no research on the general role of textbooks in teaching and learning is the absence of an appropriate textbook theory. Textbook research tends to adopt an interdisciplinary approach, involving some of the traditional disciplines, such as linguistics, pedagogics, history, sociology and psychology, often involving these disciplines in combination (Pingel, 2010).

3. PERSPECTIVE ON THE QUALITY OF TEXTBOOKS

Concern about the quality of science textbooks were expressed by Peacock and Cleghorn (2005:44):

> A recent study of middle-school science textbooks by Project 2061—a science and mathematics curriculum reform initiative of the American Association for the Advancement of Science (AAAS) – found that not a single one of the books met even the minimum requirements for effectively teaching science. American science textbooks have become larger and flashier, chock full of colourful photographs, diagrams, 'activities', 'minilabs', 'sidebars' about minorities in science, science in history and literature and art, and current issues such as the use of hormones in dairy cattle. The only thing the books utterly fail to do, according to scientific and educational experts who have examined them closely, is teach science.

On the use of illustrations (graphics) in textbooks, Peacock and Cleghorn (2005:44) warn that visual literacy, especially in science material, is often assumed.

> There is a common assumption that visual (graphics), especially in science material, will aid understanding of written text. However, learners often have problems with the use of symbols, scale and cross-sectional diagrams. Their research identified at least ten different uses for arrows in elementary science text, the use of which is rarely explained within the text."

In an analysis of science textbooks used in middle grade schools in the United States of America (USA) the AAAS observed that lavishly illustrated textbooks rarely facilitate learning because they are "too abstract, needlessly complicated, or inadequately explained" (Swanepoel, 2009:).

A comparison of elementary science textbooks from USA and Japan illustrates how textbooks can differ (Peacock and Cleghorn, 2005:44):

> Japanese text is focused on pupils doing science, using illustrations to obtain information with which they can solve science problems; whereas the US texts are more concerned to provide comprehensive coverage of facts and concepts that may be tested, as well as to look attractive"

A comparison of the use of illustrations (graphics) in two elementary textbooks used in USA and Japan is shown in **Table 1** (ibid:44).

Table 1: Comparison of elementary science textbooks from USA and Japan (ibid:44)

Mean of 2 examples from each country	USA	Japan
Size	2kg, 500 pages	0.4kg, 100 pages
Content	Wide ranging	10 topics only
Electricity unit		
Pages	18	14
Sentences	205	14
Activities	4	4
Photos	23	24
Illustrations	7	20

PISA Rating (2012)
Japan – 4^{th}
USA – 28^{th}
Total countries rated = 65

Not only is the USA textbook more comprehensive (500 pages as against 100 pages, which raises often expressed concern about content overload) but also the weight of books (2kg as against 0,4kg). In dealing with the unit (topic) electricity the American textbook uses 205 sentences and 7 illustrations to describe and explain the topic, while the textbook from Japan uses 14 sentences and 20 illustrations.

Research on the quality of mathematical textbooks undertaken by the Nuffield Foundation (Askew, Hodgen, Hossain and Bretscher, 2010:34) indicate a wide discrepancy between the quality of textbooks used in the UK compared to the textbooks in the Pacific Rim countries:

> In England, procedural fluency and conceptual understanding are largely seen as mutually exclusive aims. This polarising of procedural and conceptual is not helpful. Pacific Rim teaching is largely dominated by procedures and hence supportive of procedural fluency, but the procedures used tend to be explicitly grounded in mathematical principles and consequently more mathematically coherent and meaningful than those most commonly used in the United Kingdom. In the Pacific Rim, mathematically informed procedural teaching is introduced and promoted through carefully constructed textbooks.

In a preamble to a report on the evaluation of a number of widely used mathematics textbooks, the American Association for the Advancement of Science (AAAS) expressed concern about the reliability of most textbook evaluations:

> Because there has not been a solid, widely acknowledged conceptual basis for evaluating textbooks, the process has been largely cursory, impressionistic, and unreliable.

According to the AAAS (AAAS) selecting or approving textbooks (deciding which textbook to use) is one of the most important professional judgments that educators are required to make. Decisions about textbooks influence instruction for many years; it influences decisions that teachers make on what to teach and how to teach it. It influences learners' understanding of the curriculum, of what they are expected to learn and how they will learn it.

The problem to identify generic quality characteristics that could be applied to textbooks for 663 subjects required in four phases, or 12 grades of education in South Africa, proved to be a particularly difficult 'dark alley' issue. According to Naumann et al. (in Braslavsky, 2006) textbook specialist have not yet been able to come up with a commonly shared set of criteria (characteristics) against which the quality of textbooks can be evaluated.

Textbook analysis is often based on the essential elements or components that make up a textbook (Kojanitz, 2007). Naumann et al. (in Braslavsky, 2006), referring to the work from a number of authors, used the term 'didactic elements of textbooks' referring to aspects such as: introductions, content, summaries, structure, illustrations, language, exercises, etc., elements which seems to be "universally accepted as relevant to textbooks" (ibid:120).

For the purpose of this study a distinction is drawn between an element and a characteristic. An element refers to something that is "a necessary or essential part of something" (Oxford Dictionary, 2000:406). For example: 'a preface' is an element of a textbook. 'A characteristic' refers to "a feature or quality something has." (ibid:196). For example: 'a preface' clearly setting out . . . (explanation provided) is a 'characteristic' of a quality textbook.

Elements common to most textbooks can be identified intuitively by reviewing (exploring) a number of textbooks. **Table 2** provides a list of elements normally associated with textbooks. These elements were identified and evolved over many years through my involvement in running workshops for textbooks writers. These elements have been established arbitrarily and are structured in terms of four 'types':

- **Information elements:** General information that pertains to a textbook
- **Generic 'characteristics':** Elements that are applicable to a textbook as a whole.
- **Content elements:** Elements that are normally present in a textbook chapter and relates to the way content is covered (structured).
- **Subject specific elements:** Elements related to a specific subject and normally relates to the curriculum being presented

Table 2: Textbook elements

Didactical elements			Subject specific elements
Information elements	**Generic characteristics**	**Content elements**	
• Cover page • Preface • Table of content • References • Layout considerations • Additional resources indicated • Bibliography • Topic index	• Language • Pedagogy, didactic, learning principles applied • Transformation, gender, equity presented	• Chapter structure • Introductions • Objectives/outcomes • Information types • Definitions • Graphics • Examples • Case studies/stories • Activities, exercises • Discussion questions • Summary, key learning points • Assessments • Glossary of new/ technical/subject specific terms	• Compliance with curriculum • Content analysis , reflecting current disciplinary understanding • Level appropriate **Subject specific 'elements' may apply for different subjects:** • Languages • History • Mathematics • Science • Accountancy • etc.

A description of the quality characteristics linked to these elements, and the principles on which they are based are provided in a resource book: The textbook factor in quality education (Visser, 2014).

4. PERSPECTIVE ON THE UTILISATION OF TEXTBOOKS

Textbooks are the most important teaching and learning resource available to teachers and learners. Ultimately, however, the value of a textbook only comes into play when it is used by teachers and learners (Taylor, 2008; Moulton, 1997).

In education circles the use of textbooks are often criticised. Ulerick (2013) confirmed that much of science teaching is guided by and based upon the contents of science textbooks. However this practice is frequently condemned in gatherings of science educators. Ulerick then poses the question: "Is it the books themselves that are the problem or is it the manner in which students and teachers use them?" Most of the reasons given by teachers why they often do not use textbooks are concerns they have about the quality or weaknesses in textbooks, for instance, the language of textbooks is too difficult, or textbooks are out of date, or not relevant, or students cannot relate to the examples in the textbook, or the textbooks are full of mistakes, etc.

It is not co-incidental that Finland, in 2006, was rated first on the PISA evaluation of science teaching amongst 57 countries [Finland was rated fifth in 2012]. [**PISA:** Programme for International Student Assessment, a programme provided by the Organisation for Economic Co-operation and Development (OECD) assessing the performance of 15 year old pupils in different countries on mathematics, science or reading.] Horsley and Wikman (2009) confirmed that teaching in Finland is characterised by extensive use of textbooks; 81% of teachers use textbook much or very much, only 5% of the teachers use textbooks very little. In the Finnish system most science teachers design their lessons based on a textbook, and use it or a workbook for most of the classroom time; textbooks and workbooks provide the major instructional format for lessons; and, science homework is based on the questions at the end of a textbook chapter.

The extensive use of textbooks is also characteristic of teaching in the Pacific Rim countries, e.g. Japan, Singapore, South Korea, China, Chinese Taipei (Taiwan) and Hong Kong (Askew, Hodgen, Hussain and Bretscher, 2010). These countries are all recognised for the quality of their education systems (as indicated by the superior performance of their learners on international benchmark tests, e.g. PISA, TIMSS and PIRLS).

Reints & Wilkens (2009:468) defines a textbook as: ". . . a book designed and developed for use in a classroom by teachers and students". Naumann, et al (in Braslavsky, 2006:128) defines a textbook as a tool: "A textbook is a teaching, learning and working tool used to support teaching and learning processes in schools." In both these definitions the utility value of a textbook is raised: as a resource to be used in the classroom by teachers and learners, and as a tool which is used within the context of a teaching and learning process. As a tool the effectiveness of a textbook is determined by the way it is used by teachers and learners. Textbook alone do not improve student learning, it needs to be used effectively (Moulton, 1997).

For the purpose of this study guidelines on alternative techniques to use textbooks were developed (refer Table 3). A description of these techniques is provided in a resource book: The textbook factor in quality education (Visser, 2014:155-168).

Table 3: Using textbooks – techniques for teachers and learners (Summary)

Teachers using textbooks	Learners using textbooks
1) Plan instruction	1) How a textbook is structured
2) Construct assessment	2) Learn to use a textbook
3) Provide overview	3) Getting an overview
4) Review textbook/chapter structure	4) Reading
5) Review work already done	5) Reading ahead
6) Assign in-class activity from textbook	6) Do homework
7) Pre-instructional reading	7) Learning principle – time on content
8) Assign homework	8) Learning principle – repetition
9) Reading aloud	9) Prepare for class
10) Use as basis for discussion	10) 'What did I learn in class today'
11) Clarify concepts	11) Review work already done
12) Find answers	12) Develop subject specific vocabulary
13) Work back-words	13) 'Talk about it'
14) Mind mapping	14) Prepare to teach
15) Identify types of information	
16) Teaching the page	
17) Building subject specific vocabulary	

5. DESIGNING A TRAINING INTERVENTION

A design-based research study involves two 'designs': the one dealing with the design of an 'intervention', and the other dealing with the research methodology adopted (Dede, 2004:114). For the purpose of this study an intervention was selected (utilised) that would contribute to the development of the 'textbook competency' of educators (participants).

Peacock (in UNESCO, 2007) emphasised the need for textbook training: teachers should receive training that enables them to use a range of resource materials in a creative and flexible way. Teachers also need to be made aware that textbooks can be used in different ways (ibid) and that one cannot make easy judgments about correct and incorrect ways to use a textbook. Through training teachers need to be made aware of their pattern of textbook use, the rationale behind the patterns they choose, the alternatives available to them, and how effectiveness in textbook usage can improve quality teaching and learning. "Our research suggests that helping teachers become more aware of their patterns of textbook use, their own selectivity, the alternatives available to them, and the consequences of the choices they make for instructional activities is an important avenue to pursue" (Moulton, 1997:15).

Textbook training is not only considered an essential part of teacher development it is also seen as an important component contributing to transformation in education. According to Borovikova, and Barnashova (in Braslavsky, 2006:331) textbook training was seen as an essential part of the transformation of education in the Russian Federation. It was recommended that ". . . teachers should be trained to choose and evaluate teaching materials through in-service and pre-service training."

Knowledge about textbooks covers a range of topics, including: the characteristics of quality textbooks, the analysis, review (evaluation), and selection of textbooks, the writing, production, procurement and availability of textbooks, textbook research, effective utilisation of textbooks by teachers and learners and training in the use of textbooks. According to Horsley (2007:254) these topics (which he refers to as **'textbook pedagogy'**) are considered 'core teaching activities'. "Yet there are few resources that have been developed to explore these topics, and specifically to assist teachers and trainee teachers to utilise teaching and learning materials and textbooks more effectively" (ibid:254).

The specific roles that teachers are required to perform in the delivery of basic education have been formulated by the Department of Basic Education (DBE) as norms and standards for educators (RSA, 2000), specifying seven key roles. Integrated in three of these roles (i,e. Specialist in a phase, subject, discipline or practice; Learning mediator; and Interpreter and designer of learning programmes and materials) are practical and foundational competencies which requires from teachers to:

- be able to judge the quality of textual materials (textbooks) and develop supplementary material where weaknesses (gaps) in textbooks have been indicated;
- apply different approaches (methods) to teaching and learning, including how to use textbooks effectively to deliver quality education.

In terms of the Department of Higher Education and Training (DHET) policy on the minimum requirements for teacher education qualifications (RSA, 2011) the norms and standards for educators (seven roles) ". . . (RSA, 2011:11) continue to be a useful tool to assist in the design of learning programmes." In this regard the ability to evaluate the quality of textbooks (in terms of clearly identified quality characteristics), and the ability to use textbook effectively as part of a general instructional approach, is considered to be f**undamental learning** required for teaching purposes. These competencies can be equated with the ability to use ICTs (Information and Communication Technologies) as fundamental learning required (and often included) in teacher education. One would therefore expect that '**textbook pedagogy'** (Horsley, 2007) to be included in teacher education programmes.

The intervention developed for this study takes the form of a workshop which addresses the key textbook competencies required by teachers, namely the competence to:

- evaluate the quality of a textbook
- effectively utilise textbooks as part of a teacher's teaching methodology

The content of the workshop was formulated in a book titled **'The textbook factor in quality education**' [224 pages] (Visser, 2014), developed for this purpose. The book was made available to participants as resource material for the workshop. The book provides a comprehensive review of the research literature on the constructs quality and utilisation of textbooks. A full description is presented of the characteristics of quality textbooks identified in **Table 2** and the alternative ways of using textbooks identified in **Table 3**. Included in the workshop material is a textbook evaluation instrument, and a summary of the quality characteristics that apply to textbooks (6 x pages) to assist participants in evaluating a textbook.

The workshop was designed to be presented in three sessions of approximately three hours each, spread over three weeks, covering:

Session one: Textbooks and quality education in context

Session two: Evaluating the quality of textbooks

Session three: Alternative ways of using textbooks

The workshop was utilised as a research site to explore the views and perceptions of educators (teachers, student teachers and teacher educators) on the particular constructs. A 'workshop' form of presenting information was purposefully selected to achieve maximum participation and involvement from participants.

It needs to be emphasised that the competence to evaluate a textbook, to judge the quality of a textbook, is a higher level skill that cannot be adequately (fully) developed in a three hour workshop session. This is, however, an essential competence required of teachers and, according to Horsley

(2007, p.255) no training is provided to teachers to develop this competence. It is for this reason that comprehensive resource material was developed for the workshop that allows participants to gain knowledge in this area through independent study. The workshop itself could only focus on a limited number of the characteristics identified, e.g. preface, definitions, graphics, examples, case studies/stories, key learning points, etc. The competency to judge the language of textbooks, or evaluate the different 'information types' used in textbooks, for instance, would require more intensive 'exposure'.

Given that textbooks are considered to be the single most important learning resource available to learners (Taylor, 2008) teachers also need to assist (guide) learners to use textbooks effectively (optimally). Teachers therefore need to be advised on how to assist learners to use textbooks well. A list of alternative techniques for learners to use textbooks is provided in Table 3 and is discussed in detail in the workshop resource material (Visser, 2014:162-167).

6. RESEARCH QUESTIONS, DESIGN, METHODS AND FINDINGS

6.1 Purpose

The study aims to gain a better understanding of the constructs the quality and the utilization of textbooks, and the effect of both these constructs as enabling inputs on the delivery of quality basic education. The study is undertaken in macro educational context where the doubtful quality of textbooks [which invariably impacts on the subject specific knowledge of teachers, (RSA, 2011)] and the inability of teachers to use textbooks effectively may hamper their effectiveness to deliver quality teaching. The development of the textbook competence of teachers is seen as an appropriate strategy to effectively improve the competence (performance) of teachers to deliver quality education.

6.2 Research questions

What is the effect of a training intervention – addressing the role, quality and utilization of textbooks as an enabling input in the delivery of quality education – on the conceptual understanding of participants on the relevant constructs, in particular:

- What are the perceptions of participants on the importance of quality textbooks in the delivery of quality education?
- How does the intervention build the competence (effectiveness) of educators to evaluate the quality of textbooks? [as required by the norms and standards for educators as specified by the Department of Basic Education (RSA, 2000)]
- How does the intervention build the competence (effectiveness) of teachers in utilizing textbooks as a means to deliver and support quality teaching and learning? [a norms and standards requirement for teachers]

6.3 Design

This study adopts a design-based research (DBR) approach. According to Collins, Joseph, and Butaczyg (2004) DBR experiments were developed as a way to carry out formative research to test and refine educational designs. "This approach of 'progressive refinement' in design involves putting a first version of a design into the world to see how it works. Then, the design is constantly revised based on experience, until all the bugs are worked out."

According to Simonson (2006:7) DBR is defined as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings. ". . . DBR uses both qualitative and quantitative methods including surveys, expert reviews, interviews, etc. (ibid). In DBR, participants' feedback is particularly important (MacDonald, 2008). DBR is designed to respond to the ever-changing reality of messy educational settings (ibid:432).

In the pilot presentation of the 'workshop' that was developed as a research site for this study questionnaires were used to:

- Assess **teacher** and **student teacher** perceptions about the importance, quality and use of textbooks (refer Annexure 1);
- Evaluate participant responses to the workshop (refer Annexure 3).

Eighteen (18) student teachers and six (6) teachers who attended the workshop on a voluntary bases completed the questionnaires. Ten (10) teachers who did not attend the workshop also competed questionnaires indicating their perceptions about the importance, quality and use of textbooks (refer Annexure 1);

Questionnaires were also completed by nine (9) **teacher educators** (they did not participate in the intervention) to determine their perceptions on textbooks (refer Annexure 2).

Feedback from participants is provided using 'average responses' to the relevant questions (statements) based on the relevant five point scale used.

Responses were interpreted as follows:

- Responses between (2.5 – 3.5)* = interpreted as inconclusive (participants were not sure)
- Response between 1 – 2 and between 4 – 5 = interpreted as conclusive
- Responses between [2.1 – 2.4 and between 3.6 – 3.9]* = interpreted as borderline

***Note:** Brackets were used on the relevant data sheets (Annexures), refer above, to interpret the particular data as inconclusive and borderline.

A pilot artefact analysis was also undertaken to field test an evaluation instrument used in the workshop to assess the quality of selected textbooks. Five (5) Mathematical Literacy textbooks were evaluated. In terms of an overall rating the five textbooks reviewed rated between 49% and 62%. None of the books reviewed can be considered excellent; four of the books are average while one book is a borderline between average and good. (Average: 40% - 59%; Good: 60% - 79%; Excellent: 80% <)

6.4 Findings

As this paper provides information on a pilot study I am reluctant to provide a comprehensive analysis (interpretation) from the data gathered. From the preliminary feedback on educator perceptions about textbooks it is, however, clear that:

- Participants have not received any training on how to evaluate the quality of textbooks and how to use textbooks effectively (Q1)
- Participants consider it important that textbook training be provided to educators (Q10, Q6)
- Participants believe that teaching and learning will be improved by improving the quality of textbooks (Q2, Q7)
- Language has been indicated as an important consideration in determining the quality of a textbook (Q3)

Participants provided positive feedback about the workshop regarding (refer Annexure 3):

- The relevance of the content
- The quality of the workshop material
- Presentation methodology (approach)

Some of the comments made by student teachers were particularly significant:

> I feel that the workshop should not only be a workshop but included as a course in our studies.
> I would suggest that this workshop should be compulsory to all UJ (University of Johannesburg) students.

From the data gathered the importance of textbooks as an enabling input in the delivery of quality education was confirmed. As a result of the workshop both teachers and student teachers indicated new insights about the quality of textbooks and particular characteristics that influences the quality of textbooks. A greater understanding was indicated of alternative ways to use textbooks. The emphasis on ICT in teacher training programmes was indicated as a contradiction. Student teachers indicated (strongly) that textbook training should not be offered as an alternative 'ad hoc add on' by way of an optional workshop but that it should be included and form an integral part of teacher education programmes. The time allocated for the workshop was indicated as insufficient.

In general the study revealed that the value of textbooks as an enabling input in the delivery of quality education is curtailed by the inability of teachers to adequately assess the quality of textbooks and to effectively utilise textbooks in a teaching learning situation. The study further revealed that this situation is aggravated by: the non-inclusion of 'textbook pedagogy' in teacher training programmes and the exclusion (non-provision) of textbook training as part of ongoing professional teacher development. The literature study confirmed that limited research is undertaken on the quality and utilisation of textbooks. The effectiveness of evaluating the quality of textbooks is reduced by the absence of commonly shared and scientifically based quality characteristics (evaluation criteria).

6. CONCLUSION

The literature review together with feedback from educators in this study strongly suggests that the poor quality and ineffective use of textbooks in South Africa negatively impacts on the provision of quality education in schools in the country.

It is recommended that teacher education institutions be encouraged to implement relevant programmes to enhance the textbook competence of student teachers. Programmes to enhance the textbooks competence of teachers should also be offered to practicing teachers as part of an ongoing professional teacher development programme.

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ANNEXURE 1

TEACHER and STUDENT TEACHER responses to a questionnaire assessing their perceptions on the quality and utilisation of textbooks
Participants were requested to indicate to what extent they agree/disagree with the statements listed in the questionnaire (see statements below), using the following key:
Legend:5 = totally agree; 4 = agree; 3 = not sure; 2 = disagree; 1 = totally disagree.

The table below provides data on average responses received (based on legend provided)

	Statements	A*	B*	C*
1.	I have never received any training on how to evaluate the quality of a textbook or how to use textbooks effectively with learners	4.5	[3.8]	4.3
10.	It would be important for me to learn how to evaluate the quality of textbooks and how to use textbooks effectively	4.7	5.0	4.8
6.	Knowing how to use textbooks effectively will enhance (improve) the effectiveness (performance) of teachers	4.8	5.0	4.6
2.	Improving the quality of textbooks overall will contribute to improve the quality of education in the country	4.4	4.6	[3.8]
7.	A (good) quality textbook is an essential requirement (a pre-requisite) for quality teaching and learning	4.5	5.0	4.4
4.	Poor quality (difficult) textbooks may cause learners to drop out from school	(3.0)	4.2	[3.7]
3.	Learners whose home language is different to the language of instruction often find the language of textbooks difficult to understand	4.3	4.4	4.2
5.	Competent teachers does not needs to use textbooks	1.3	1.6	1.9
12.	I'm perfectly comfortable to teach without a textbook	[2.3]	(3.0)	[2.4]
11.	The effectiveness of a teacher is determined by the way he uses textbooks	4.1	4.6	4.2
8.	I'm totally dependent on using a good textbook for the teaching that I do	(3.0)	[3.8]	[3.7]
9.	The value of a textbook is determined by how well it is used by teachers and learners	[3.6]	4.4	[3.8]
13.	Most of the homework given to learners must require from them to use their textbooks	[3.4]	4.0	[3.6]

*Participants
A. Group of ten (10) teachers attending a workshop for Masters and Doctoral students from the education faculty, University of Johannesburg (2-4 May 2014)
B. Group of six (6) teachers who attended a workshop on the quality and utilization of textbooks, (4 & 10 March 2014)
C. Group of 18 student teachers from the University of Johannesburg who attended a workshop on the quality and utilization of textbooks (8 & 15 March 2014)

ANNEXURE 2

TEACHER EDUCATORS responses to a questionnaire assessing their perceptions on the quality and utilisation of textbooks

Participants were requested to indicate to what extent they agree/disagree with the statements listed in the questionnaire (see statements below), using the following key:

Legend:5 = totally agree; 4 = agree; 3 = not sure; 2 = disagree; 1 = totally disagree.

The table below provides data on average responses received (based on the legend provided)

	Statements	Average Response
1.	Training on textbooks (how to evaluate and use textbooks) are normally not included in teacher training programmes.	4.4
10.	Learning how to evaluate the quality of textbooks and how to use textbooks effectively should be included in teacher training programmes	4.1
15.	Whether to include textbook pedagogy in teacher education creates between the what (theory) and how (practice) often prevalent in the content of academic programmes where the focus tend to be on the what.	(2.9)
6.	Knowing how to use textbooks effectively will enhance (improve) the effectiveness (performance) of teachers	4.1
2.	Improving the quality of textbooks overall will contribute to improve the quality of education in the country	4.0
7.	A (good) quality textbook is an essential requirement (a pre-requisite) for quality teaching and learning	[3.9]
4.	Poor quality (difficult) textbooks may cause learners to drop out from school	(2.8)
3.	Learners whose home language is different to the language of instruction often find the language of textbooks difficult to understand	4.2
5	Competent teachers does not needs to use textbooks	[2.4]
12.	Teachers should not have a problem teaching without a textbook	[3.9]
11.	The effectiveness of a teacher is determined by the way he uses textbooks	[3.7]
8.	I'm totally dependent on using a good textbook for the teaching that I do	4.3
9.	The value of a textbook is determined by how well it is used by teachers and learners	[3.8]
13.	Most of the homework given to learners must require from them to use their textbooks	[3.6]
14.	Not enough research is conducted on the quality and utilization of textbooks.	[3.8]

Participants

A group of nine (9) teacher educators attending a workshop for Masters and Doctoral students offered by the Education Faculty, University of Johannesburg (2- 4 May 2014).

ANNEXURE 3

Feedback from TEACHERS and STUDENT TEACHERS attending a Workshop on the quality and utilisation of textbooks.

Participants were requested to indicate to what extent they agree/disagree with the statements listed in the questionnaire (see statements below), using the following key:

Legend: 5 = very good (or yes); 4 = good; 3 = not sure; 2 = not good; 1 = poor (or no)

The table below provides data on average responses received (based on the legend provided)

	Criteria	A*	B*
1.	The content relevance of the workshop?	4.8	5.0
2.	Transferability of the content of the workshop (will I be able to apply what was covered during the workshop in my work)	4.4	5.0
3.	Knowledge component – what content: was new knowledge/ information presented?	4.6	5.0
4.	Skills component – how-to content: exposure to new/practical ways of doing things?	4.8	4.8
5.	The quality of the workshop material (Hand-outs, Manual)?	4.7	5.0
6.	The suitability of the venue?	4.2	5.0
7.	The duration of the workshop?	(2.9)	(2.5)
8.	The quality of the PowerPoint slides used in the workshop?	4.6	5.0
9.	The use made of break-away (group activity) sessions?	(3.4)	(3.0)
10.	Opportunity for me to participate and share my views?	[3.9]	5.0
11.	Times allocated for the workshop (start, finish, breaks)?	[3.9]	(3.0)
12.	Size of the group?	[3.9]	4.8
13.	Facilitation process?	4.4	5.0
14.	Concerns addressed?	4.3	5.0

*Participants

A. Group of 18 student teachers from the University of Johannesburg who attended a workshop on the quality and utilization of textbooks (8 & 15 March 2014)

B. Group of 6 teachers who attended a workshop on the quality and utilization of textbooks, (4 & 10 March 2014)

IMPLEMENTING A FLEXIBLE STRUCTURE IN UNDERGRADUATE SCIENCE CURRICULA

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Abstract–"*A proposal for undergraduate curriculum reform in South Africa: The case for a flexible curriculum structure*" (CHE, 2013) suggests a number of scenario (models) in order to increase the number of graduates nationally. For the past 20 years South African higher education institutions were expected to start implementing a number of new policies and to align their internal functions and structures more optimally towards increased access, student throughput and quality teaching and learning, amongst other policy indicators.

Since 1994, the SA government has been steering a radical transformation and restructuring of higher education, which kicked off with the White Paper on HE transformation (1995), the latter which formally culminated in the Higher Education Act 101 of 1997. Policies are generally developed in response to challenges, problems or inadequate progress in respect of nationally identified strategic goals or targets. Some policies are geared at national quality enhancement, in the process, establishing new national structures with dedicated terms of reference and responsibilities. Policies are thus created to bring about desirable change and are generally regarded as strong symbolic indicators of national intent (Bunting, 2008; Bunting, 2004).

This paper reports on a sample of national and institutional policies and the directives stemming from them. The pertinent emphasis on an increase in the participation and eventually the academic success of undergraduate students in Science programmes is linked to insights brought about by increasingly improved National Senior Certificate (NSC) results, especially over the last decade. The quantitative investigation compares the academic performance of 1563 main stream first year degree students with 2110 extended degree students in seven fundamental science modules at the University of Johannesburg. Mean values were compared and regression provided predictive value of the different modules on performance. The enquiry culminates in speculation on the implications that the above mentioned Flexible Curriculum Structure might bring about and the dataset investigate flexible curriculum in practice at the University of Johannesburg.

Keywords: Flexible curriculum**,** Policies**,** Widening access**,** Academic success in Science programmes

1. PURPOSE AND CONTEXT OF THE RESEARCH

The South African higher education landscape has transformed with every term of Ministry by influential policy declarations and revisions of existing procedures. The fifth minister, Dr Blade Nzimande, has published the Green Paper (RSA DHET) in 2012 and a CHE Task Team (CHE, 2013) has reported on the undergraduate curriculum reform in 2013. These two documents indicate massive transformation agendas with all the other policies (Hay & Monnapula-Mapesela in Bitzer, 2009, p.12).

The geo-political South Africa (SA) has moved from a higher education sector where racial inequalities were evident for almost 50 years as dictated by apartheid planners since 1948 (RSA DoE, 1999). White South Africans had more access to educational resources and opportunities than their Black, Coloured and Indian counterparts (Van Wyngaard & Kapp, 2004, p.185) and were over-represented in higher education (HE). The SA education (school and higher education) sector was fragmented along provincial and racial lines (Habib & Parekh, 2000, p. 39-51; Hay & Fourie, 2002, p.115-131). International universities were subjected to powerful forces of change with pressure to widen access, penetration of the market, accompanied by increasing public and societal demands and expectations, but in South Africa the apartheid era delayed these international trends. Colin

Bundy (2006, p.3) states that in South Africa, Higher Education "…remained largely insulated from the global climate change prior to 1994."

The purpose of this study is to review some of the policies that suggested radical changes in South African HE. To apply these policies this study investigates the implementation of extended programmes as a flexible undergraduate curriculum (CHE, 2013) as a response to widening access, improving quality and graduation rate, addressing scarce skills, enrolment management, emphasis on research and institutional governance.

2. MAJOR POLICY INITIATIVES IN HIGHER EDUCATION POST-1994

2.1 Theoretical framework

This investigation will interrogate the literature perspectives of different government policies that influence enrolment, teaching and learning and curriculum development in specific Science offering. The high drop-out and failure rate of students are costing the students and the government money, also waste time and resources (CHE, 2013). This investigation compared policies and provides evidence that the foundational provision model as stated in the Flexible curriculum model (CHE, 2013) could result in successful throughput of students in Science programme. The theoretical framework that underlies this quantitative inquiry relates to the literature perspectives and research goals to achieve via descriptive, exploration and predictive measurement. The descriptive nature of the research represents description of student marks at school and university level (first year) and describes policies stemmed on the success of students. The exploratory nature of the research is represented by the exploration of the policies and the predictive nature of the research represents the prediction of academic success when students exit the foundational provision phase.

The quantitative approach of the investigation compares student results before and in university first year and determines predictors of success and can be quantified and measured. This approach is therefore post positivist which presumes that an external reality exists independent from the researchers, but that this reality cannot fully be known (Heppner and Heppner, 2004, p143). This approach does not aim to generate theories, models, frameworks, guidelines or programmes that reflect absolute truths about the reality of the participants. The outcomes should rather be judged with respect to the usefulness (substantively and practically) of the findings it generates.

The first post-apartheid term of the SA Government (National Unity in April 1994) brought about transformation at every level of society, with a vision for "reconstruction and development". This government focused on the challenge of economic development, as well as social and political change which created high expectations for fundamental change within the Higher Education sector. The procedure to change processes was through policies, and therefore the following discussions of eight major policies pertaining to changing the organisational culture of the HE sector within the democracy in SA. The second is an outline of the significant implications in Science programmes which also serves as its fundamental roots in Engineering and Health Science curricula.

2.2 The National Commission on Higher Education (NCHE) report (1996)

The National Commission on Higher Education (NCHE, 1996) conducted a groundbreaking investigation, with a direct and long-lasting impact on subsequent policy deliberations. Recommendations made by the Commission had the potential to change the entire SA higher education sector. The following NCHE recommendations are most pertinent within the context of this study:

- "Successful policy must overcome a historically determined pattern of fragmentation, inequality and inefficiency" (NCHE, 1996, p.5). Increased participation to accommodate a larger and more diverse student population and address the shortage of students in the Sciences and related disciplines.
- "Successful policy must restructure the HE system and its institutions to meet the needs of an increasingly technologically-oriented economy" (NCHE, 1996, p.7). Higher education should produce graduates who are better prepared for the labour market and to meet societal needs.

Resulting from this report the implementation will challenge staff, governance and student success. In practice, it will probably take more than one generation to counter stereotyped effects in full.

2.3 The White Paper 3 on Higher Education Transformation (1997)

The Department of Education (DoE) published the White Paper 3 on Higher Education Transformation (WPHE) in August 1997 (RSA DoE, 1997a). This policy provides further impetus for the achievement of a uniform national Higher Education system. The policy places social broadening of the Higher Education sector (in terms of race, class, gender and age) at the forefront. The key to the social, cultural, and economic development of the country relies on the optimal accommodation of a diverse student population.

The relevant recommendations from the WPHE (RSA DoE, 1997a, p.8-10) explicitly expresses a future vision to increase democratisation and broaden participation (and provision) of Black, female, disabled and adult students. Flexible models of teaching and learning to accommodate a diverse and larger than before student population will have to be developed and proven mechanisms of academic development and support for students will be geared towards optimal academic success.

2.4 The Higher Education Act (Act 101 of 1997)

The WPHE (RSA DoE, 1997a) preceded and culminated the Higher Education Act in 1997, underpinning transformation at a national level. The proposed restructuring of the Higher Education landscape required this legislation to drive the change resulting in the mergers of several Higher Education institutions (HEIs) a few years later, while the interconnected nature of planning, governance and funding was also prominent. The Act provided the Minister with powers to enforce with increased government control, and gave new and unexpected meaning to the original desirable notion of cooperative governance.

One of the implications of the Act was the expectation that institutions were to provide successful and qualified students within an optimal period of time. The emphasis on the increasing academic success specifically of undergraduate students and even more pertinent in the scarce skills programmes challenged the Fundamental Sciences (Mathematics, Physics and Chemistry), constituting the basis of most Science, Engineering and Health Science programmes.

2.4 The National Plan on Higher Education (2001)

The second democratic Ministry of Education took the bold step of revealing greater transformation in HE with a declaration in the National Plan on Higher Education (NPHE) which proposed increased subsidy and greater institutional efficiency and effectiveness. Four principles underpinned the NPHE (RSA DoE, 2001a), summarised by Jacobs (2010) in an acronym "READ":

I. **Research** promotion (**R**): To "retain current research strengths and to promote the kinds of research and other knowledge outputs required to meet national development needs…" (RSA DoE, 2001a, p.60).
II. Increased **Equity** (**E**): To "…ensure that the student and staff profiles progressively reflect realities of South African society" (RSA DoE, 2001a, p.30). The NPHE specifically cautioned against unacceptably low levels of enrolment of Black students in SET programmes, which had to be addressed urgently.
III. Increased **Access** linked to Success (**A**): To "increase the number of graduates through improving the efficiency of the Higher Education system …" (RSA DoE, 2001a, p.14).
IV. Promotion of **Diversity** in the Higher Education system by means of mission and programme differentiation (**D**): To "ensure diversity in the organisational form and institutional landscape of the Higher Education system through mission and programme differentiation" (RSA DoE, 2001a, p.36).

These underpinning principles of the NPHE are particularly relevant to the widening of student access, simultaneously linking to increased student success, effectiveness and funding implications. The earmarked funds were to realise particular objectives such as access for poor students, supporting under-prepared students and building research capacity (NPHE, 2001a, p.10).

2.5 Restructuring of the Higher Education System in South Africa (2001)

Colin Bundy (2006, p.20) stated that the NPHE marked the end of "symbolic policy making". There was an urgency to "…ensure diversity in the organisational form and institutional landscape" and to "build new institutional and organisational forms and new institutional identities…" (RSA DoE, 2001b, p.12). In July 1999 Prof. Kader Asmal, announced that the shape and size of the Higher Education system "…cannot be left to chance if we are to realise the vision of a rational, seamless Higher Education system…" (RSA DoE, 1999). The task was to reduce the number of institutions and establish "…new institutional and organisational forms…" The restructuring would result in a reduction of the existing 36 universities to 21, by implementing institutional incorporations, mergers and closures (RSA DoE, 2001b). A table by Bitzer, (in Van Wyngaard and Kapp 2004, p.187), indicates the 'old' and 'new' envisaged Higher Education landscape (see Table 1 below):

Table 1: The Higher Education Landscape Pre-And Post-Mergers (Adapted from Bitzer in Van Wyngaard and Kapp, 2004, p.187)

INSTITUTIONS	Number of institutions before amalgamations, incorporations, mergers and closures	Number of existing or envisaged institutions in 2003
Technical colleges	152	51 clusters
Colleges of Education	94	0
Nursing colleges	35	17
Agricultural colleges	11	11
Universities & technikons	36	21
Total	328	80

The reduction meant 241 less institutions with the closure of all colleges of education, the reduction in the number of agricultural and nursing colleges with universities impacting on the landscape. It was strange that the department would close colleges of education and incorporate these into universities at a time of a serious shortage of teachers in Mathematics and Physical Science and this remains a great concern.

2.6 Student Enrolment Planning in Public Higher Education (2004)

The central premise underpinning the above mentioned national policies and projects is that the Higher Education system "…must be planned, governed and funded as a single national coordinated system" (RSA DoE, 2004, p.2). The student enrolment planning document (2004, p.2) emphasises planning, funding, and quality assurance. Enrolment planning in the SA HE sector was officially introduced by the Ministerial Statement on Public Higher Education Funding (RSA DoE, 2003). Three key factors informed enrolment planning namely, matching of enrolment plans with available resources, linking of the enrolment plans to national human resource and research priorities with an emphasis on scarce skills (Science and related fields) and enhancing quality, throughput and graduation rates. This includes the development of alternative programmes and support mechanisms in specific scarce skills areas mentioned. The funding according to the Classification of Educational Subject Matter (CESM) (RSA DoE, 2004, 2008) provides a weighting factor that corresponds with a qualification type. In Table 2 an example of government subsidy per student is provided.

Table 2: The Funding Grid for Teaching Inputs (Adapted from RSA DoE, 2003; RSA DoE, 2004; RSA DoE, 2008)

Funding group	CESM categories included in funding group	Weighting factors for Teaching inputs			
		Under-graduate	Honours	Masters	Doctoral
1	Education, Law, Librarianship, Psychology	1.0	2.0	3.0	4.0
2	Commerce, Communication, Computer Science, Languages & Social Sciences	1.5	3.0	4.5	6.0
3	Architecture, Engineering, Math- and Physical Education.	2.5	5.0	7.5	10.0
4	Agriculture, Fine Arts, Health-, Life & Physical Sciences.	3.5	7.0	10.5	14.0

According to Table 2, the subsidy for an undergraduate student in Law and Psychology (weight of 1) is less than for an undergraduate student in Health Sciences. The amount is only calculated based on the minimum study years for any qualification and HEIs are therefore competing to recruit students who will earn more comprehensive and faster turnovers for subsidy purposes. The Sciences, Engineering, Technology and Health Science (SETH) environment could generate more income but due to under preparedness more students fail or even drop-out (RSA DoE, 2004, p.5) and financial difficulties, inability to adjust to HE, lack of counselling, incorrect study habits, and immaturity (Bunting, 2004, p.73-94; Scott in Bitzer, 2009, p.21) also contribute to unsuccessful studies.

2.7 Green Paper for Post-School Education and Training (2012)

In 2009 the Department of Higher Education and Training (DHET) was established and this department brought all post-school education and training and separated HE from the Department of Basic Education (DBE). The Green Paper had a priority to address inequalities that still existed after 20 years of democracy placing a lens on Black graduates. Whereas only 12% of the SA higher education population comprised of Black students 1993 (NCHE, 1996, p.64), it increased sharply to 59% in 1999, 65% in 2002, and 79% in 2010 (CHE, 2013, p.39). The growth in Black student participation also introduced complications with retention and progress. Bundy (2006, p.12) notes that "…access gains also prove less healthy when measured against student success levels". A 'wasteful' number of enrolled students fail to complete their studies, there is a decline in retention rates, and dropout rates are as high as one out of five".

There was only 45% Black PhD graduates in 2008 and 41% of these are women (DHET, 2012, p.7), indicating the under-representation at the highest academic level. The low success rates and throughput with shortage of academics in scarce skills (DHET, 2012, p.10) still remains an issue. The redress of participation in higher education is improving with 80% Black representation in 2010 compared to 55% in 1994 (DHET, 2012, p.34) with a noticeable growth in SET graduation (5.5% per annum) but this is still not sufficient for economic development.

The impact of widening participation with more students entering the sector from poor households, rural schools and a high non-payment rate (DHET, 2012, p.36) prompts institutions to be innovative. In presenting high-quality undergraduate education "…universities should be supported in offering and mainstreaming four-year undergraduate degree programmes where necessary" (DHET, 2012, 36).

2.8 A proposal for undergraduate curriculum reform in South Africa (2013)

The above review addressed access, quality and restructuring but during the 20 years of democracy, the low graduation rate in South Africa continues to deter social and economic development. The task team appointed by the CHE determined that 25% of SA students graduate in regulation time (a three year degree in three years) (CHE, 2013, p.43); 29% of BSc students and 23% of BIng students graduate in regular time.

Success and failure in HE can attributed to "…a complex interplay of factors" (CHE, 2013, p.54-57). The factors affecting success are all inter-related but the report groups them in three categories namely, material factors (socio-economic background); affective factors (attitude towards studies, psychological and social support) and academic factors (response to the educational process and poor schooling). The problems in the SA schooling system will not change soon and HE will have to address the articulation gap between school and university (CHE, 2013, p.60). The nature of the articulation gap is complex with under preparation in subject knowledge, academic skills and literacy, approaches to learning, contextual knowledge and forms of social capital contributing to the deficits in the transition of students.

This specific report brings tangible solutions to the table. The report recommends that institutions need to reform and modify structures to provide more time ad curricular space that would provide for strengthening and enhancement of learning (CHE, 2013, p. 68). The task team warns HEIs not to re-teach school content but slowly initiate new students into the HE approach. Many assumptions are made about prior knowledge and skills and by extending the time and curricular space students will be able to become more intellectually mature. The CHE (2013, p.95-96) suggests a flexible approach where students enter into a longer programme but those who show confidence and good progress could accelerate and be exempted The report acknowledges the deficits in the HE sector and proposes a pragmatic model to address access and quality. The foundational provision such as language abilities, quantitative literacy and attributes that 21st century graduates need would be absorbed in this four year B-degree or five year professional qualification.

2.9 Synthesis of Policy Influences on Higher Education in South Africa

In a study by Jacobs (2010, p.38) the review of post-1994 Higher Education policies indicate that these influence institutions to become seriously involved with student academic success. The eight policies discussed above converge into key strategic issues of concern namely steering access and flexibility. In a diagrammatic presentation the policy drivers are presented in the metaphor of a lens system converging and diverging light, as shown in Figure 1, adapted from Jacobs (2010, p.38).

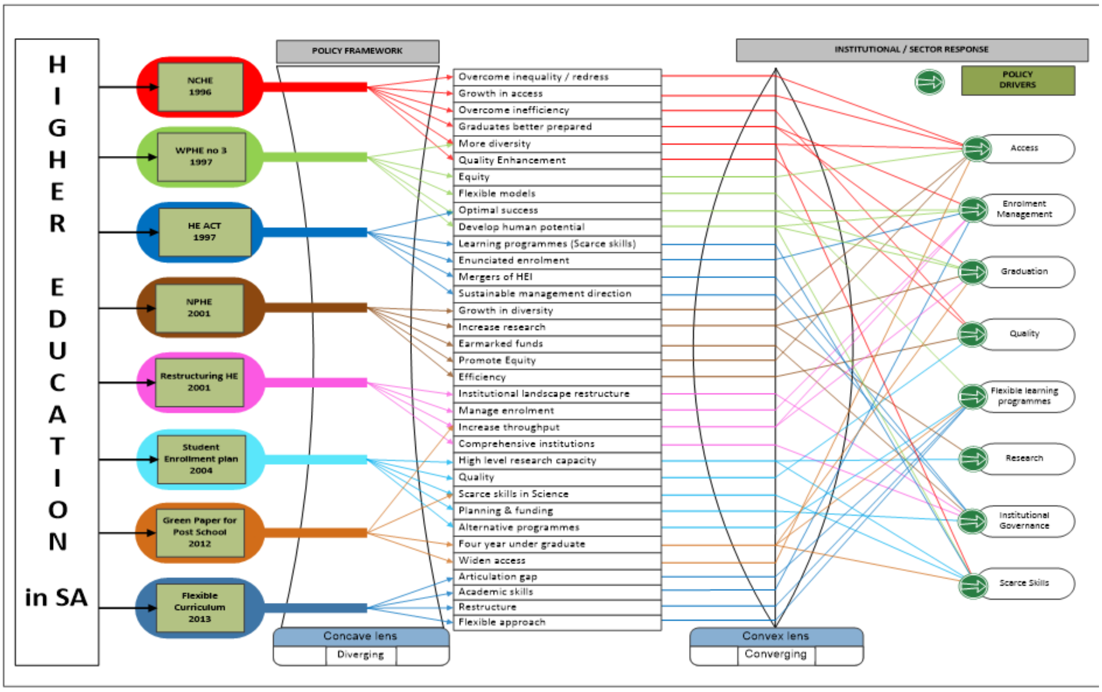

Figure 1: Policy Drivers Stemming From HE Policies
(Adapted From Jacobs, 2010, P.38)

The aforementioned policies challenge HE to respond, with the response presented as an optical lens system – "shedding more light" on the implications (the researcher's own presentation). In Figure 1, the HE system sends light rays via the eight selected policies represented by eight light sources. Each of these policies has emergent issues (shining from the light source) entering a concave lens, from where light is refracted in a diverging direction. These proposals represent light rays entering a second lens, namely a convex lens, which converges light rays to eight responses of higher education. The responses are policy drivers directing the suggested flexible curriculum to address enrolment management, access, graduation, and quality, alternate learning programmes, research, institutional governance and scarce skills.

The following section will discuss a few of the policy drivers (access, enrolment management, flexible management and scarce skills) applied in practice with extended programmes.

3. EXTENDED CURRICULUM

In the CHE report (2013, p.70-91) experiences and models of South African exemplar extended programmes are discussed. The origin of extended programmes was to provide alternative access and interventions to the non-qualifying students who did not meet admission requirements or to widen access for equity purposes. The programmes started to cater for the minority with the established "main stream" programmes continuing as if non-disturbed. The success rate for foundation courses ranged from 60%-80% (CHE, 2013, p.75), with SET students achieving a 74% success rate in foundation courses and 66% in regular courses. The DHET is really supporting SET programmes where students have challenges with content such as Mathematics, Physics and Chemistry, are being funded with a double weight. Every HEI has its own model to apply extended curriculum and receive foundational grants.

3.1 Extended Science programmes at University of KwaZulu-Natal (UKZN)

The CHE-report compares the performance in BSc extended and mainstream programmes for the 2005-2008 intake (2013, p.87) stating that 1200 students would not have been enrolled if there was no extended programme. The completion rate of the mainstream students was 59% for African, 54% for Indian and 68% for White students. The students from the "Augmented" programme (blended with mainstream) had a completion rate of 43% and those entering from the yearlong Foundation programme had a 31% completion rate.

3.2 Extended Engineering programme at University of Pretoria (ENGAGE)

The University of Pretoria (UP) started the Engage programme in 2010 with the five year BIng-programme and enrolled 291 students (CHE, 2013, p.88-89). About 65% of these students passed and went into the second year and then almost 60% went into the third year. Black students made up 35% of the ENGAGE enrolment with 71% retention in the third year. In comparison the mainstream enrolled 793 students in 2010 with 80% into second year and 73% in third year, with retention of 63% of the 25% Black students that initially started in the main stream.

3.3 Four year BSc degree programme at University of Johannesburg (UJ)

The University of Johannesburg (UJ) started an alternative access programme in 2004 with a year-long bridging programme and from 2006 the four year programme was designed to address the under preparedness in Sciences. In 2004, only 27.2% of the total intake in HE was in SET and of these only 26.1% graduated in regular time (Jacobs, 2010, p.107). Table 3 the profile of the enrolments in cohorts 2010-2013:

Table 3: Enrolment Figures: Main Stream & Extended (Faculty Of Science UJ, 2013)

Progr	Cohort	Total enrol-ment	Black participation	Gender		Mean GR 12 APS	Mean Gr12 Math	Passed all 1st mod	Failed all 1st mod
				M	F	%	%	%	%
MS	2010	570	75.9% (433)	57.7% (329)	42.3% (241)	34.46	71.14	45.3	19.5
	2011	543	81.4% (442)	56.4% (306)	43.6% (237)	34.54	69.02	46.0	24.7
	2012	392	73.2% (287)	55.6% (218)	44.4% (174)	35.74	68.21	48.4	18.6
	2013	398	79.6% (317)	61.3% (244)	38.7% (154)	35.47	68.03	54.4	11.3
EXT	2010	316	62.3% (197)	50.3% (159)	49.7% (157)	29.80	56.48	39.8	36.1
	2011	604	87.4% (528)	45.7% (276)	54.3% (328)	30.50	55.80	50.5	27.3
	2012	396	91.1% (360)	54.3% (215)	45.7% (181)	30.70	54.94	59.1	11.5
	2013	573	79.7% (317)	50.8% (291)	49.2% (282)	31.32	57.24	51.8	15.6

Table 3 demonstrates that more students are enrolled in the extended programme; provide access to more Black students and have a good female representation. The mainstream Grade 12 APS ranges from 34.5 to 35.7 and the extended APS ranges from 29.8 to 31.3. The Grade 12 Mathematics also indicates the difference with mainstream average above 68% and extended average of 54%. Many students fail modules during studies and when they pass more than 50% can continue with studies. The students who failed all the first semester modules range from 11% to 25% in the main steam and 11% to 36% in the extended. The extended programme does allow students to articulate from the mainstream to the extended programme after six months. The admission requirements as well as space limitations determine if students are placed in the mainstream or in the extended programmes.

TYPE	SEM 1	SEM 2	SEM 3	SEM 4	SEM 5	SEM 6	SEM 7	SEM 8
YR	YEAR 1		YEAR 2		YEAR 3		YEAR 4	
4 yr Ext BSc	MAT1AE1	MAT1AE2	MAT1AE3	MAT1B	MAJOR (i) 2A	MAJOR (i) 2B	MAJOR (i) 3A	MAJOR (i) 3B
	CEM1AE1	CEM1AE2	CEM1AE3	CEM1B				
	PHY1AE1	PHY1AE2	PHY1AE3	PHY1AE1				
	LANGUAGE FOR SCIENCE	LANGUAGE		BIC1B/ BOT1B/ ZOO1B	MAJOR (ii) 2A	MAJOR (ii) 2B		
		BIO1AE1	BIO1AE2					
	COMPUTER COMPETENCE						MAJOR (ii) 3A	MAJOR (ii) 3B
		APM1AE1	APM1AE2	APM1B	MAJOR (iii) 2A	MAJOR (iii) 2B		
		STA1AE1	STA1AE2	STA1B				
		GGR1AE1	GGR1AE2	GGR1B				
	IFM1A	IFM1B	CSC1A	CSC1B				
			YEAR 1		YEAR 2		YEAR 3	
Main stream 3 yr BSc			MAT1A	MAT1B	MAJOR (i) 2A	MAJOR (i) 2B	MAJOR (i) 3A	MAJOR (i) 3B
			CEM1A	CEM1B				
			PHY1A	PHY1B				
			BIO1A	BIC1B/BOT1B/ ZOO1B	MAJOR (ii) 2A	MAJOR (ii) 2B		
			APM1A	APM1B			MAJOR (ii) 3A	MAJOR (ii) 3B
			STA1A	STA1B				
			GGR1A	GGR1B	MAJOR (iii) 2A	MAJOR (iii) 2B		
			IFM1A	IFM1B				
			CSC1A	CSC1B				

Figure 2: Extended Bsc Programme (UJ)

The design of the four year programme is shown in Figure 2 and consists of three semesters of foundational provision, smaller classes, dedicated lecturing and language and computer support. In the first semester all students register for Mathematics, Physics and Chemistry and the curriculum is based on fundamental and conceptual knowledge and skills development. After completion of the first semester the successful students continue with two semesters (covering the one main stream module) in Mathematics, Physics and Chemistry. It is only after the first semester that students choose fields of specialisation and then start with two semesters of Geography, Biology and Applied Mathematics. Thus, the students have three semesters before they register for the second semester (with main stream first years) and complete the entire first year curriculum.

4. RESEARCH

4.1 Research Methodology

The empirical component of this study adopted a quantitative approach, where the focus fell on comparing the performance of students in the three year (main stream) with students from the four year (extended) programme. All the students in the faculty (and Engineering and Health Sciences) register for the fundamental science modules (Mathematics, Chemistry and Physics). From this perspective, the outcome of research may be judged with respect to the usefulness (substantively and practically) of the models and theories that it generates.

4.2 Research Purpose

The purpose of this investigation is to establish the progress of the students in the four year programme measured when the students from the two streams come together in the second semester (main stream) and fourth semester (four year). The assumption is made that there are many factors which influence progress and that more time and more space could be but two of the interventions that could contribute toward academic success.

The overarching goal of the empirical component is the identification of valid and reliable predictors of student success in Science modules. The following empirical research objectives are pursued in this study:

- To compare the performance in the final module of first year (1B) in Mathematics, Physics and Chemistry when the two streams join to write the same examination in the same time.
- To examine the predictive value of school performance in Mathematics with regard to success in first-year Science modules (e.g. Mathematics).

4.3 Participants

The target population included all first-year students registered for three fundamental Science modules (i.e. Mathematics, Chemistry, and Physics) at the University of Johannesburg in Gauteng, South Africa. Participants were drawn from the cohorts of first-year students registered for these modules in 2010-2013. These students were registered for programmes in the Faculty of Science but also serve as service modules to mainly the Faculties of Engineering and Health (1563 in the main stream and 2110 in the extended programme).

4.4 Data collection instrument

The data collected were the grade 12 profile of students entering university (school results and biographical detail) and university results within specific science modules (as captured from official results). The measurement tool was the results and therefore the instrument measured the performance at school or university level. The instrument had face validity (measured what it was supposed to measure). The instrument is reliable as it would yield the same results if the measurement is repeated.

4.5 Investigating progress in fundamental science modules

The focus of this study is on the three fundamental modules Mathematics, Chemistry and Physics. Table 4 reflects the total enrolments and success rates of the whole cohort registered in the three mainstream modules used in this investigation as well as the extended modules.

Note the class sizes differ from Table 3 since students from other faculties and repeaters are also in the same class. Students in the main stream have to pass the 1A-module and then proceed to the 1B-module whereas extended students complete 1AE1, E2 and E3 (only the first semester marks 1AE1 is indicated) and then all of them join in 1B. In Table 4 the success rates of the final sample is made up by students that progressed to the 1B modules, please note students that failed are out of the system and do not progress to the 1B module. The mainstream and extended students come from two different precursor modules (mainstream only module 1A in one semester and extended from three modules) and are all in the same module 1B indicated in the last column.

A further analysis of the 1B class indicates that the students from the extended have a fair chance of passing the module and in some cases the lecturers report that these students are the top students in the class. The extended students have a year and a half to adapt, they have foundational provision in language and computer competence and have compulsory class and tutorial attendance.

5. RESULTS

In Table 4 the descriptive statistics indicate the mean values of the different variables.

Table 4: The Success Rates in Main Stream / Extended Modules

DEPT	MS / EXT	N	Mean GR 12 MATH %	Mean Succ Rate MS MAT1A %	Mean Succ Rate EXT MAT1AE1 %	Mean Success Rate 1B % (sample size) (MS/EXT)
MATH	MS	615	72.93	54.82		58.59 (388)
	EXT	777	59.99		56.04	50.86 (211)
CHEM	MS	265	71.70	54.83		59.56 (140)
	EXT	455	60.06		54.35	57.67 (135)
PHYS	MS	179	75.80	51.41		56.39 (99)
	EXT	331	60.98		54.59	57.00 (28)
BIOL	MS	228	66.85	53.46		
	EXT	324	59.74		58.83	
BOT 1B	MS	69				64.91
	EXT	78				60.59
BIC 1B	MS	126				66.94
	EXT	92				62.66
ZOO 1B	MS	81				58.80
	EXT	53				58.15

* The descriptive statistical techniques were performed with SPSS (Pallant 2007).
* The significance levels, means and SD are available for the Chemistry, Physics and Biology modules but are omitted due to limitations to the length of this paper.

The **Mathematics** modules (both programmes) had significance levels of "*p* = 000". The first semester **Mathematics** (mainstream) has as expected lower Mean of 54.82 (*SD* = 11.855) than the first semester Mathematics (extended) Mean of 56.04 (*SD* = 10.297). In the second semester Mathematics both had a pass average Mainstream: *M* = 58.59, *SD* = 10.184 and Extended: *M* = 50.86, *SD* = 9.738 in the 1B module. The students from the extended stream have an equal opportunity to pass in the second semester and the three semesters prepared them for the challenges of mainstream curricula.

In a regression analysis revealed a statistically significant relationship between overall Grade 12 achievement and university achievement (Mathematics 1A). Table 5 contains the Pearson correlations between the variables of interest, whereas Table 6 reflects the relative contribution of Mathematics at school level towards the prediction of success in Mathematics 1A.

Table 5: Correlations of Mathematics 1A With Mathematics Gr 12 (Mainstream)

		MAT01A1	Gr12 Math
Pearson Correlation	MAT01A1	1.000	.384
	Gr12 Math	.384	1.000
Sig. (1-tailed)	MAT01A1	.	.000
	Gr12 Math	.000	.
N	MAT01A1	615	615
	Gr12 Math	615	615

Inspection of Table 5 shows that Mathematics 1A correlated most strongly with the Mathematics Gr 12 (r = 0.384) and that a statistically significant relationship between exists (p = 0.000).

Table 6: Regression Coefficients in Math 1A (Mainstream)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
	Program = 1 (Selected)				R Square Change	F Change	df1	df2	Sig. F Change
1	.247[a]	.061	.060	11.496	.061	39.938	1	613	.000

a. Predictors: (Constant), GR12 APS
b. Dependent Variable: MAT01A1

Table 6 shows that Mathematics Gr 12 on its own accounted for 6.1% of the variance in Mathematics 1A (ΔR^2 = 0.061; F = 39.938; df = 1, 613; p = 0.000), thus the Mathematics at school level contributed significantly towards the explanation of student achievement in Mathematics 1A but is less than we expected.

Table 7 presents the regression equation as applied to a graph (*y=mx+c)* the following Mathematics 1A results would be indicated.

Table 7: Regression Equations for Achievement In Math 1A(Mainstream)

Regression line equation	Gr 12 Math mark of x is predicted to be a y mark in Math 1A.		To get a Math 1A mark of y, a mark of x in Gr 12 would be sufficient	
y = mx+c	x (Gr 12 Math)	y (Math 1A)	y (Math 1A)	x (Gr 12 Math)
Math 1A = .497 (Gr 12 Math) + 18.610	80	58.37	80	123.52
	70	53.40	70	103.40
	60	48.43	60	83.28
	50	43.46	50	63.16
	40	30.49	40	43.04

The statistical regression equation if applied to students with 63% in Grade 12 would not have been passing Mathematics 1A (50%) (Table 7). Analysis of the mainstream 1A results 54 students would have failed with Grade 12 below 63% and in reality 149 of them failed. Thus other variables than Grade 12 Mathematics contribute so that these students failed although they had above 63% in Grade 12 and leads to follow-up research to be conducted. It also implies that all 153 extended students that did pass the Math 1B module would not have been enrolled for the module at all.

Empirical synthesis

The empirical investigation among the policies and mainstream and extended data generated the following noteworthy findings:

- **Admission requirements** (mainstream): Academics should interrogate the value of school results to determine who to place where and where to start teaching in Sciences
- **Extended programmes** (flexible curriculum): This should become a policy with aligned funding as fully subsidised programmes and part of the core activities should be a priority.
- **Extended programmes** (enrolments): Institutions should seriously consider placing more students in these programmes to ensure throughput and ultimate graduation.

4. IN CONCLUSION

Government drove widening participation and redress for 20 years and the CHE flexible curriculum provides a pragmatic solution for not only the dysfunctional schooling system in SA but also graduation and ultimately research (with more students feeding into post graduate programmes). The UJ-model provided substantial evidence that more students can pass in Science faculties if placed in extended programmes with more time and more space to mature.

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PORTRAYING THE HUMAN FACE OF SCIENCE IN THE CLASSROOM

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Abstract–This paper describes a short intervention programme based on a humanistic socio-scientific issues instructional strategy (Hu-SSI) that seeks to develop in–service science teachers' pedagogical content knowledge to teach for the affective domain. The study is design-based and adopts a constructivist worldview involving predominantly qualitative methods of data collection and analysis, with limited used of quantitative data. Krathwohl's taxonomy of the affective outcomes is applied to profile the teachers based on change in understanding of affective teaching. Through Saldana's code –to- theory coding model, the emerging themes suggest that the intervention enabled the teachers to have better understanding and also to express the challenges they experience in teaching for the affective domain. The themes were further explored by using Cultural Historical Activity Theory (CHAT) to identify the contradictions experience by the teachers as they engaged in PCK development. Findings were refined to distil design principles that could inform such an intervention future.

Keywords: Affective Domain**,** Design-based Research (DBR)**,** Pedagogical Content Knowledge (PCK)**,** Cultural Historical Activity Theory (CHAT)**,** Krathwohl's Taxonomy of Affective learning outcomes**,** Humanistic socio-scientific issues instructional strategy (Hu-SSI)

1. INTRODUCTION

This paper focuses on developing the pedagogical content knowledge (PCK) of science teachers to use contemporary science-related social issues in the classroom, in order to portray the human face of science. In this study, science refers to Life Sciences (LS), Natural Sciences (NS) and Physical Sciences (PS) as outlined in the Curriculum and Assessment Policy Statement (CAPS), which is currently the core framework document for school level education in South Africa.

2. BACKGROUND TO THE STUDY

Science education in South Africa is problematic, a situation which is evidently not unique to South Africa (Dass & Yager, 2009: 100; Liu, Liang & Liu, 2012: 1966 ; Loughran, Mulhall & Berry, 2004). Reports by CDE note that science education in SA is underperforming and blame this on shortage of good teachers, especially in scarce but vital areas such as mathematics and science (Bernstein, 2005:230; McCarthy and Bernstein, 2011:4). As a result, there is demand on science teachers to develop in learners the educational objectives as outlined in CAPS as specific aims. Literature pertaining to research on this suggests that the affective outcomes seem to be the least addressed (Krathwohl's, Bloom & Masia, 1970) and has been referred to as a "missing link" by Van Rooyen and De Beer (2006:225) or as the "undiscovered country" in the college curriculum by Pierre and Oughton (2007:2). An aspect of the affective domain, clearly captured in the CAPS (Specific Aim 3), is that of indigenous knowledge which is being ignore in many classrooms and Odara-Hoppers calls this " knowledge apartheid" (2004:17).

Drawing from these views, we use the analogy of an iceberg to illustrate how addressing the affective domain is of least concern at schools, irrespective of its proposed role as the foundation on which the cognitive and psychomotor domains are built, as indicated in Figure 1 below.

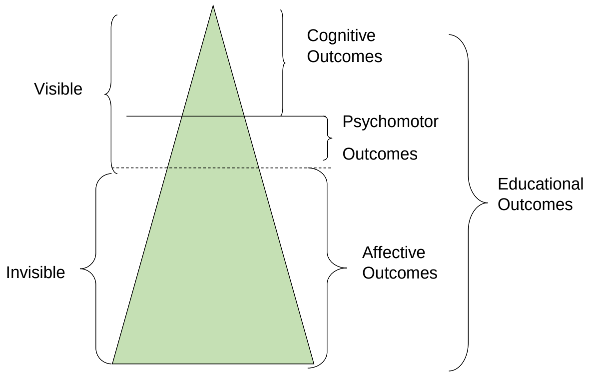

Figure 1:An iceberg concept illustrating the non-alignment of educational outcomes (cognitive outcomes, psychomotor and affective outcomes)
Source: Compiled by researcher from literature according to Krathwohl et. al. 1970; Neumann and Friedman (2010:7)

Figure 1 illustrates the cognitive and the psychomotor outcomes appearing at the tip and visible as they are often more addressed at schools. The affective learning outcomes often do not receive a high level of attention and although they are available in school policy documents and specifically CAPS in the case of SA, the issue seems to be with the inability, or unwillingness of the educators to explore them. Many studies associate this problem to several challenges (Neumann & Friedman, 2010:7; Pierre & Oughton, 2007:4), some of which include: the difficulty in understanding the concept due to its ambiguity, lack of appropriate teaching methods (teachers' PCK) (Neumann & Friedman, 2010:7), lack of resources, difficulties in teaching and measuring of affective learning outcomes (Birbeck & Andre, 2009; Pierre and Oughton, 2007:5), time constrain just to name a few.

If one considers the ongoing developments in the fields of science and technology, then teaching for the affective domain should be imperative, as learners are faced with the need to develop affective abilities required in the consumption of the enticing products and services that emanates from the ongoing developments (Dass & Yager, 2009:99; Van Rooyen & De Beer, 2010: 232). Such abilities enable learners to make responsible decisions and to demonstrate the act of caring with respect to humanity and environment. The reality however points to the contrary, as several studies note the widespread neglect of affects in classroom.

Having worked in both private and public schools in South Africa over the last ten years, our experience is that the teacher is at the coal face and plays a vital role in unleashing the educational objectives and therefore, a justification for the purpose of this study to develop teacher's PCK to teach for the affective domain using the humanistic socio-scientific issues instructional approach and to distil design principles for designing and implementing such programmes in an effort to develop best practices for future use in similar interventions.

2.1 REGARD FOR AFFECTIVE OUTCOMES IN SCIENCE CLASSROOMS

The Hu-SSI instructional strategy is proposed as an innovative pedagogical approach, that includes a variety of creative and exciting teaching methods that integrate current science related social issues with the science content and implemented in the classroom in a way that stimulates learning (Kiviet & Du Toit, 2010: 54-57; Van Rooyen & De Beer, 2010:93-108). Such an approach makes science content alive and relevant to the learners who intend to develop critical decision making skills and caring attributes, which resonates with the affective domain.

2.1.1 What is affective domain?

It is one of the domains in teaching and learning that is branded as vague and controversial. According to researchers (Krathwohl, et al., 1970:17; Main, 1992; Pierre and Oughton, 2007), it deals with any behaviour thatinvolves emotions and includes: values, attitudes, beliefs (Birbeck & Andre, 2009; Neumann & Friedman, 2010), feelings, self-esteem, academic self-concept, and interest (Kocakaya & Gonen, 2013:29). It also equip learners with favourable dispositions to manage self and group dynamics, and decision making abilities that portray social and ethical responsibility. Krathwohl, Bloom and Masia in 1964 put forth a model for classifying affective learning outcomes based on principle of internalization.This includes a continuum for affective behavior consisting of five categories, with each level depicting the degree to which an affective trait is incorporated into the learner's personality (Krathwohl, 1964; in Bolin, 2006:7) as in shown in the figure below.

Figure 2: A continuum for affective behaviour consisting of five categories, according to Krathwohl (1970)
Source: Neumann and Friedman (2010:4)

In promoting teaching for the affective outcomes, (Van Rooyen & De Beer, 2006; Williams, 2012:35) argue that it increases learners' ability to make personal decisions which reflect behaviours that are socially and environmentally responsible, against the backdrop of recent developments in fields such as genetics, medical science and technology which lead to new products and services that could address societal challenges but require difficult ethical and moral decisions. One such issue is the case of Angelina Jolie's cancerous genes and the double mastectomy where such technology for cancer prevention and treatment can only be available to the wealthy. Thus, although various approaches including: the humanistic (Taylor, 2013:2), nature of science and socio-scientific issues approach (Dass & Yager, 2009:99; Sanders & Nduna, 2006: 28; Zeidler & Nichols, 2009) etc. have been proposed to promote teaching and learning in this context, we tap into the desirable qualities of these approaches to construct an innovative comprehensive Hu-SSI approach that combines a variety of frameworks and in this process we adopted the following principles:

- Learning should focus on affective learning outcomes.
- Current SSIs from the media are incorporated with content to design learning activities (Zeidler & Nichols, 2009; Dolan, Nichols & Zeidler, 2009) and,
- Encourage different teaching methods; group work, whole class discussions.
- Learning should be learner-centred and activity-based.
- The teacher is a facilitator of learning.
- The science curriculum should be relevant to the learners (DoE, 2011; Sanders & Nduna, 2010; Van Rooyen & De Beer, 2010).

A framework for the Hu-SSI pedagogy and its related tenets are illustrated in the figure below.

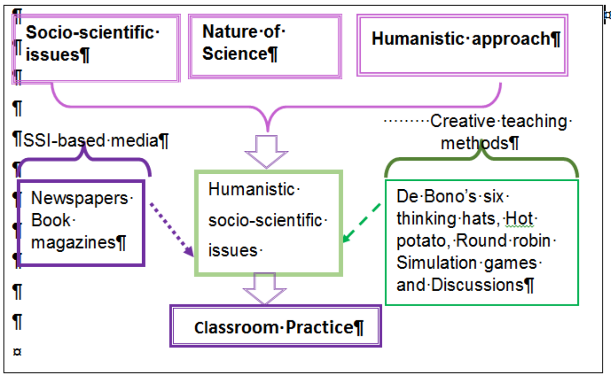

Figure 3. A framework for the humanistic socio-scientific issues instructional strategy and the tenets that inform it.

Source: Compiled by researcher from; Celik and Bayrackceken (2012:76); Crawford and Meyer (2011:53), Van Rooyen and De Beer (2010).

2.3 DEVELOPING TEACHERS' PCK: A Hu-SSI PERSPECTIVE.

PCK is viewed as a framework for teachers' knowledge that is used to make a specific topic understandable to learners (Berry, Loughran & Van Driel, 2008: 1272; Williams, 2012: 35). It was introduced into the literature by Shulman (1986:9) who suggests that PCK is an integrated framework of pedagogical and the content knowledge. It was later developed by Magnusson, Krajcik and Borko 1999 into a model with four main categories including; knowledge of content, knowledge of educational context, pedagogical knowledge and PCK (Aydin & Boy, 2012:498). As earlier mentioned, the study involves teachers' PCK development and as a result, Magnusson's transformation model is adopted in conceptualizing the envisaged PCK and this is done by establishing how the Hu-SSI instructional strategy of this study might fit into Magnusson's PCK model as presented below.

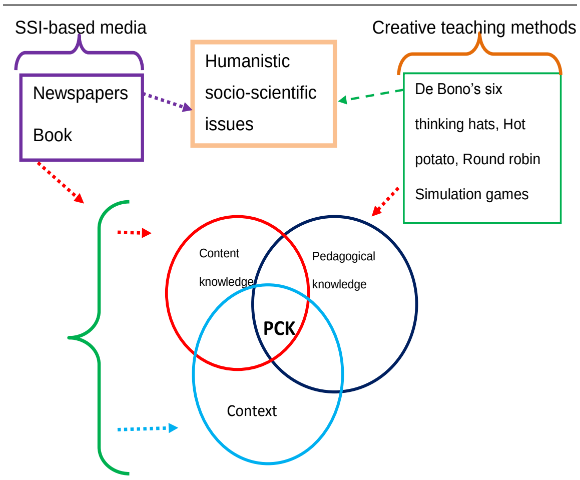

Figure 4: A conceptual connection between the Hu-SSI approach in this study and Magnusson et al.'s model of PCK.

Source: Compiled by researcher from literature according Magnusson et al., (1999): Pierre and Oughton, (2007); Sanders, (2010) and Williams (2012).

3. RESEARCH METHODOLOGY

This study falls under design-based research. Amiel & Reeves (2008:34) and many others (Anderson & Shattuck, 2012: 16; Barab & Squire, 2004:2; Juuti & Lavonen, 2006:54; Thein & Barbas, 2012:122) consider design-based research as a systematic approach to innovative practices which addresses issues of theory and practice in Education. Vygotsky's notion of zone of proximal development, which Warford (2011) refined to include zone of proximal teachers development influenced our conceptualization of the PCK development of science teachers in this study. By this notion, learning is enhanced through scaffolding between the expert and the novice teachers. Our approach to PCK development was effected through a short intervention that drew on the Japanese lesson study approach of professional teacher development (Lewis, 2000; Stigler & Hiebert, 1999) which is rooted in Amiel and Reeves (2008) model of design-based research.

Our approach consists of two cycles of training in which a group of science teachers participated. For each cycle, a two-day short learning programme was implemented. Whereas the first training took place at University of Johannesburg where the researchers are based, the second was held at one of the participating schools.. The first cycle consisted of five phases that include: (a) analysis of the research problem to identify design elements then (b) teachers designed, enacted, reflected and gave feedback on the lesson, after which they (c) implemented the Hu-SSI in their natural sciences classroom during lessons and (d) refined and revised the short learning programme to (e) distil design principles for designing such a programme in future. Here, the teachers were involved in a series of practical sessions where they worked in small groups and jointly: design, enact, observe, reflect and revise lessons, where they initially participated as students wanting to learn, and subsequently as teachers implementing what they have learned by designing and enacting lessons at the experimental classroom at UJ and also at their natural classrooms at the schools. Thereafter, a prolonged engagement with the teachers continued for two school terms.

The 2nd Cycle involved redesigning a second short learning programme based on insights from the first programme and the distilled design principles. In this cycle, science teacher were invited to take part in a two-day learning programme aimed at enhancing PCK development and ultimately to establish a school-based community of practice that promotes both face-to-face and online interaction where professional development is supported in a sustainable manner. In both cycles, the practical sessions involved the teachers in individual, small group and whole class discussions based on exciting activities such as; De Bono's thinking hats, the jigsaw method, hot potato method and simulation games, science related social issues including HIV AIDS, rape, racism, poverty, cancer, genetic engineering, cloning, rhino poaching etc. from the newspaper and other books such as the *Immortal Life of Henrietta Lacks* that deals with issues of poverty, racism and injustice. It is important to note that though built-in in this study, data from the 2nd cycle of the short intervention does not form part of this study as it is beyond its scope.

This study adopts a predominantly qualitative approach of data collection and analysis (Teddlie & Tashakkori, 2009:84; Creswell & Plano Clark, 2011:38) with limited aspects of quantitative method involving the use of questionnaires and descriptive statistics. Although there are elements of a phenomenological study in the sense that we attempted to capture teachers' lived experiences, it is not phenomenology, amongst others, since we already have a predetermined lens which is Cultural Historical Activity Theory (CHAT).

3.1 THE SHORT INERVENTION PROGRAMME AS AN ACTIVITY SYSTEM

The educational encounter was situated within a particular community aimed at developing teachers' PCK and as such was considered an "activity system". In conceptualizing the study, we drew from Vygotsky's ideas of Cultural Historical Activity Theory (CHAT) (Hardman, 2007:55; Roth & Lee, 2007:188) and more specifically, Engeström's third generation CHAT as the analytical lens to examine the "activity system" for the contradictions that the teachers could encountered as they learn. The elements of CHAT and applicability in this study are illustrated in the figure below:

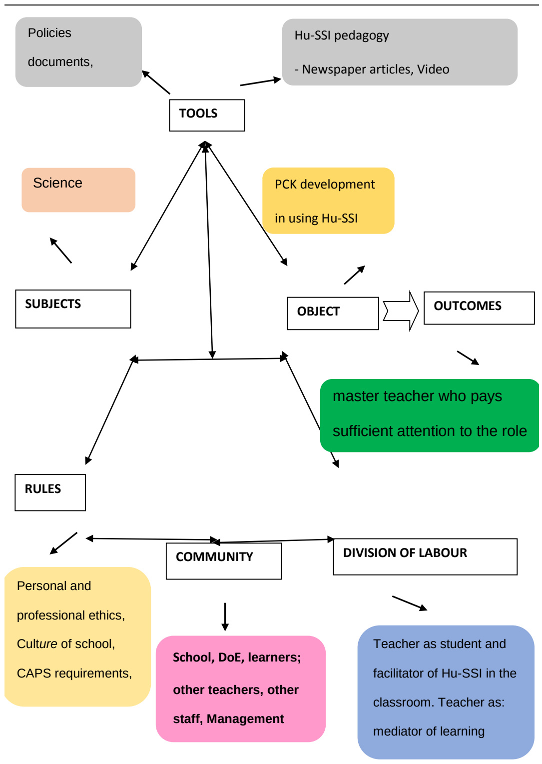

Figure 5: Looking at the themes with a CHAT lens.
Source: Adapted from Hardman, 2008

In getting the teachers to work in small groups, sharing ideas, expertise and learning how to use the Hu-SSI instructional strategy in their experimental classroom and subsequently in the context of real classrooms at the respective schools, we propose that CHAT stands a better chance to examine this type of collaborative learning and in identifying the contradictions that these teachers encounter in the process.

- TOOLS in the activity system: This include: the Hu-SSI pedagogy, small group works; Newspaper articles, resources at the schools. A shortage in a tool could result to tension as the teacher will not be able to effectively teach.
- Rules could pose a challenge in the sense that the school rules or culture of a school could be such the learning only takes place in a quiet environment. This could prevent the teacher from implementing activities that allow the learners to engage in class discussions and debates issues.
- Community in the activity system: The teachers belong to the school community and could be members of communities of practices. These communities can promote the professional development of teachers, and this is because, in such communities, teachers are likely to share their individual classroom experiences with others (CDE, 2011:23) or get support from the HOD or subject advisers. There could be problems where such communities are not existing or do exist but not supportive of the teacher's professional development, and thus the teacher will not enjoy the professional space or could lack the resources to implement lessons for the affective domain. Consequently, such tensions could result in ineffective teaching.
- Division of labour: Here, teachers play multiple roles (mediator of learning, moral and ethical mentor, and life-long learner) and such diverse identifies could be overwhelming with the teachers having no time to focus on teaching for the affective domain which normally requires lots of efforts and time consuming.
- Object in the activity system: This includes the PCK to teach for affective domain and deficiency in this will result in the inability to address the affective learning outcomes in the classroom.

- Outcome in the activity system will refer to a master teacher who pays sufficient attention to the role of the affective in cognition. If one studies recent findings in neuroscience research, one is convinced of the central role of the affective domain in cognition (Immordino-Yang & Damasio, 2011). The "master teachers" that is envisaged in this project, would understand the art of incorporating the affective domain in teaching.

3.2 SAMPLING

The sampling strategy utilized in this study was purposive sampling and samples were selected based on principles of purposeful sampling (Merriam, 1998). Demographic variations and diversity was considered regarding the social context of schools in which the teachers function naturally. The unit of analysis was the teachers' engagement with Hu-SSI during the intervention that involved a total of 53 participants from schools ranging from under-resourced, medium-resourced and well-resourced schools. This was a strategy to generate a rich and diverse data that contained personal observations and a wide range of perceptions and experiences expressed by the participants regarding the purpose of this study.

3.3 DATA SOURCES AND COLLECTION

The data sources comprised of the following;

- Pre- and post-intervention questionnaires administered to the teachers before and after the learning programme at University of Johannesburg. An evaluation form was completed by teachers at the end of the programme.
- Observation tools were completed for different activities during the intervention and include:
  - ✓ Rubric for evaluation of lessons presented by the teachers during the SLP at University of Johannesburg.
  - ✓ Rubric for evaluation of learner's reaction/response to lessons presented by teachers.
  - ✓ The Reformed Teacher Observation Protocol (RTOP instrument).
- In-depth semi-structured one–on-one interviews with teachers guided by an interview schedule with open-ended questions conducted after short programme at University of Johannesburg and after lesson presentation at the schools.
- Focused group interviews with learners guided by interview protocol with open-ended questions were conducted after lessons at the schools.
- Photo images taken at experimental classroom at University of Johannesburg and at the schools to see how teachers and learners' behave during lesson presentations; to establish learners' level of engagement in the activities during the lesson presentation, and to validate the elicited responses from the participants
- A portfolio comprising of lesson plans, activities and reflection was submitted by each of the six teachers whose lessons were observed at the schools.
- Documents (pacesetters and CAPS) that complemented one another and to validate information provided by the participants were studied.

3.4 DATA ANALYSIS

For the purpose of detail analysis, the collected data was transcribed and analysed qualitatively to establish the emerging themes. Despite the fact that this is a qualitative study (with a relatively small sample) we did summarize the limited numerical data into interpretable frequency tables and graphs (Krathwohl, 1993:157; Teddlie & Tashakkori, 2009:259) in order to detect patterns and relationships that would address the question of how teachers experienced the short intervention programme. By applying Krathwohl's taxonomy of the affective outcomes, the teachers were profiled based on their understanding of affective teaching and learning before and after the short intervention programme. This is represented in the table and graphs below.

Table 3.1: Summary of positions and average shift in participants' understanding of affective teaching as indicated on the different levels of Krathwohl's taxonomy based on their responses to questions 1, 2 and 3 on the pre (P1) and post intervention questionnaires (P2).

Participants	Positions of participants per question			Average shift per participant
	Question 1	Question 2	Question 3	
A1	+1	+1	0	+0.67
A2	+2	+1	+2	+1.67
A3	+1	0	+2	+1.00
A4	+1	+2	+1	+1.33
A5	0	0	+1	+0.33
A6	+1	+2	+2	+1.67
A7	0	0	+1	+0.33
A8	0	+1	+2	+1.00
A9	+1	+1	+1	+1.00
A10	+1	+1	0	+0.67
A11	0	+1	+2	+1.00
A12	+1	+1	+2	+1.33
A13	+1	+1	+1	+1.00
A14	+2	+2	0	+1.33
A15	0	+2	+1	+1.00
A18	+1	+1	+2	+1.33
A17	+1	0	0	+0.33
A18	+1	+1	+2	+1.33
A19	+2	+2	+2	+2.00
A20	+1	+1	+1	+1.00
A21	+1	+2	0	+1.00
A22	+1	+1	+1	+1.00
Total shift	20	24	26	
Number of participants	17	18	17	
Average shift	+1.18	+1.3	+1.5	
Total Average shift				+1.34

Source: Compiled by researcher based on Krathwohl's taxonomy from the data

Table 3.2: Summary of the number of participants and the shift in level of awareness based on Krathwohl's taxonomy for questions (Q) 1, 2 and 3 on the pre (P1) and post (P2) intervention questionnaires.

Level of awareness on Krathwohl's taxonomy	Number of participants per level and per question					
	Question 1 P1	Question 1 P2	Question 2 P1	Question 2 P2	Question 3 P1	Question 3 P2
L0	6	1	16	3	16	4
L1	13	5	6	7	5	3
L2	3	16	0	12	1	15
L3	0	0	0	0	0	0
L4	0	0	0	0	0	0
L5	0	0	0	0	0	0
Total	22	22	22	22	22	22

Source: Compiled by researcher based on Krathwohl's taxonomy of the affective learning from table 5.8, 5.10, and 5.12.

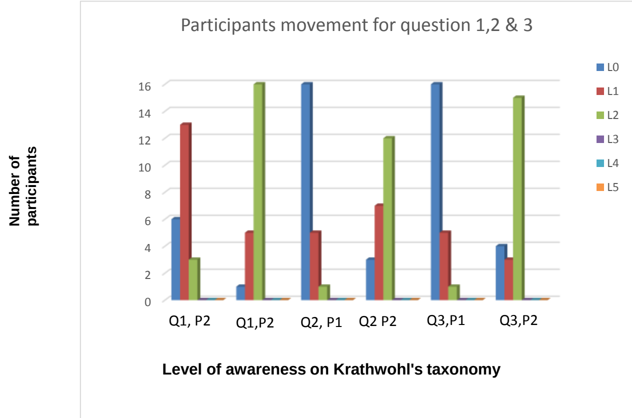

Figure 3.1: Summary of the relationship between number of participants and level of awareness based on Krathwohl's taxonomy for questions 1, 2 and 3 on pre intervention (P1) and post intervention questionnaires (P2).

The following interesting observations emerged from this analysis

Responses from question 1, 2 and 3 for both the pre and post intervention questionnaires, reveal that there is a positive increase in the teachers' awareness in teaching for affective domain for all three questions with an average shift of +1.3, as can be seen in Table 3.1.

However, looking at the level of shift among the three questions, there is a more significant shift for question three with an average shift of +1.5. This question deals with the different methods for teaching in the affective domain. Therefore, this overwhelming shift in understanding as we perceived for question 3 could be associated to the practical sessions which enable the participants to engage in exciting SSI activities involving the Hu-SSI teaching methods.

An issue which we observed from the data, particularly from the responses to question 3 of the questionnaire is that of certain beliefs held by some of the teachers regarding teaching for the affective domain. This question was meant to capture teachers' understanding of the different teaching methods that they employ in their classrooms to enhance affective teaching. Interestingly, some of the teachers seem to believe that they are effectively teaching for the affective domain by talking to learners about desired values and attitudes during lessons, without actually involving learners in activities that will get them to actively engage in order to internalize these attributes.

Although they have this conviction, we see this as a naïve understanding and therefore an ineffective approach to teaching for the affective domain, and this is because, according to Birbeck and Andre (2009); Pierre and Oughton (2007:7); Zeidler and Nichols (2009: 52), teaching for the affective domain requires more than just talking which is creating awareness and represent learning at the lower level of understanding on Krathwohl's affective learning outcomes. To effectively teach for the affective domain, requires teachers to intentionally employ appropriate instructional strategies that will enable learners to develop the affective learning outcomes that are outlined in the school policy documents and specifically CAPS for SA schools.

Through Saldana's code–to-theory coding technique (Saldana, 2009), involving vigorous analytical reflections themes emerged from the data. The emerging themes are viewed from a Cultural Historical Activity Theory (CHAT) lens, to better understand the teachers' learning of Hu-SSI approaches.

4. FINDINGS AND DISCUSSIONS

The main findings are that the short intervention had some immediately observable effects on the teacher's perception and behaviour regarding teaching for the affective domain. The findings are discussed below.

4.1 This short intervention programme developed a more nuanced understanding of the affective domain in teaching.

It is the finding of this research that most of the participants experienced a more nuanced understanding in teaching for the affective domain. They believe that the short course was quite insightful and provided opportunities for better understanding and how it could be implemented at the school level. The intervention(together with Hu-SSI) served as an awareness raising tool in the community and different aspects of the intervention including practical sessions that were activity-based with interesting SSIs could have contributed to the increased awareness and understanding. This is what we discerned from a majority of the responses, pictorial and other visual illustrations, and also an important observation that emerged from the data.

In line with previous studies such as Pierre and Oughton, (2007), Zeidler and Nichols (2009), it can be argued that the better understanding experienced by the teachers could be associated to the SSIs component in this approach that stirred up their imagination and enable them to learn. This is supported by recent developments in neuroscience and learning in school context which emphasise the role of affective domain in cognition and that emotion-related processes promote learning and the ability to remember (Immordino-Yan and Damasio, 2011:113; Sousa , 2011:35).

4.2 The short intervention programme enabled teachers to express their concerns about the fact that the affective domain is marginalized, because of several systemic, teacher- and learner-related factors.

Another broad finding derived from this study is that teaching for the affective domain might be marginalized. This is the experience of most of the teachers who face problems in this regard and associate this to certain issues which were categorized under three sub-themes as systemic, teacher and learner related factors. The systemic factors identified relate to the DoE and school management and include; over-loaded curriculum, a strong quest for immediate results, bigger-than-optimal class sizes, lack of support from district and school management and lack of resources. Teacher and Learner related factors refer to certain issues that emanate from teachers and learners respectively and some of these include; lack of motivation, prior misconceptions, cultural conflict, learner discipline, language of instruction and lack of teachers' PCK which all form part of the different elements that mediate teaching and learning in the community. If the teachers lack PCK and do not receive adequate support, it might culminate to tension and consequently ineffective teaching for the affective domain. The following comment by the teachers highlights this finding:

> It is the support and the structure ... You need to go on your way finding how to implement it in an effective way because you can just thing that you are doing it but you are not doing it the correct way. Also there are no resources and our classes are very big. Like we did in the example today, I've just learnt that certain cultures do not do kidney transplant. It could be myths, superstition or beliefs. When the learning content comes to conflict with the cultural pre-knowledge of the learners. The biggest problem is to change the attitudes of the learners since most of them learn it from home.
> Time   Time Time. There is no time to go to all those lengths with the academic pressure from the department. Learners' prior knowledge is not taken into consideration by teachers; Learners struggle to see the practical relevance of science lessons(Teacher).

However, evidence from the school visits and class observations do not support the teachers' claims regarding aspects like class sizes and general level of resources at the school. For example, we noticed that some of the best performing classes in respect of promoting affective learning outcomes were found in the poorest school, which also had the highest pupil: teacher ratio. This suggests that the teacher (and the relevant teacher attributes) might be a more important determinant than systemic factors such as the level of resources or the class size.

One major concern was that of language constrain as the English language seem to limit the participants as they struggled when communicating during lessons. we believe that it was a good idea for the teachers to give learners the opportunity to express their views and at times switching to the home language. It could benefit the learners as practice makes perfect and if interactive activities are encourage. Irrespective of the challenges, teachers should be encouraged to incorporate SSIs in the classroom with the hope that the situation could improve over time and learners could experience the advantages of affective teaching which Kocakaya and Gonen (2013:29) refer to as a more important educational goal as it develop affective attributes that equip learners to act responsibly and exercise care for humanity.

4.3 The innovative pedagogies used during the short learning programme appealed to teachers and made it a powerful learning experience.

The next aspect of the broad findings of this study is that the innovative teaching methods used during the short intervention programme were appealing to the participants and made it a powerful learning experience. Apparently, the appealing attributes were branded into the three sub-themes that include exciting teaching methods, stimulating activities and attractive choice of resources. These views are expressed in the following quote from teacher' responses:

> The course was very useful and informative as it addresses the lack of application of the affective domain in science. It was an awareness course and empowering too.
> The different methods- Round robin, Hot potato, Jigsaw method as well as the use of the Bono's hat to address controversial issues . I really enjoyed seeing how different teachers teach and prepare lessons. I love the book as it has many examples that I can use in my class**.** I gained a lot of insight with regards to how to go about incorporating the affective domain in lessons.
> Practical hands-on approach i.e. presentation of a "lesson". Gave an opportunity to come up with ideas as a group, which resulted in effective idea sharing Lesson presentations were nice- learnt different ways of teaching the same thing.

Additionally, learners' responses and reactions to sessions which were deliberately designed to promote the attainment of affective outcomes demonstrate that such pedagogies resonated well with learners' interests, thus enabling them to engage and participate more meaningfully. Evidence to this was also perceived from the following responses from learners:

> The whole class was involved. Even the people who don't talk so much, they actually spoke for a change and I found that it is exciting yes. The fact that we were put in groups and we had to present our topics to the rest of the class, I think the best way to learn something is to explain it to someone else, therefore you learn more yourself. So this teaching of other people, I will sort of remember it a lot better than I will when a teacher teachers me because I taught myself. It is a good way of studying because to explain it to someone is the best ways to learn (learners)

4.4 The short intervention programme enabled teachers to suggest measures which could be considered for future development and refinement of similar interventions which aim to promote teaching for the affective domain among in-service teachers.

The final broad finding made during this research is that most of the participants made suggestions which could be considered in improving the short course offered at UJ. This was in response to the expressed concerns regarding the duration of the course which was too short and thus contributes to primary contradictions within the system as the teachers felt that more time could have enabled them to learn better. This view is supported by the following quotes from the teachers' evaluation forms:

> More days Please and I would wish to go through the whole process of affective domain step by step so that I can understand the pyramid more properly. Since we never had much days to me it was short and I had a feeling that I should have gain more information if we had more days to do this. By making resources available to learners
> I think for me, teachers themselves need to be creative and be able to find examples that are real to these learners. You know, another way is to come together as teachers and discuss which ways can create effective teaching

We therefore believe that, this has implications for promoting affective teaching and learning, which is to inform future courses and through regular interventions and on-going support groups such as school-based and online communities of practice to enhance science teachers' ability and in so doing address the marginalization of teaching for the affective domain.

5. DESIGN PRINCIPLES

The following design principles were distilled from the findings to inform future short intervention programmes on affective teaching offered at UJ.

- The intervention programme should include reflection before, during and after
- Should be a setting that includes little ostensive and mostly heuristic teaching and learning to support teachers in developing a better repertoire of teaching methods
- Instruction for affective teaching should involve participants with engaging activities based on relevant contemporary socio-scientific issues.
- The intervention programme should be longer
- The programme be supplemented with an online community of practice

6. CONCLUSION

On the basis of the extensive findings, this study concludes that this short intervention programme developed a more nuanced understanding of the affective domain in teaching and served as a powerful learning experience to the teachers. It also enabled teachers to express their concerns about the fact that the affective domain is marginalized and also put forth improvement measures for such a programme in future which all contributed to the refinement of the design principles.

Read together (that is, the teachers' perceptions and experiences, students' responses and researcher's school and class observations), the evidence from this study suggests that most of the challenges which hinder the promotion of teaching and learning for the affective domain can be effectively controlled at the level of the teacher. This is so because the onus is on the teacher to interpret the curriculum requirements, carefully select resources appropriate to the context and lead the students with the enthusiasm necessary to teach for affective outcomes.

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PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS: THE A-TEAM HYBRID ECOLOGY OF LEARNING PRACTICE

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Abstract–Professional development interventions in South Africa do not always address teachers' needs or necessarily result in better realisation of outcomes in science. South African teachers' learning of science and their emerging science pedagogy need urgent attention and this issue can be addressed through focused continuing professional teacher development (CPTD) programmes. The University of Johannesburg launched a unique CPTD project named the *A-team project – Excelling in Science Education* in October 2010. This project focused mainly on developing the science teachers' inquiry-based teaching approaches, advancing scientific process skills and enriching their pedagogical content knowledge in CAPS themes. The aim of this longitudinal empirical qualitative study was to introduce both primary and secondary school teachers to new (and exciting) science experiences in hybrid ecology of learning practice. In this intervention the hybrid group of science teachers experienced a wide range of different activities. As the project progressed, we tapped into the overwhelming social capital resources of scientists, professors and the Natural Sciences, Life Sciences and Physical Sciences teachers themselves sharing a wealth of experience and information. The findings of this study revealed that hands-on activities in real laboratories not only improved the science teachers' technological pedagogical content knowledge but also motivated teachers to include inquiry-based teaching strategies in their classroom practices.

Keywords: Continuing professional teacher development, inquiry-based learning, teacher motivation, design-based research, hybrid ecology of learning practice

1. INTRODUCTION

We argue that South African teachers' learning of science and their emerging science pedagogy need urgent attention and that this issue can be addressed through focused continuing professional teacher development (CPTD) programmes. We believe that motivated philosophically literate science teachers could impact positively on learner outcomes. A philosophically literate science teacher incorporates the history, philosophy and sociology of science in an attempt to humanise science (Mathews, 1992). Connecting science with social scientific issues such as local, national and global societal concerns could make science classrooms more challenging, enhancing problem-solving and critical-thinking skills of learners (Andersen, Harty & Samuel, 1986; Hodson, 1985; Mathews, 1992; Ratcliffe & Grace, 2003). Moreover, the inclusion of personal, cultural and ethical values could contribute to the understanding of difficult science concepts (Mathews, 1992). Hence, the urgent call for teachers to reinstate the nature of science (NOS) into classrooms, as NOS incorporates "the values and assumptions inherent to the development of scientific knowledge" and "facilitates the understanding of science subject matter" (Lederman, 2006:3; Lederman & Zeidler, 1987:3). The true nature of science is empirically based, in that scientific knowledge is tentative, yet durable; scientific knowledge is theory-laden, yet partly subjective; imagination and creativity play a role in science; and there is no single scientific method (Vhurumuku, 2010). However, the hope of science teachers teaching learners to appreciate the true nature of science and to develop a scientific outlook has not yet been realised and calls for a new brand of CPTD. For this reason a unique brand of CPTD in science education was launched in September 2010 by the Faculty of Education at the University of Johannesburg, called the *A-team project – Excelling in Science Education.* The main objectives of this study were to motivate teachers to employ inquiry-based practices for the teaching of science in an attempt to promote and reinstate the true nature of science into classrooms, and also to develop teachers' PCK in some of the more "problematic" content areas in the CAPS, e.g. biotechnology, evolution, or chemical equations.

2. METHODOLOGY

This qualitative study over a period of three years followed a design-based approach in documenting science teachers' professional development in both a physical and on-line community of practice. Regarding sampling, a snowball approach was employed and teachers applied to become members based on word-of-mouth. Data were collected by means of individual interviews, focus group interviews, questionnaires, on-line reflections, observations and studying artefacts.

3. LITERATURE REVIEW

The concern is that learners find school, including science classes, progressively boring. To counter learner boredom it has been suggested that teachers should not only focus on content knowledge but also find ways to enthuse their teaching (Fullan & Langworthy, 2013). There are still many teachers who require learners to memorise key scientific terms and definitions of concepts without the excitement of experiencing true conceptual change. An increasing number of studies argue that most schools and their teachers still use textbooks for disseminating static bundles of information, assessing content recall and evaluating learners using test scores, despite having access to the latest information and knowledge through technological advancements (Hargreaves, 2003; Fainholc, 2005; OECD, 2009; Drucker, 2009; Lyons & Quinn, 2010; Nikkhah, 2011). Alberts (2009) also argues that science has lost its attraction for learners and that teachers often use chalk and talk teaching methods because as non-specialists they are dependent on textbooks (Lyons & Quinn, 2010). Thus, teachers and their learners reason intuitively instead of scientifically and instead of embracing the real nature of science (Carey, 1977). The learners cannot see themselves in monotonous science careers if the teachers do not make the subject interesting and dynamic (Lyons & Quinn, 2010). This may lead to fewer science teachers being educated and a spiral of decline in the numbers of science teachers and learners.

In a 1992 study Matthews (1992:11) already pointed out the "well documented crisis of contemporary science education – evidenced in the flight from the science classroom of both teachers and learners, and in the appallingly high figures on science illiteracy". We need to develop our teachers, convincing them that science teaching requires more than content knowledge and that teaching and learning should include values, goals and skills for orientation and transformation in an ever-changing society (Kaplan & Flum, 2012). Lederman and Zeidler (1987) argue that there is a direct and positive relationship between teachers' conceptions and positive conceptual change in learners. Lyons and Quinn (2010) argue that a teacher's positive attitude and scientific literacy results in successful classroom practices and successful learner outcomes.

The scarcity and low quality of science teachers in a developing country such as South Africa are still a reality, as the low quality of science results may be due to the shortage of well-motivated science teachers who are qualified and competent to teach science (Departments of Basic Education and Higher Education and Training, 2011; McCarthy & Bernstein, 2011). The quality and scope of science teaching do not meet the national needs of the South African society, especially regarding the development of scientists and engineers. The Engineering Council of SA (ECSA) has stated that South Africa has one engineer for every 3 100 citizens, Germany one for every 200 and Japan, Korea and the US hold a ratio of one to 310 (Gotthardt, 2014). This paints a bleak picture for the economy of South Africa, especially in the light of large scientific initiatives and projects such as the Square Kilometre Array (SKA) Telescope Project, the discovery of vast shale gas resources in the Karoo, and the fast developing alternative energy industry (Alfreds, 2012). Producing scientists and engineers is not an easy feat, as the poor science results in the South African National Senior Certificate statistics show.

The overall pass rate for Physical Science has increased from 61.3% in 2012 to 67.4% in 2013 and Life Sciences from 69.5% in 2012 to 73.7% in 2013 in South Africa. However, statistics show that 73.7% of

Life Sciences learners and 67.4% of Physical Science learners achieved less than 40% in the National Senior Certificate exam (Basic Department of Education, 2013). These statistics indicate that learners are not achieving the required science results to gain access into higher education institutions and will not be able to apply for science-related degrees at higher education institutions. This is not very encouraging, as South Africa urgently needs quality science teachers to ensure improved learner outcomes which could contribute towards developing more scientists and engineers for the 21st century in response to global challenges (Zeidler, Walker, Ackett & Simmons, 2002).

There is an urgency for the South African education system and higher education institutions to focus not only on preparing new science teachers but also particularly on supporting in-service teachers to produce high-quality science teaching. In-service CPTD is necessary as 70% of the teacher population is younger than 50, which implies that many teachers will still be teaching for at least another decade or more (OECD, 2009a). Furthermore, many teachers still teach the way they were taught. Kereluik, Mishra, Fahnoe and Terry (2013) point to a "disjuncture" between centuries, where a gap is evident between how teachers taught in the past and how they should teach science in the 21st century. Resnick (1987) suggests "bridging apprenticeships" to reintroduce the key elements of teaching and learning. Science teachers need continuing professional development to reinvigorate their teaching practices in order to enthuse learners, motivating them to achieve better results and choose science as a subject in the pursuit of career as a scientist or engineer.

A serious concern in South Africa is that only 35% of the few qualified science teachers mentioned above are employed at previously disadvantaged schools (Departments of Basic Education and Higher Education and Training, 2011:36). Many of these teachers would rather teach a different subject in an ex-model C (previously whites only) or a private school than their specialised subject such as science in a township or rural school. Hence, a qualified science teacher may teach geography or maths in a privileged school, while teachers qualified in English may teach science at a disadvantaged school. This worsens the problem as South Africa does not have enough teachers in specialised scientific fields, yet many of these qualified science teachers are not teaching in their field of expertise and many teachers not qualified in the field of science are teaching science. This results in poor science teaching in some classes and intensifies the problem of enhancing scientifically literate teachers offering quality teaching in all schools, not only in the more privileged schools.

The National Department of Education (DoE) embarked on the Dinaledi schools project in 2001, focusing specifically on improving science teaching and learning in previously disadvantaged schools. This project was established with corporate support and aimed to increase the number of students entering university with mathematics and science (USAID, 2009). It started with 102 historically disadvantaged, mainly rural and township schools and has increased to more than 500 schools. Yet, the Parliamentary Monitoring Group (2013) recently reported that these schools still face the challenge of teachers with poor science teaching skills. Most of the funds (R61.5 million) were spent on infrastructure development and resources such as science textbooks and equipment. Subsequently, these schools only achieved on average 10% higher than non-project schools during 2011/12. This revealed the "transversal expenditure framework" which revealed that professional teacher development was often compromised for resources, equipment and infrastructure (Wildeman, 2008:163). The DoE spent more money rectifying the physical injustices of the apartheid regime and not much on the actual desperately needed development of the teachers as human capital. The teaching resources are only mediating tools, a "kit of good activities", which will only prove to be worthwhile if teachers know how to use and adapt these to suit their contextual needs informed by their pedagogical reasoning behind a particular approach or strategy (Loughran, Berry & Mulhall, 2012).

In addition to the Dinaledi project, the national DoE and many donors embarked on CPTD training in content knowledge in an attempt to familiarise teachers with the content of curriculum changes since 1994. The Outcomes-based Education (OBE) curriculum, the National Curriculum Statement

(NCS), the Revised National Curriculum Statement (RNCS) and most recently the Curriculum Assessment Policy Statement (CAPS) required content knowledge training, but the need for pedagogy was often compromised (Taylor, Fleisch & Shindler, 2008; Kriek & Grayson, 2009; Crouch, 2011; McCarthy & Bernstein, 2011; Schleicher; 2011; Bantwini, 2012; Department of Education, 2012). This limited the impact of the interventions and emphasised Shulman's (1986:8) claim that, "Mere content knowledge is likely to be as useless pedagogically as content-free skill" and gave rise to the term pedagogical content knowledge (PCK). Shulman (1986) argues that the content knowledge of a subject is extended by matching specific content knowledge to particular ways of communication and teaching strategies in order to create optimal learning experiences for learners. Similarly, Loughran (2011:290) argues that teachers need to be "experts in the knowledge generation, dissemination and practice of the discipline of teaching".

Another reason for the limited impact of these CPTD interventions could be that the interventions were "either too basic or too advanced for the different of levels of teachers" given the history of education in South Africa (Department of Higher Education and Training, 2010; Bantwini, 2012; Parliamentary Monitoring Group, 2013). The "one size fits all" approach, which only provides resources and content knowledge to teachers, is not sufficient in South Africa, due to the legacy of different education systems. Furthermore, the national INSET programmes offered short workshops, despite teachers requiring district officials to ensure ongoing quality engagement and guidance.

District officials are fundamental in scaffolding and supporting teachers, and should be experts in their respective fields (Bantwini & King-McKenzie, 2011; Bantwini, 2012). Thus, the actions of district officials, school managers and even unions can contribute to teacher development and the improved conduct of teachers (McCarthy & Bernstein, 2011). Teachers and their teaching are at the front line of improving the quality of science education, but require multiple levels of support to achieve real change and success (Edwards, 2011; Roth & Lee, 2007).

The DoE acknowledges the continuing dilemma of science teachers and teaching in many South African schools. The OECD (2008), reports that progress has been made as education reform has been a priority since 1994. While the government and the DoE have excellent policies and strategies for CPTD in place, the actual focus on teachers and the implementation of the interventions seems to be a concern (Departments of Basic Education and Higher Education and Training, 2011). Consequently, the current professional development interventions in South Africa do not address teachers' needs or result in improved student outcomes in science, although these interventions have many factors that contribute to limited success.

4. THE A-TEAM HYBRID ECOLOGY OF LEARNING PRACTICE

The University of Johannesburg's Department of Education adopts an approach to CPTD that introduces science teachers to new (and exciting) experiences as professionals. Its A-Team project draws on the success stories of the Amandla development using non-governmental organisations (NGOs) to improve science teachers and teaching. They contend that in education "equitable opportunity development is complex and needs a multifaceted approach to achieve sustainability" (Amandla Development, 2009:1). The NGO LEAP (Leadership, Effectiveness, Accountability and Professionalism) initiative was established in 2005 and achieved excellent science results. Moreover, 72% of LEAP's matriculants are currently pursuing tertiary studies. One of their claims to success is their acknowledgement that both emotional and cognitive issues influence teaching and learning.

A recent report by the Centre for Development and Enterprise (CDE) (2011) found that while there are good teachers in the public schooling system, there are many teachers who are not teaching well or are poorly utilised especially in subjects such as maths and science (McCarthy & Bernstein, 2011; Departments of Basic Education and Higher Education and Training, 2011). We need to tap into the human capital of good experienced teachers, to build the social capital of the entire science teacher community in all schools.

CPTD has evolved on the international front and recent international studies yielded successful outcomes. Many of these successful CPTD interventions were led by higher education institutions. Examples of successful CPTD interventions are: the Ohio Public Schools Project called *Target Inquiry* (TI), which focuses on inquiry-based teaching approaches in a laboratory setting (Yezierski & Herrington, 2011); the FINNABLE project using ICTs in education (Niemi, 2012); the Annenberg Institute for School Reform aimed at tapping into social capital (Kronley & Ucelli-Kashyap, 2010); and the Japanese Lesson Study using model lessons (Crockett, 2007; Makinae, 2010).

However, CPTD is the "worst problem and the best solution" and it is never easy, as this requires of teachers to change" (Fullan, 1998:2).

5. THE BIRTH OF THE A-TEAM PROJECT

The Faculty of Education at the University of Johannesburg was the first to initiate an intervention similar to the *TI* intervention and includes elements from the Finnish, Annenberg and Japanese lesson study examples. It has a unique comprehensive approach specifically aimed at improving the quality of science teachers and teaching in the South African context and addressing the needs of South Africa's diverse teachers.

The A-team CPTD intervention follows a design-based method. It is formative and the iterative cycles allow the project's developers to adapt and improve the programme as new insights evolved from the programme's implementation (Reeves, 2000; McKenney & Reeves, 2013). The A-team project is longitudinal in nature and the participating science teachers are asked to commit for a period of five years. This project is also systemic as it involves not only science teachers but also school principals, expert scientists and other role-players from the University of Johannesburg and various international partners. George Dawson, a retired professor from Florida State University, and Joel Dawson, a retired school principal, were invited to participate as mentors in the programme. The study follows an empirical qualitative approach of observing the lived experiences of the science teachers in the project. The socio-cultural approach used in the A-team project focuses mainly on developing the technological pedagogical content knowledge of science teachers using a hands-on inquiry-based learning approach. The data collection methods include observations, interviews, questionnaires, teacher reflections, visual data (such as photographs and videos), and other artefacts The artefacts included lesson plans, shared teacher ideas and resources and physical products such as solar cookers made during actual contact sessions. The need for visual data was emphasised as a recommendation for ethnographic research and numerous photographs and videos were included as evidence. In addition to this the interviews and online reflections posted by teachers also provided evidence of improved teacher motivation and the implementation of hands on –inquiry based activities in classrooms. It also indicated the importance of validity in the data analysis phase, which prompted the use of both emic and etic approaches (Hoare, Buetow, Mills & Francis, 2013). The emic approach is threefold. Firstly, in understanding science teaching in a SA school context, secondly the daily lives of science teachers, their motivation for teaching science alongside their language and culture and thirdly their behaviours within the intervention. The etic perspective is more deductive in nature as it involves an investigation of collective cultures, also known as meta-cultures of science teaching. This is evident from using the literature, not only locally, but also international perspectives of science teaching and interventions alongside theoretical perspectives. This study also adheres to the six general principles for high quality Scientific Research in Education (SRE) (Towne, & Shavelson, 2002). In addition to this, an autobiographical approach ensured that the researcher bias was limited as far as possible. The data was analysed using both Microsoft Excel and Atlas.ti. Furthermore, the third-generation cultural historical activity theory (CHAT) is used as a heuristic tool to identify the contradictions, tensions and opportunities arising from the intervention.

6. CHOOSING A THEORY OF ACTION

The biggest problem the programme's developers faced was in selecting the most appropriate action theory of change to create a comprehensive CPTD A-team intervention. Using communities of practice (CoP) was the first option. Wenger (2006:1) defines a CoP as “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly”. Wenger and Snyder (2000:141) argue that “studies have shown that apprentices learn as much from journeymen and more advanced apprentices as they do from master craftsman.” This theory is related to the purpose of the A-team to create interactive opportunities for science teachers to improve their teaching of science. Following a socio-cultural approach, the underlying belief of the programme is that teachers can learn much from each other by sharing their ideas in a science domain and that this exchange could promote best practices. This was the first consideration as the human capital of expert teachers and scientists could result in social capital shared among diverse science teachers.

The second option of a professional learning communityalthough similar to CoP focuses on school-based staff development programmes. This is a good theory of action for some schools, but is not viable in the South African context, as many schools have only one science teacher while others do not have any qualified science teachers at all. It was the programme’s aim to use expert teachers from diverse schools to build the capacity of less experienced teachers, thus not focusing on individual schools.

The third option was networked learning communities. Steeples and Jones (2002) in De Laat (2006:149) define networked learning as “learning in which information and communication technologies are deliberately used to promote connections between learners in a community, their tutors and learning resources”. This was also an action theory to consider. However, the limited access to technology and the Internet in South Africa, together with the limited technological skills of many teachers, would not allow equal opportunities for all teachers to participate optimally in such a venture. Many features of the three theories are essential for effective CPTD and the A-team project included elements from all of these theories. However, the researchers chose to use the term “hybrid ecologies of learning practice” (HELP) as an action theory, as it was better suited to the purpose of this intervention.

This A-team intervention aimed to develop philosophically and scientifically literate teachers. The Centre for Unified Science Education at the Ohio State University had already defined scientific literacy in 1974, a definition which included the following seven elements:

The scientifically literate person:

1. understands the nature of scientific knowledge;
2. accurately applies appropriate science concepts, principles, laws, and theories in interacting with his universe;
3. uses processes of science in solving problems, making decisions, and furthering his own understanding of the universe;
4. interacts with the various aspects of his universe in a way that is consistent with the values that underlie science;
5. understands and appreciates the joint enterprises of science and technology and the interrelationship of these with each other and with other aspects of society;
6. has developed a richer, more satisfying, more exciting view of the universe as a result of his science education and continues to extend this education throughout his life; and
7. has developed numerous manipulative skills associated with science and technology (Rubba & Andersen, 1978:450).

The A-team project aimed to achieve all of the above, but it was not an easy feat for teachers to achieve. Lederman (1992) mentions that researchers have been concerned that the teachers’ classroom practices are influenced by complex factors such as their beliefs and attitudes, the curriculum, their content knowledge and other school-related factors such as the school environment and administrative responsibilities. Similarly, Hargreaves (1994) argues that good teaching is a complex process, requiring motivation, expertise, insight and moral purpose alongside competence and technical skills. Hence, developing real scientific literacy requires adherence to the long-standing call from experts such as Lederman and Zeidler (1987), Matthews (1992), Lyons and Quinn (2010) and Nikkhah (2011) to reinstate the NoS into classrooms. Lederman and Zeidler (1987:3) argue that NoS incorporates "the values and assumptions inherent to the development of scientific knowledge" and "facilitates the understanding of science subject matter" (Lederman, 2006:3). The main tenets of the nature of science are:

1. Science is empirically based.
2. Scientific knowledge is tentative.
3. There is a difference between observation and inference.
4. Scientific knowledge is theory laden, yet partly subjective.
5. Imagination and creativity play a role in science.
6. There is no single scientific method.
7. There is a difference between law and theory. (Vhurumuku, 2010:28)

The A-team believes that philosophically literate science teachers will reinstate NoS in classrooms. The incorporation of NoS will facilitate deep learning, as well as citizenship, enhancing the learners' social responsibility towards global challenges and working towards a sustainable future for all (OECD, 1996). The notion of incorporating NoS into classrooms will prepare learners by building accountability for participation in a globalised 21st century society (Sahlberg, 2010; Elliott, 2012). Hence, the importance of developing philosophically literate teachers guides the choice of using HELP as a theory of action in this A-team intervention.

7. THE A-TEAM AS A HYBRID ECOLOGY OF LEARNING PRACTICE

> The ecology of human development is the scientific study of the progressive, **mutual accommodation**, throughout the life span, between a **growing human organism** and the **changing immediate environments** in which it lives, as this process is affected by **relations obtaining within and between these immediate settings**, as well as the **larger social contexts, both formal and informal,** in which the settings are embedded. (Bronfenbrenner, 1977:514)

The term "ecology" was proposed by Ernst Haeckel in 1869 as "the study of the natural environment including the relations of organisms to one another and their surroundings" (Odum & Barrett, 1971:3). Odum and Barrett (1971:2) simplified it as the study of "life at home", emphasising "the totality or patterns of relations between organisms and their environment". These definitions are particularly relevant to the A-team project as multi-cultural and multi-skilled teachers will interact socially in a scientific laboratory environment, the natural home of science.

The programme developers chose not to host a homogeneous group as it is essential that the conflicts, tensions and opportunities develop in order to inform and improve the design of the intervention. Furthermore, ecology also refers to "biodiversity", where the community and non-living elements function together in their natural environment (Odum & Barrett, 1971; Savard, Clergeau & Mennechez, 2000). It could be described as a symbiotic relationship, as the programme developers attempted to create interactive mutualistic science environments for diverse multi-cultural teachers, encourage enquiry-based teaching and the inclusion of socio-scientific issues (The impact of sociological theory on empirical research, 2002).

7.1 The hybrid nature of the A-team

(mutual accommodation)

The Merriam Webster dictionary describes "hybrid" as something that has two different types of components performing essentially the same function. In this scenario, hybrid firstly relates to the A-team intervention, which offers a spectrum of activities for teachers.

Figure 1 shows the integration of the different activities of the programme which the teachers participated in:

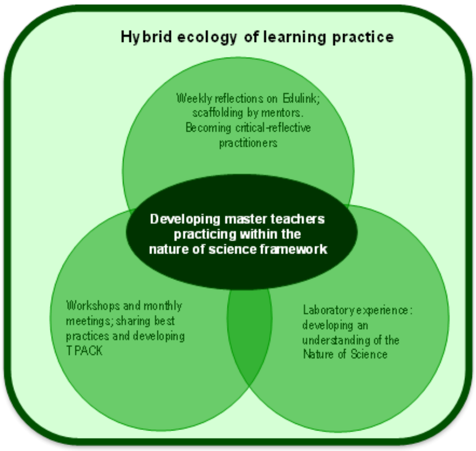

Figure 1: The A-Team Concept: A three-tier programme

In this intervention the science teachers shared experiences at short monthly workshops and two longer workshops of between three and five days per annum. In addition to this, teachers could collaborate with and support each other in online communities and write online reflections.

The first cycle of this intervention hosted 31 teachers during a week-long programme during the school holidays. The Natural Sciences, Life Sciences and Physical Sciences teachers participated in a variety of hands-on activities, which included among others *Gardner's theory of multiple intelligences*, *Edward de Bono*'s *Six Thinking Hats, making solar cookers* and computer skills sessions in a computer laboratory on the Soweto Campus.

7.2 Monthly workshop sharing experiences
(larger social contexts, both formal and informal settings)

The monthly workshops hosted teachers' modelling and sharing their best practices and resources. These sessions included some features similar to the Japanese lesson study, as the teachers offered positive criticism, which led to improved lessons. These lessons demonstrated best practices in topics such as human anatomy, constructing a real life skeleton, chemical reaction in the process of making soap, highlighting and sharing technological resources such as Internet sites and PowerPoint slides. Some sessions were facilitated by lecturing staff and post graduate students at the University of Johannesburg. A physics lecturer presented a lesson on the solar system and a botany lecturer offered a session on plant reproduction, the aromatic world of flowers. One teacher commented, "This is exactly what I am teaching now. I cannot tell you how much this means to me." These sessions produced enriched and motivated teachers, especially as less privileged schools gained physical resources and the skills of integrating technologies into the classrooms.

7.3 Attending two longer workshops per annum
(changing immediate settings)

The science teachers once more gave up their school holidays to participate in real-life laboratory experiences, gaining hands-on experience with real scientists. The teachers experienced DNA Barcoding and extracting their own DNA in the Botany laboratories, heart dissection in the Zoology laboratories and electroplating in the Physics laboratories. These laboratory experiences revealed the real world of science to teachers and inspired them to use inquiry-based learning in their classrooms.

Inquiry-based teaching and learning is not new as evidence of this is found in the 1960s to 1980s in the works of Robert Gagne, a very influential learning theorist (Matthews, 1992). Rubba and Andersen (1978 in Lederman, 1992:348) found that:

> the classes of the most effective teachers were typified by frequent inquiry-oriented questioning, active participation by learners in problem-solving activities, frequent teacher-student interactions, infrequent use of independent seat work, and little emphasis on rote memory/recall.

Inquiry-based teaching and learning is central to science teaching and success stories advocating improvement in the learners' understanding of science have been reported widely (Matson & Parsons, 2002; Anderson, 2002). However, a large and growing body of literature reveals that using inquiry-based teaching strategies resulted in teachers' misconceptions in their attempts to simplify science and revert to "cookbook" laboratory experiments (Matthews, 1994; Bencze & Hodson, 1999; Matson & Parsons, 2002; McComas, 2002; Herman, Clough & Olson, 2013). These cookbook inquiry-based activities may include scientific processes, but are still aimed at reaching pre-determined outcomes that defy the purpose of authentic scientific investigations (Bencze & Hodson, 1999). Thus, teachers need to understand, not only the science processes involved, but also the nature of science and develop the skills to conduct a scientific inquiry (Matson & Parsons, 2002). Teachers need to portray the nature of science in the classroom, and mediate learners' understanding that science is empirically based, that scientific knowledge is tentative, yet durable, that scientific knowledge is theory-laden, yet partly subjective, that imagination and creativity play a role in science, and that there is no single scientific method (Vhurumuku, 2010). Teachers need to understand, think and work like real scientists in order to develop the learners problem-solving skills, thus promoting the notion of innovative and creative knowledge creation (McComas, 2002). Meichtry, (2002: 239) argues that real science should include:

> a way of thinking about problems and curiosities, a method of discovery, an organized process in which ideas are tested, conducting an experiment to test a hypothesis, science is ever-changing and growing with new information, systematic approach to obtain knowledge, involves repeated trials, science is an ever-changing experience, discovery-inquiry-exploration, and going through a process that involves thinking and may involve attitudes and values.

Hence, real-world experiences in laboratories are important for the development of philosophically literate science teachers. Dewey's statement of "learning is learning to think" implies that the thinking process is about the brain's processing of information received by the senses and the context in which the learning takes place (Van Lier, 2000). Ecology specifically deals with the interaction of people with their environment and the environment holds much potential for learning and practice to think and making meaning. Furthermore, in ecology, the term "population" represents a group of people and a community is a group within a population occupying a specific area. Science teachers represent such a community within the teacher population as they are specialising in the area of science teaching.

In addition to the laboratory experiences, teachers developed their computer skills using Blackboard and open source software for integration into their classrooms and to ease the burden of administrative tasks. Furthermore, an excursion to the Sterkfontein Caves and the Cradle of Human Kind also offered the teachers enriching socio-scientific experiences.

7.4 The A-team's online experiences

(larger social contexts, both formal and informal settings)

The University of Johannesburg uses the Blackboard learning management system. Teachers used this system to communicate asynchronously, to share resources and to post regular reflections on their classroom practices and their A-team experiences. In addition to this, teachers received support from the programme's international partners, George and Joel Dawson, to improve lessons and planning. Another session which impacted greatly on the teachers and their teaching was an interactive Skype session, with Walter Lewin, Professor Emeritus of Physics at the Massachusetts Institute of Technology. Professor Lewin demonstrated the moment of inertia and hosted a question and answer session after the demonstration.

All of the above-mentioned activities convey the hybrid nature of the intervention as all the components of the project performed essentially the same function of enhancing the quality of the science teachers and their teaching by following a socio-cultural inquiry approach. It is clear that

":hybrid" was the correct name for this project as the Merriam Webster dictionary also describes hybrid as "a person whose background is a blend of diverse cultures or traditions".

The A team participants are a diverse multi-cultural, -lingual and -skilled science teachers, also reflecting the hybrid nature of the programme. This heterogeneous hybrid group involved teachers from two privileged private schools, four ex-model C schools and five previously disadvantaged schools in the greater Johannesburg area. A total of 31 science teachers from 11 schools in the greater Johannesburg area attended the first week-long workshop during the October school break. After the first intervention, teachers already expressed their delight with the approach: "We sacrificed a September holiday in 2010 and came back to school invigorated! Far better than any holiday!"

The idea of snowball sampling was evident as the number of participants varied between 24 and 42 science teachers from multiple schools throughout the intervention (Heckathorn, 2011). At one session teachers from Mpumalanga travelled to Johannesburg to participate in the programme. However, only 24 teachers of the original October 2010 A-team remained, alongside the new entrants. The exit interviews of the original teachers who no longer participated in the A-team revealed that they were allocated different subjects to teach. This is very worrying for the teaching of science, as we lose expert science teachers to teaching English, Geography or Mathematics, thus draining the pool of expert science teachers. This is also mentioned in the 2011 CDE report above (McCarthy & Bernstein, 2011). This emphasised the distress experienced by teachers, who cannot become expert teachers if they are required to teach different subjects every year.

The participants in the A-team intervention varied throughout the duration of the programme as participation was voluntary and thus flexible. This also added to the dynamics of the interactions as new participants complemented the intervention by adding new views and insights to the A-team. Consequently, the mix of activities and Natural-, Life- and Physical- Science teachers could result in hybrid science teachers and leaders embracing and dispersing quality science teaching practices. Hence, the co-evolution of a new hybrid teacher leader is possible within the framework of an ecological perspective.

However, science teaching does not occur in a vacuum and is embedded within a particular national education system and school context and climate. Bandura (2001: 14) argues that "human functioning is rooted in social systems". Consequently, the different levels in education such as the department of education, the district, the particular schools and classroom factors have a definitive influence on the quality of teaching and learning (Deakin Crick, McCombs, Haddon, Broadfoot & Tew, 2007). Figure 2 offers a view of the different interdependent levels of the education system in South Africa (Rogan & Grayson, 2003).

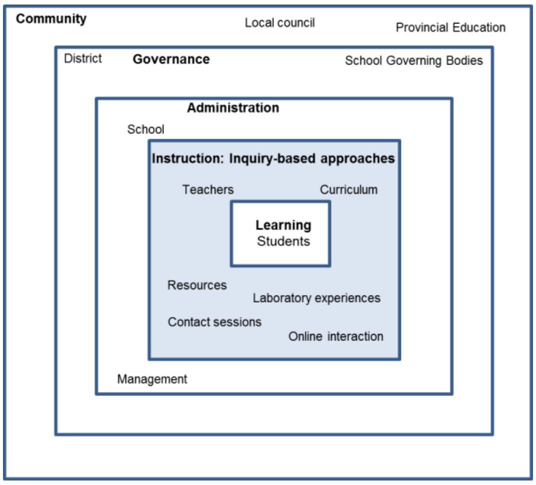

Figure 2: The various interdependent levels of education as organised in SA (Adapted from Rogan & Grayson, 2003:1180)

The A-team teachers and their teaching are influenced by the interdependent hierarchical levels and, for this reason, school principals were also included in this study, thus making it systemic in nature. Edwards (2009:211) mentions “collaborative intentionality capital” as “an emerging form of organisational asset”. Personal agency, as mentioned in Bandura’s social cognitive theory above, is embedded in the collaborative intentionality capital as it includes diverse science teachers with different beliefs and teaching practices collaboratively working towards quality science teaching practices (Bandura, 1989; Bandura, 2006). Also, as the project progressed we tapped into the overwhelming social capital resources of scientists, professors and the teachers themselves, sharing a wealth of experience and information.

7.5 Mutualism within the A-team

(growing human organism)

The term “mutualism” refers to the “cooperative interactions between pairs of species” (Jones, Bronstein & Ferrière, 2012:66) and can be defined as “an interaction between species that is beneficial to both, since it has both historical priority and general currency” (Boucher, James & Keeler, 1982:315). This is particularly relevant to the A-team intervention as the project aimed to create an environment where diverse science teachers are able to cooperate and interact. This environment could allow for the cross-pollination and diffusion of best practices alongside the expertise of scientists, adding to the sustainability and dynamics of the intervention (Margolis, 2012; Jones, Bronstein & Ferrière, 2012). Teachers could share, combine, develop and grow their teaching practices alongside their peers and experts, which resulted in a hybrid species of teacher leaders able to enhance science teaching in all communities (Margolis, 2012). Thus, the A-team teachers as participants in a scientific environment could offer a keystone specie of hybrid science teacher leaders.

7.6 The A-team members as keystone species

(growing human organism relations obtaining within and between these immediate environments)

The Oxford online dictionary defines “keystone species” as “a species on which other species in an ecosystem largely depend, such that if it were removed the ecosystem would change drastically” (Oxford online). Quality science teaching depends on quality science teachers as keystone species. These teachers could have a dynamic influence at any level, producing a cascade effect in improving the quality of science teaching in South Africa (Paine, 1995; Petersen & De Beer, 2012). The A-team hoped to develop the participants as keystone species, characterising them as expert science teachers in the system.

7.7 The A-team members as flagship species

(larger social contexts, both formal and informal settings)

Cristancho and Vining (2004:153) claim that “those species that can be considered most important to the structure and function of a community deserve the keystone species label.” The keystone science teachers of the A-team could evolve towards becoming a flagship species. These science teachers are charismatic in nature, and have the ability to become ambassadors for science in schools (Cristancho & Vining, 2004; Savard, et al., 2000; Paine, 1995). Moreover, the A-team teachers could become ambassadors for inquiry-based science teaching not only within their own schools but also in entire districts and even on a national level.

8. FINDINGS AND CONCLUDING REMARKS

The nature of the concept “ecology” and the link with the social sciences gave rise to the term “hybrid ecology of learning practice” (HELP). The HELP model includes all of the above-mentioned theories and theories of action and is most relevant to the purpose of the A-team intervention.

I contend that combining learning and practice in a hybrid ecology of learning practice is essential for the professional development of science teachers.

Findings of this study revealed that hands-on professional development activities in the continuing professional development of science teachers, not only improved their technological pedagogical content knowledge but also motivated teachers to include inquiry-based teaching strategies in their classroom practices. The hands-on experiments with scientists in the UJ laboratories, that emphasized the true nature of science, proved to be the greatest motivating feature of the entire intervention. These activities included DNA barcoding, electroplating, heart dissections and extracting DNA from strawberries and even their personal DNA. The main aim of these sessions was to develop the teachers' science process skills and to enhance the teachers' perceptions of the true nature of science. This proved to be successful in that the teachers' online reflections revealed the successful transfer of these activities into classrooms. Moreover, these inquiry-based A-team teacher experiences transferred into classrooms ignited the learners' interest in science as a subject and could also entice students towards taking science as a subject. A group of Life Science learners from a participating A-team school were also hosted for a DNA barcoding session. One teacher's response after this learner experience was that "a few new scientists were born." In addition to this these hands-on inquiry-based activities positively affected the learners' attitude and behaviour in the science classroom. Furthermore, the data also revealed that some teachers teaching science in SA schools have never been exposed to real science experiences in laboratories, which is of grave concern.

Successful outcomes are already evident from of the A-team project. One teacher was in the process of leaving the teaching profession. However, the support and the guidance of the A-team members resulted in her becoming a facilitator for many provincial programmes offered in science. Two more of our teachers (as flagstone species) were approached to present at a CAPS training session. The Life Science A-team teacher presenter used her A-team experience to present an inquiry-based hands-on session, resulting in a positive and motivating CPTD experience for the teacher attendees. Another A-team teacher was invited as a guest lecturer for a group of first year science teachers. In addition to this, some of these teachers made time to embark on further studies to improve their teaching of science. These are but a few outcomes of the A-team project – Excelling in Science Education as a hybrid ecology of learning practice.

Hybrid ecologies of learning practice provide support to teachers in challenging the status quo, offering opportunities to address larger and more difficult issues (Hargreaves, 1999). It allows for cultivating creative spaces and conditions for information sharing and knowledge generation, not only within a specific school but also between different schools, often referred to as "lateral capacity building" (Chapman, 2003). Hargreaves (1999:127, 139) contends that networks connect people, groups and communities, resulting "in combination, [in] a process of systemising and elaborating explicit knowledge by combining different bodies of knowledge" and that "networks within and between schools could promote professional knowledge creation within the individual school and in the education service as a whole". These wider circles embrace not only systemic change but also the impact of globalisation and rapid change, thus applying new ways to teaching and learning, by participating in global hybrid ecologies of learning practice (Stoll, 2006).

I conclude by advocating hybrid ecologies of learning practice as an outcome of the social cognitive, social constructivism and situated learning theories which is considered to be most effective, as collective action tends to create energy within a group that could promote positive behaviour, create a sense of belonging and enhance motivation (Kritsonis, 2005). By working together these science teachers could become a force for change to bring about new system beliefs and practices in the field of science teaching and learning. The A-team could fulfil the role of change agent within the system as "human agency gains unusual powers when future-oriented activity-level envisioning and consequential action-level decision-making, come together in close interplay" (Engeström, 2005:313). For this reason, I believe that the A-team as a hybrid ecology of learning practice offers HELP on demand for distressed science teachers and their teaching, as similar CPTD interventions could bring about an entirely new approach to science teaching in a South African context.

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SCAFFOLDING PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS WITHIN A COMMUNITY OF PRACTICE: A CASE STUDY

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Abstract–This paper focuses on how teacher professional development can be scaffolded within a school as a bounded community of practice (CoP). Recommendations are made as to how tailor-made interventions can provide a continuous and needs-driven professional development programme. It is vital to understand the extent and depth of teacher's experiences and challenges in their classroom in terms of their Pedagogical Content Knowledge (PCK), in order to plan meaningful professional development interventions. Teachers in South Africa experience challenges due to the continuous change of the curriculum, and many teachers are the product of ineffective teacher education that characterised apartheid South Africa. In order to improve science education rigorous and relevant professional development is needed together with support through induction, mentoring and practice teaching programmes (Bernstein 2011). Bernstein also states that teachers will learn better through interaction with other teachers and with experts in professional learning communities. The aim of this research is the scaffolding of educator professional development within a bounded CoP (a school in Johannesburg). In this paper the authors describe the professional growth of teachers within the zone of proximal teacher development, and how professional scaffolding and mediation took place in distinct phases, namely self-assistance, expert-other assistance, internalization and recursion.

Keywords: Teacher professional development, community of practice, zone of proximal teacher development

1. INTRODUCTION

The spark that ignited this study originated from the first author's daily interaction and observations, as Head of the Science Department at a Johannesburg school, with Life Sciences and Physical Sciences educators in terms of their passion, frustration, experiences and challenges in their everyday professional lives. Science education in South Africa is in disarray due to the continuous change of the curriculum, under-qualified Science educators and ineffective training that comprises once-off two- or three-day Curriculum and Assessment Policy Statement (CAPS) workshops. Therefore, there is a need for effective continuous professional development for science educators within an institution.

Bernstein (2011) feels strongly that, in order to improve the system, rigorous and relevant training is needed together with support through induction, mentoring and practice teaching programmes. She also states that teachers will learn better through interactions with other teachers and with experts in professional learning communities characterised by mutual trust. In this way the focus will be placed on a few important instructional priorities over a long period of time which will be more effective.

The gap that this study addresses is to aid educators in a community of practice (CoP) in their professional development, by offering tailor-made interventions addressing the teachers' needs. The CoP is school-based and, with the assistance of the University of Johannesburg, tailor-made interventions will be implemented to scaffold teachers' PCK development. We also use Warford's (2011) construct of the zone of proximal *teacher* development (ZPTD), based on Vygotsky's well-known zone of proximal development (ZPD), and explain how this scaffolding can happen in very distinct phases.

2. BACKGROUND TO THE STUDY

In the diverse South African science classroom there exist many demands on the science educator. The difficulties that science teachers have to deal with on a daily basis include large classes in which learners are second- and third-language learners. It can be said that the sciences (Physical Sciences and Life Sciences) are languages on their own which need to be mastered, understood and applied especially if one considers the complexity of the terminology and processes involved in these disciplines. Learners need to firstly master the language of instruction before they can even embark on understanding the language and the subject at hand. Does this extend beyond the pedagogy of our educators? It is important in this study to establish how educators make science content accessible to learners, and to establish which methods educators consider most appropriate in the classroom where second- and third-language learners experience barriers to learning, and where they often have misconceptions.

Sullenger (2005) explains that learners who have English as a second or third language may even begin to believe that they have no capability for learning science. Sullenger (2005:1) sums it up by saying "There is a gap between our ability as learners to observe and language available to communicate our observations and thoughts between what I call knowledge and information". Sullenger (2005:2) says "learners may find it difficult to be successful observers if they lack the vocabulary to capture and share their observations"; and she states that she believes it when learners tell her, "I know, I just don't know how to explain it". It is therefore important to understand and document the difficulties and experiences of science educators in teaching second- and third-language learners. Textbooks are also not in the learners' mother tongue, which compounds the problem.

It is important that educator`s PCK be extended as to incorporate learner misconceptions, as Sullenger (2005) mentions that most of us teach increasingly multi-cultural classrooms. This is true in South Africa since 1994, and young learners often come to school with different explanations of the same phenomena that scientists are interested in describing. Sullenger (2005) further states these could originate from family, religious or other cultural origins. This is especially true in the context of the South African sciences classroom where content matter may clash with traditional beliefs.

To further complicate matters, many educators are not very knowledgeable on curriculum topics such as evolution, molecular biology and genetics. Therefore, the PCK of the educator is challenged to incorporate the complex demands of language barriers, cultural barriers, learners' cognitive abilities, religion, learner interest, gender and even a changing curriculum which includes the implementation of CAPS (Curriculum and Assessment Policy Statement).

It is also important to investigate how educators in the Science Department view the Nature of Science (NOS) and whether there is evidence of inquiry-based learning in their classrooms. Do teachers have sufficiently developed PCK to follow open-ended inquiries in the various CAPS content themes? Do teachers know how to implement indigenous knowledge in the science classroom, taking cognisance of the tenets of the nature of science? These are all concerns in terms of teacher PCK that this study attempts to addresses.

If we are to maintain our science educators and achieve good results in the sciences, it is vital that we understand the extent and depth of their experiences and challenges in the classroom in terms of their PCK. Tytler, Sumington, Darby Malcolm and Kirkwood (2011) observe that educators "draw strength" from discourse communities and that these need to be recognized, especially in rural areas where teachers may be isolated from training institutions or expert others. Attention needs to be paid to developing such communities within schools and across networks of schools including the local community, especially in support of secondary school teachers' professional development.

Cochram-Smith and Lytle (1999) state that for educators to improve practice they must implement, translate and put into practice the knowledge they gain outside their class. Wilson (2013) explains that only interventions that take a systematic approach to reform hold promise for improving professional development effectiveness. Diamandidis and Shaheen (1998) agree very strongly with the Vygotskyan notion that, when educators construct knowledge, it is an active and social phenomenon. They emphasise the important link between thought and language, and how important it is for educators to be skilled in mediation in the science classroom. They further state that the re-conceptualisation of educators' approaches in the classroom is a long term goal which happens slowly over many years of exposure; and that educators should work in an environment that is supportive and creates an opportunity for them to share this change or transformation in their approach, and their awareness about mediation. This is in agreement with the importance of having a community of practice within the teaching environment for science educators.

3. PURPOSE AND OBJECTIVES OF THIS STUDY

The gap that this study addresses is to aid educators in a bounded community of practice (COP), namely educators in a Johannesburg school, in their professional development, by identifying tailor-made interventions to address the educators' needs. The community of practice is school based, and with the assistance of the University of Johannesburg, tailor-made interventions will be implemented to scaffold educators' professional content knowledge (PCK) development, taking note of the different knowledge's that scholars like Schulman (1986) identify. These interventions will be based on Warford's (2011) 'zone of proximal teacher development' (ZPTD) that represents the distance between what science teachers can do on their own without assistance, and a proximal level they might attain through structured mediated assistance (scaffolding) from more capable others (2011:253). In this case, the 'more capable others' are the HOD, staff from the University of Johannesburg, as well as colleagues at the school. Warford suggests a number of stages for this scaffolding within the zone of proximal development that we adopted for this project:

Phase 1: Teachers are required to reflect on prior experiences and assumptions. The teachers are required to write a learning autobiography, in which they reflect on their professional development as the programme progresses. Warford calls this the self-assistance stage.

Phase 2: Warford refers to the next phase as the expert-other assistance phase. We share the view of Van Lier (2004) that, in an expanded ZPTD, scaffolding happens on four levels:

- Inner resources (resourcefulness, self-access)
- Interaction with less capable peers ("we learn by teaching")
- Assistance from more capable peers (scaffolding; mediation)
- Interaction with equal peers (If one member of a dyad undergoes developmental change, the other is also likely to do so)

Phase 3: The third phase is that of internalisation. Through critical reflection and journaling, the teachers start to develop an own (or improved; more nuanced) footing and voice. In this phase there is often evidence that the teacher starts to "de-learn" some prior experiences or preconceptions, and starts valuing new knowledge and practices.

Phase 4: Warford's fourth stage is the recursion or de-automatisation phase. This can be described as the 'theory into practice' stage, as the teachers confront the dichotomy of theory and practice in all its intensity (Warford, 2011:255). Teachers accommodate new concepts in their conceptual understanding, and this equilibration might entail discomfort and stress.

4. RESEARCH DESIGN AND METHODS

The main research question that this study attempted to answer was: How can teacher professional learning be supported within a school-based community of practice (CoP)? In order to address this question, a qualitative case study design was adopted.

4.1 Sampling

The participants in this study were purposively sampled since the participants in this Cop could provide the most information-rich cases for answering the research question. Merriam (1998) identifies purposive sampling as the most common and logical choice in qualitative research.

4.2 Data collection

In order to collect meaningful data multiple research instruments were employed:

- Questionnaires
- Interviews
- Observations
- The Views of the Nature of Science (VNOS) instrument (Abd-El-Khalick, 1998) and
- The Views of the Nature of Indigenous Knowledge (VNOIK) instrument (Cronje, 2013).

The following research process was followed:

- Questionnaires were administered to 8 teachers in the CoP. The questions were open ended and aimed to identify challenges in their everyday science teaching. Identified issues guided the design of the interviews.
- Individual interviews were conducted with 8 teachers in the CoP. The questions posed were open-ended and sought to further explore their individual needs and concerns.
- Lesson observations were conducted to observe the teachers pedagogy, particularly in relation to the challenges identified from the questionnaire and explored in the interviews; and to determine each the educator's profile of implementation. These observations were guided by the Reformed Teaching Observation Protocol (RTOP) (Pilburn, Swada, Falconer, Turly, Benford & Bloom, 2000).
- The VNOS and VNOIK instruments were administered to ascertain the participants' views on NOS and IKS in science teaching as these views were anticipated to influence pedagogy.

4.3 Data analyses

The multiple research methods mentioned above lead to a richness of data for triangulation (Merriam, 1998).

Firstly, a personal profile was sketched for every educator, drawing on Rogan's profile of implementation. Three important aspects of the educator profile were analysed namely:

- Content knowledge
- Contextual factors
- Pedagogy

The interviews with the educators were electronically recorded in order to make the transcription of the interviews possible. The questionnaires and interviews were analysed according to the Saldana (2009) coding method as shown in Figure 1. Themes generated contributed to the 'needs and strengths' tables discussed in the findings.

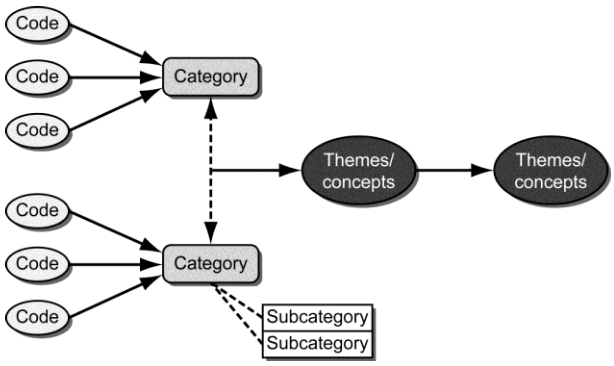

Figure 1: Schematic representation of coding method according to Saldana (2009)

The RTOP, VNOS and VNOIK instruments were analysed according to the protocols supplied for those instruments. The results of these analyses were combined with the Saldana themes generated to construct a 'needs and strengths' table for each participant. These tables are presented and discussed under findings.

The next step in this research will involve use of an interpretive framework, namely the use of Cultural Historical Activity Theory (CHAT) after Engestrom (2001). It is anticipated that a CHAT analysis of this CoP as an activity system will provide a powerful tool for the identification of tensions that can be addressed by further professional interventions, or by drawing on the strengths of the members of this CoP, as identified in the initial analysis (see 'needs and strengths' tables).

Engestrom (2001) presents five central principles of the activity theory, namely the activity system as a unit of analysis, multi-voicedness of activity, historicity of activity, contradictions as a driving force of change in activity and expansive cycles as possible forms of transformation in activity. A generalised activity system is presented in Figure 2.

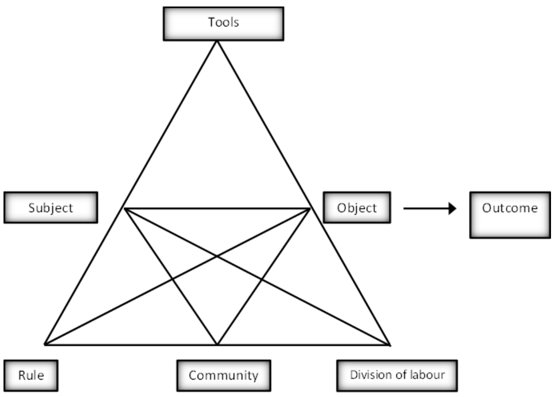

Figure 2: Cultural Historical Activity Theory (CHAT)

In this study, the educator is the subject within the triangle. The learners, other educators, Head of Department (HOD), principal and subject advisers form the community, while the object would be the professional development of the science educator. Division of labour refers to the educator who is a lifelong learner and at the same time an educator. The tools include the pedagogy of the educator and PCK as well as the educator's view of the nature of science (Abd -El-Khalikck et al, 1998). The rules referred to are CAPS and school rules.

CHAT analysis thus far identified a tension between the *subject and the rules* where time constraints of the work schedules restrict the use of learner-centred activities and games leading to learning. Another tension exists between the *subject and the tools* in terms of teacher pedagogy and the creativity of a teacher in creating fun activities or learner-centred activities, also having to extend their pedagogy to overcome language barriers. A further tension exists between the *subject and the rules* in the triangle as adhering to the work schedule allows no time to implement activities that might be time consuming such as learning games or other "fun activities". When practicals are observed, they are mostly "cook book" practicals because of time constraints.

4.4 Validity and reliability

The following strategies were used in this research to enhance validity and reliability:

Strategy	Description and application
Triangulation	Triangulation involves the use of different methods of gathering data, especially observations, focus groups and individual interviews, and document analysis. Cheng (2005) calls triangulation "cross examination". Altrichter, Feldman, Posch and Somekh (2008) contend that triangulation "gives a more detailed and balanced picture of a situation". Different data-collection methods were used in this study to ensure that their individual limitations were compensated for and to reduce the effect of investigator bias.
Member checking	Newman and Benz (1998) stated that a researcher could return to the subject who was interviewed to check informally and confirm that what the researcher has recorded is accurate. Guba (1981) and Lincoln (1995) consider member checking to be the single most important provision that can be made to bolster a study's credibility. Checks relating to the accuracy of the data may take place 'on the spot' or at the end of the data-collection interviews and observations. Participants may also be asked to read any transcripts of dialogues in which they have participated. Here the emphasis should be on whether the participants consider that their words match what they actually intended since, if a tape recorder has been used, the articulations themselves should at least have been accurately captured. Member checking was applied after analysing and coding my interviews, questionnaires and observations.
Peer review	The peer-review process contributes to the quality control of the study, and it is an essential step to ascertain the standing and originality of the research (Chanson, 2007). Opportunities for scrutiny of the project by colleagues, peers and academics should be welcomed, as should feedback offered to the researcher at any presentations (e.g. at conferences) that are made over the duration of the project. The fresh perspective that such individuals may be able to bring may allow them to challenge assumptions made by the investigator, whose closeness to the project frequently inhibits their ability to view it with real detachment. One of my colleagues, who is also my mentor, was requested to critically observe and challenge my texts and my methods and gave me in-depth opinions on the data and the strategies I employed.
Audit trail	For an audit to take place, Merriam (1998) suggests that the investigator describe in detail how data was collected, categories derived at and decisions made throughout the inquiry. My audit trail was done through the use of diagrams and a detailed narrative record keeping of everything I collected in the form of data. My records are organised in an archive for retrieval purposes.

5. FINDINGS

Preliminary findings from questionnaires revealed that educators did not have enough time due to curriculum overload; or sometimes even the skills to make science exciting by including more practical work, games, quizzes, role play, excursions, etc. Large classes make it difficult for educators to do open-ended inquiries and experiments in their lessons. Language barriers also emerged as a problem when instructions needed to be carried out by the learners, and in answering formal assessment tasks. Teachers had a limited understanding of the nature of science, and did not know how to include indigenous knowledge systems in their teaching.

5.1 Needs and strengths profiles

Based on the Saldana themes generated in the analysis of the questionnaires and interviews; and on the analysis of the of RTOP, VNOIK and VNOS instruments, a needs and strengths profile was constructed for each participant, these are discussed below, together with their personal profiles.

Naomi

Naomi is in her seventh year of teaching. She has a BSc in Human Physiology and a BSc (Hons). She has just enrolled for her PGCE. She is currently teaching Grade 11 and 12 Physical Science

Naomi feels frustrated in that the work schedules prescribe time frames which are difficult for her to adhere to and describes them as "unrealistic". She feels that there is not enough time to do the prescribed practicals in those time frames as they require much more time that is indicated as the "write up" takes long and must be done in class: ".....the learners have done the practicals, they have to do the 'write ups' under exam conditions. They do not allocate sufficient time in class for write ups to be done...."

She also needs to complete theoretical content in the prescribed time too. She further explains that there is not sufficient time for her to do exciting activities such as quizzes, games and class outings: "……it leaves very little time for fun activities…."

Needs and strengths profile for Naomi	
Strengths	Needs
Learning games, quizzes Stimulating activities Creative thought ideas Record keeping	Time management Discipline, work ethic Demanding work load Increased admin Making Science more visual/practical Learners need to be stimulated Language barriers

Brenda

Brenda is in her eighth year of teaching Life Science and has a BA and PGCE qualification. She is currently teaching Grade 9, 10, 11 and 12.

Brenda explains that there is "a sense of belonging in the Life Science department mainly because it is a small department and people (HOD) is understanding." She explains in her interview that "a sense of belonging is very important because you have to feel like you belong to a department and then you'll be willing to put in the effort, and put in the time, so belonging is very important."

Brenda explained in her interview that she feels she needs guidance content wise:

> "… content wise if you're not sure of what's happening, what's next, what's maybe – something is not clear in the notes or – you just have to ask, so that it all comes together with the support and you, feeling like you can ask."

Needs and strengths profile for Brenda	
Strengths	Needs
Lesson preparation Making worksheets Designing assessment Discipline	Admin/Paperwork Classroom atmosphere Time management Size of classes Work ethic of learners Resources Learner controlled independent learning Language barriers

Geraldine

Geraldine has been teaching for thirty three years. She teaches Natural Science Grade 8 and 9. She has a BEd, BprimEd and HDE qualification. Geraldine feels that she is supported in the science department and adds "…. In times of crises we all pull together and complete the task at hand. Support is always available."

Geraldine believes that practicals are vital and explains: "….you cannot teach a lesson without a practical demonstration, is the last line of action I would actually take, for the kids to be hands on, working doing the practical, seeing the outcome, to me just reinforces the theory that your teaching, and theory without practical is airy-fairy, it has no meaning to the kids."

Needs and strengths profile for Geraldine	
Strengths	Needs
Experience Practical work Research	Work ethic and discipline (Framework and tasks) Language barriers Investigative processes Gaps from primary school Scientific Calculations Indigenous knowledge

Simone

Simone is in her eleventh year of teaching Life Science. She has a BSc degree and her first job was in a laboratory which she didn't enjoy. Simone explains very passionately that in the science department the educators are nurtured, they are allowed to "grow" and they are encouraged to go to workshops and to move up in the department and teach higher grades. She feels that the science department is successful because when they need to do something "it is never done alone," the HOD is there with them and makes sure that the work is done in a "loving" and "caring" way. She continues to explain that in other departments staff are told "what to do and how to do it". In the Science department they are "lovingly" guided.

Needs and strengths profile for Simone	
Strengths	Needs
Passionate about the learners in her class Interpersonal skills Content	Time management (syllabus) Language barriers Alternative methodologies "get learners more active" Socio-economic barriers (nutrition) Stimulate learners (work ethic) Independent learning Discipline Biochemistry

Sylvester

Sylvester is a first year science teacher he is currently teaching Gr8, 9 & 10. He has a BEd degree. He feels that his HOD and colleagues in the science department have been there for him. He explains: "…

> so I find myself as a qualified student to a certain extent. So a lot of what I have been learning is almost quite 'fresh' and quite 'new' to a certain extent especially in terms of admin requirements a lot of the classroom management in demeanor, its something that you just don't learn at University…"

Although Sylvester feels that looking back to his first month of teaching he has:

> "changed in leaps and bounds, because the – just the sheer – if I think back …. was almost running around and trying to find my place in the world, and now to a certain extent I've started to settle in."
> Sylvester explains that he now knows how to consult the policy documents and speak to others in the department: "….because experience itself just lends a lot towards 'growth' especially being a teaching professional, because it's something that doesn't happen overnight. A degree doesn't make you a teaching professional…."

Needs and strengths profile for Sylvester	
Strengths	Needs
Skilled in using "analogies" and "metaphors" to explain content	CAPS implementation Time management Admin management Latent development Planning for curriculum Learner participation and insight Workload (marking) Indigenous knowledge Socio-scientific Issues Problem-solving skills

Penelope

Penelope is in her second year of teaching science, she has a BEd degree and is currently teaching Grade 8–10. Penelope explains that when she was doing her teaching practicals in other schools she realised that "antagonism" existed and so when she finally joined this school she felt: "…okay let me have my own back type of thing and then I very soon realised I don't need to have my back up. I can relax and I can go to people and ask and everybody is always willing to help. First week actually I realised that I could go to anybody and ask them all the time they would always be ready to help."

Penelope explains that she is struggling to instill independent research learning skills in her learners which she feels is important. Penelope explains that she is also struggling with time to incorporate more practical work than they are already doing, although she excitedly adds that: "…I find that they are thirsty. They're very curious and they want more and they want to learn." She would like to introduce more "minipracs" to her lessons which "aren't necessarily for marks but that would help them understand the theory that would bring it to life."

Needs and strengths profile for Penelope	
Strengths	Needs
Videos and I-box Lesson preparation Innovative Class group work	Instill research skills Independent inquiry learning Practical skills with open inquiry Introducing more investigative practical skills to reinforce theory More resources (textbooks) Alternative methodologies Chemistry and Organic Chemistry Practicals

Jodi

Jodi has been teaching for twenty years. She taught Grade 8 and 9 Life Sciences when she started teaching and then went overseas. She later returned but went to teach primary school for six years and finally has returned this year to teach Life Sciences once again. Despite the fact that she feels new, Jodi feels that she has developed her subject knowledge: "by talking to other staff members, asking questions and whoever I've spoken to had gone out of their way to just make time for me, and sit down and no question was too dumb or stupid and time was never a factor, even busy teachers they've always just made time for me."

Jodi finds that many learners experience language barriers and scientific terminology becomes a problem. Jodi is coordinating all the Grade 8 work including all the assessment and would like to start coordinating some of the other grades as well. Jodi's excellent computer skills have helped with entering marks and she has made a major contribution.

Jodi explains that since returning to the science department after so many years "everything's new actually" for her. Since having returned CAPS, has been implemented so everything is new for her. She feels it is important to get knowledge from different sources to be able to answer questions better.

Jodi feels that she could learn a lot from her colleagues even by observing some of their lessons: "just to see how other teachers portray things, what they say, because every teacher brings their own knowledge to a lesson, so it's not just what's on the notes, there's lots more that teacher bring and I'd like to see that in my colleagues."

Jodi is also concerned that many of her learners do not have access to internet, printers etc. and struggle to do project work due to a lack of resources.

Jodi explains that although some people learn better on their own, people on the whole are: "…social beings and need to interact with others in order to learn effectively." She believes in talking, debate, answers and questions and involving learners as much as possible as this leads to good learning. Jodi also explains learners are visual learners and need pictures, diagrams, flowcharts and tables to learn effectively so she attempts to incorporate all of that in her teaching. Jody feels confident about teaching the content although she has not been trained in high school CAPS.

Needs and strengths profile for Jodi	
Strengths	Needs
Computer skills Admin Assessment Worksheets Notes	Content development Practical skills development Language barriers Alternative methodologies Curriculum development and support Indigenous knowledge systems CAPS

Mia

Mia has been in education for thirty-six years. She administers all the practicals and all the lab work. She has, over the years, stood in and taught from Grade 8 to Grade 12. She has attended all the CAPS workshops, is familiar with the syllabus and extremely knowledgeable with all the chemistry, physics and life science practical work. All the teachers ask Mia for guidance and advice. Mia has even trained educators before they carry out their practicals. Mia has, over the years, trained and helped other schools sort out their laboratories. Mia coordinates all the Olympiads and research projects.

Mia explains that as the learner numbers have increased enormously: "… so sizes of the classes have grown which makes practical work more difficult…" Mia explains that the practical work reinforces the theory "… and if they actually understand the practical they will understand the theory…" In her teaching and also close interactions she has with learners during practical work she observes that the learners "…not read as they used to…" and adds "they watch an enormous amount of television…."

Needs and strengths profile for Mia	
Strengths	Needs
Practical investigation Administrative skills Investigative procedures Scientific vocabulary/terminology Content knowledge: - Chemistry - Physics - Life Science Practical applications of theory. Research methodology.	Time Workload Make Science relevant Indigenous knowledge

5.2 Common needs expressed by participants and remedial actions planned

Common themes were sought from the needs expressed by the various participants. These common themes are given in Table 1 below. Remedial actions in the form of interventions to be provided by the University of Johannesburg (UJ) or the school were identified. These interventions are described in Table 1.

Table 1: Common needs and planned remedial actions

Developmental need expressed	Intervention planned by UJ/ school
Making science more exciting and fun for learners	A short learning programme on addressing the affective domain in the science classroom, and focusing on socio-scientific issues.
More open-inquiry approaches (instead of transmission mode teaching or demonstrations)	Practical laboratory sessions at UJ- e.g. DNA barcoding at the African Centre for DNA Barcoding.
Knowledge and skills in addressing indigenous knowledge in the science classroom	A three-day short learning programme on ethno-botanical techniques that could be used when presenting inquiry-based lessons in the classroom.
Need to express agency (share talents with other teachers)	Arrange best-practices sessions, with peer-mentoring.
Addressing language barriers in the science classroom	Arrange an alternative methodologies learning programme for language barriers to learning.
Need to manage time and a demanding work schedule effectively with effective completion of all school-based assessment tasks and demanding admin requirements.	Arrange a time management programme to assist in effective time management.
More effective classroom management strategies, and ensuring better discipline.	Arrange a discipline workshop for the teachers on how to approach disruptive behaviour or methods to motivate learners.

These interventions are planned taking cognisance of the phases of development within the zone of proximal teacher development:

Table 2: Scaffolding learning within the Zone of Proximal Teacher Development

Phase	Activities	Research instruments
1. Self-assistance	Preparing learning autobiographies	Initial interviews; questionnaires
2. Expert-other assistance	Laboratory sessions at UJ Short learning programmes (e.g. on the affective domain; IKS)	Questionnaires such as VNOS and VNOIK
3. Internalisation	Journaling	Classroom observations; interviews
4. Recursion	Journaling and reflections	Interviews

It is hoped that this series of interventions will assist teachers in their professional development within this community of practice. In accordance to Warford's (2011) model, teachers need to internalise the new knowledge and skills, and eventually they will change their teaching philosophy and practice, to incorporate these new pedagogies.

6. CONCLUSION

This research provides an in-depth view of a community of practice that exists within the science department of a Johannesburg school. Various strengths and development needs of its members have been identified. A further CHAT analysis of this CoP as an activity system promises to provide more textured insights.

Scaffolded interventions have been designed to address some of developmental needs identified by members of the CoP. These interventions could be offered by UJ or by members of the CoP itself. Those offered by the school would take advantage of the various strengths identified by the members of this CoP. The latter option would provide the most sustainable solution and enrich an already functional community of practice. Interventions offered by UJ would provide an impetus for the further development of members of the CoP.

These interventions would have to be well-planned, systemic and needs-driven in order to best scaffold pedagogical content knowledge development. Effective scaffolding asks for a good needs analysis first, which has been completed. At the time of writing, these interventions have already begun in the form of a workshop on the implementation of indigenous knowledge systems in the science curriculum. This intervention was well received and has provided an impetus for further self and peer development within this CoP.

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SCIENCE EDUCATION: BUILDING ON A SOLID FOUNDATION

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Abstract–This paper reports on a study that aims to develop a deeper understanding of the pedagogical content knowledge of Foundation Phase Bachelor of Education student teachers on the natural sciences curriculum strand *matter and materials* at the University of Zululand. The focus is specifically on student teachers' PCK related to teaching these science concepts to young learners aged 6-9 years. The University of Zululand (UNIZULU), where the study is conducted, is a rural-based comprehensive university in northern Kwa-Zulu Natal (KZN). The student intake for the B.Ed. (FP) ranged from 100 to 200 students for the period 2010 to 2014.

There is currently no research on 1) how well foundation phase student teachers understand the science concepts taught in this phase of South African schools, 2) nor their understanding of science concept development in learners aged 6-9 years. An understanding of science concept knowledge of student teachers is important as these future teachers will be expected to teach science concepts to learners of the Foundation Phase in South Africa, particularly in KZN. Their own conceptual knowledge is paramount for teaching. The science concepts that are required to be taught to South African Foundation Phase learners are listed under topic headings in the Life Skills Foundation Phase Curriculum and Assessment Policy Statements (South Africa. Department of Basic Education, 2011). The study aims to find whether the student teachers' understand how conceptual change happens in young learners, aged 6-9 years. We would argue that having a better idea of student teachers own conceptual understanding, may assist teacher educators to plan interventions that may lead to an improvement in the student teachers' pedagogical content knowledge, that may in turn improve science education in the foundation phase. There is, as yet, no research in South Africa that has shown the impact of teacher knowledge of cognitive developmental psychology (as pertaining to understanding children's conceptual development in science) and their own knowledge of science concepts that they teach, on their pedagogical content knowledge.

This research forms part of a programme of research on science cognition of children and of student teachers within a larger programme of research, under the auspices of the Centre for Education Practice Research hosted by the University of Johannesburg's Faculty of Education at the UJ Soweto Campus. The data collected by the study will be interpreted and conclusions will be drawn on the pedagogical content knowledge of Foundation Phase student teachers at this South African rural based university, namely UNIZULU. As teachers require pedagogical content knowledge to facilitate the learning of concepts, this study could add to the knowledge required to develop science teacher education for Foundation Phase.

Keywords: Foundation Phase science learning, conceptual change theory, Matter and Material concepts, teacher professional development, PCK

INTRODUCTION

Fewer South African secondary school learners are choosing physical sciences as a subject for study in grade 10 - 12. Coupled with that, the pass rate for those that choose physical sciences is low for the final grade 12 examination. This has implications for the number of students that can choose science and engineering as a career, which impacts on the growth of the South African infrastructure and economy. Although there are many reasons why learners choose physical sciences, it is our contention that the way science concepts are taught in the in the early grades will have an impact on secondary school learners' choice for physical sciences as a field of study. Furthermore, research on what can be done to improve the state of science education in South Africa, mostly focus on older learners, neglecting the children in the foundation phase.

Studies have shown that schooling plays an important role in the choice of science as a field of study, especially in learners from developing countries (Cho et al 2012). This differs from learners in developed countries where other factors such as activities initiated by parents and the home environment play a greater role (Aschbacher, Ing and Tsai 2013). It has also been reported that students who showed an interest in science, reported that by age eight, their interest had already been developed and that Intermediate phase schooling had little impact on their interest. For these reasons, we feel that the teaching of science concepts in the foundation phase in South Africa needs attention, particularly the education of student teachers for this phase. Adler, Pournara, Taylor, Thorne and Moletsane (2009) point out that research is needed about science teacher education, among other areas of science education.

There is currently no research on 1) how well foundation phase (FP) student teachers understand the science concepts taught in this phase of South African schools, 2) nor their understanding of science concept development in learners aged 6-9 years, or how teacher knowledge of cognitive development psychology pertaining to young children's conceptual development in science and how this impacts on their own knowledge of the science concepts they teach. We would argue that an understanding of these aspects of science teacher education for foundation phase student teachers can lead to improvement in science teacher education and science education in the foundation phase in South African schools.

A study is underway at the University of Zululand (UNIZULU) in which the pedagogical content knowledge (PCK) of FP student teachers is being measured, particularly their science concept knowledge about the curriculum strand, *matter and materials* and their understanding of how young learners develop science concepts. The UNIZULU is a rural- based comprehensive university in northern Kwa-Zulu Natal (KZN).

SCIENCE TEACHER EDUCATION FOR THE FOUNDATION PHASE

Student teachers in South Africa study in a four year Bachelor of Education (B.Ed.) programme. The UNIZULU student teachers teach in mostly rural schools in KZN at the completion of their studies. The number of students enrolling in this programme numbered between 100 and 200 students during 2010 to 2014. Teacher education in South Africa is governed by the policy on *Minimum Requirements for Teacher Education Qualifications* (MRTEQ) (South Africa. Department of Higher Education and Training 2011) (SA Department of Higher Education and Training 2011). The policy requires teacher education programmes to address poor content and conceptual knowledge of South African teachers and to make inter-connections between different types of knowledge and practices. The policy further lists the types of learning associated with "the acquisition, integration and application of knowledge for teaching purposes" as among others, disciplinary learning, including subject matter knowledge and pedagogical learning. The policy refers to pedagogical learning as both general pedagogical knowledge, "which includes knowledge of learners (and) learning….and specialized pedagogical content knowledge, which includes knowing how to represent the concepts, methods and rules of the discipline in order to create appropriate learning opportunities for diverse learners, as well as to evaluate their progress." Teacher educators in South Africa are faced with the challenge of implementing the policy for teacher education (MRTEQ), which highlights the importance of inter-connections between different types of knowledge and practices. These interconnections come together in developing the student-teachers' PCK. Shulman (1986: 9) defines PCK as

> the ways of representing and formulating the subject that makes it comprehensible to others…….. (and) includes an understanding of what makes the learning of a specific topic easy or difficult: the conceptions and pre-conceptions that students of different ages and backgrounds bring with them to the learning of these most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in re-organising the understanding of learners, because those learners are unlikely to appear before them as blank slates.

Loughran, Mulhall and Berry (2004) argue that much research on PCK has been concerned with trying to understand various facets of PCK, such as exploring what teachers do and do not know about some aspect of teaching a particular topic or the relationship between teachers' subject matter knowledge and PCK about a particular topic, rather than exploring the whole of a teachers' PCK about a topic. They say that "it is a complex task to capture and portray PCK despite the fact that PCK itself is an almost unquestioned academic construct" (Loughran et al 2004:372).

This study focuses on two aspects of FP science student teachers' PCK, namely the *content* and the *pedagogical* knowledge, particularly knowledge of learners and learning. The study will measure, first, UNIZULU student teachers' knowledge of "matter and materials" science concepts listed in the curriculum - the *Foundation Phase Life Skills Curriculum and Assessment Policy Statements* (South Africa Department of Basic Education 2011), and second, the students' ability to reflect on how young learners learn science concepts. The second measure fits both in the general pedagogical knowledge area, as it includes knowing the learner and learning (of science in this case), as well as a small aspect of specialized pedagogical content knowledge, (or PCK), as without the pedagogical knowledge of how learners learn science, the teacher would, arguably, not be able to "create appropriate learning opportunities for diverse learners …….or evaluate their progress" (SA Department of Higher Education and Training 2011).

SCIENCE CONCEPTS IN THE FOUNDATION PHASE CURRICULUM

The science content knowledge for South African learners, aged 6-9 years, is describe in the curriculum. The content is listed under topic headings, an example of which is given in Table 1. The example is the content knowledge described for the topic "water" in grade R, term 3.

Table 1 Content for Water Topic Grade R

Topic: Water – 2 hours
• Objects that float and sink • Things that live in the water • Mixing different things in water to change what it looks like • Pouring and measuring water • Saving water

The table shows the only information available to the teacher. Science concepts such as floating and sinking, solutions, properties of a liquid or volume are not well explained in the documents used by teachers. Using only the sub-topic, "objects that float and sink", the science concepts that should be understood when describing sinking and floating are mass, volume and density. If the teacher of these young children does not make it obvious by using different examples that the size of the object does not matter for floating and sinking, then the concept of density and therefore the concepts of sinking and of floating are unlikely to be understood by the young learners. In addition, the science concepts of volume, mass and density are not covered by the curriculum in the following years of the primary school. Mass and volume are dealt with in the mathematics curriculum for intermediate phase in the section for learning about measurement. This means that measurement is supposedly a skill that could be learnt without a good understanding of the property being measured (Intermediate Phase Mathematics CAPS (SA DBE 2011)]. The next time learners encounter these scientific concepts via the curriculum is in secondary school, in grade 8 in the topic "particle model of matter" (Senior Phase Natural Sciences CAPS (SA Department of Basic Education 2011). An understanding of mass and volume is crucial when developing an understanding of science concepts in grades 10-12, in the FET band of the system. We refer to two examples from the FET curriculum: First, Grade 11 physical sciences learners are expected to know that the density of ice is less than liquid water and therefore floats, forming an insulating later between the atmosphere and the water below, allowing aquatic animals to survive. Second, there is a need for a clear understanding of mass, volume and density by the time when grade 11 learners are expected to do calculations with stoichiometric equations, especially with ideal gases.

Spaull (2013) states that it is very difficult for learners to make up a deficit in science and mathematics conceptual understanding as these subjects rely heavily on early foundations. He adds that the sequence, pacing, progression and coverage requirements of the secondary school curriculum makes it virtually impossible for learners who have been disadvantaged by their early schooling to “catch up”. It is our contention that the science concepts found in the foundation phase science curriculum should be well understood by FP teachers to ensure that basic science concepts are well understood for development in the following years of study. Shulman (1986) refers to the teachers’ familiarity content before and in later years of schooling as vertical curriculum knowledge of a specific topic. This would imply that FP teachers should be familiar with why, for example, in the topic sinking and floating, young learners need to understand that an object floats because of its density, and not its volume, weight or mass.

Research such as reported by Timur (2012) shows that primary school teachers across the world do not feel confident with their understanding of science concepts. Timur (2012) found that attitudes of early childhood education (ECE) student teachers towards teaching science to young children depended on their science content knowledge as well as their science teaching practice experiences. Kallery and Psillos (2001), in their study of ECE teachers’ science content knowledge, showed that the teachers’ understanding of science concepts and phenomena they introduce to young children were limited. Their research also confirmed that teachers’ limited understanding of science concept knowledge, including their alternative conceptions, influenced planning activities, representation of content, nature of teachers’ questions and their understanding of learners’ preconceptions. These aspects of teaching have bearing on teachers’ PCK and this is why we feel science teacher education for FP teachers is of paramount importance.

The present study aims to document the FP student teachers’ concepts (or alternate concepts) of matter and materials. It will be only one example of teachers’ knowledge, but could serve as an indication of where research should continue in future. According to Shulman (1986: 10) there has been much research “about the misconceptions of students and their influence on subsequent learning……. (and) the instructional conditions necessary to overcome and transform these initial conceptions.”

Continuing with our example of a topic taught in foundation phase (sinking and floating) research by Skoumios (2009) showed that students hold the following conceptions: dependence of floating and sinking of an object in a liquid on the object’s shape, surface, weight/mass, volume, density or on the liquid’s density. Students struggle with the concept of density

because they have difficulty coordinating mass and volume. They are often unable to state that all samples of a pure substance have the same density, that the ratio of mass to volume is constant for a pure substance, or that these ratios are different for substances with different densities (Baker and Piburn 2004: 65).

SCIENCE PROCESS SKILLS FOR FOUNDATION PHASE TEACHING

Abruscato (2012) and Charlesworth and Lind (2013) advocate the planning of science activities which develop the natural curiosity of young learners, noting that careful planning allows for the investigation of science concepts while developing and using science process skills. The FP Life Skills curriculum states that:

> key concepts and skills relating to these disciplines (including natural sciences) are detailed below:……..
> *Natural Science concepts*; life and living, energy and change, matter and materials; planet earth and beyond;
> *Scientific process skills*; the process of enquiry which involves observing, comparing, classifying, measuring, experimenting, and communicating ((SA DoBE 2011: 8).

We would argue that this description is anything but detailed and does not give the teacher guidelines for developing lessons for science concept development, particularly using the process of inquiry. We are reminded of the wisdom of Klopfer (1974), who is of the opinion that the scientific method and approach to inquiry learning presented in school to learners bear just as little relation to Einstein’s cognitive processes, as the colour-by-number colouring sets resemble Michelangelo’s paintings. An example of where the document is lacking is in listing experimenting as one process skill. This is very misleading and not a true reflection of how young children learn. Experimenting requires skills of inferring, predicting, hypothesising and defining and controlling variables. Science process skills can be classified into basic, intermediate and advanced process skills (Charlesworth and Lind 2013) (Abruscato (2012). This classification is given for clarity in Table 2: Science Process Skills.

Table 2: Science Process Skills

Basic Process Skills	Intermediate Process Skills	Advanced Process Skills
Observing Comparing Classifying Measuring Communicating	Inferring Predicting	Hypothesising Defining and controlling variables

Although the basic process skills are appropriate for pre-school and primary school learners, Charlesworth and Lind (2013) argue that learners vary greatly in experience and intellectual development and young children may be ready to use advanced process skills earlier than many assume. The development of the three cognitive components of domain general scientific reasoning, namely hypothesis generating, experimentation and evidence evaluation was measured for pre-school learners in Germany by Piekny and Maehler (2013). They found that these three components emerge asynchronously during early and middle childhood and suggested that in the last year of pre-school (and we would argue for grade R and 1 learners), there should be an arousal of interest in experimentation. They suggest that learners should be confronted with situations in which competing hypotheses exist and an experiment might help solve the problem.

> This confrontation should be accompanied by an adult who thinks aloud about what could be done to clarify the ambiguous situation. Strategies like these might foster children's interest in inquiry processes and prepare them for science education during their (later) school years (Piekny and Maehler, 2013:164).

For this reason it is vital that young teachers graduate with a clear understanding of how young children develop scientific reasoning by applying the listed science process skills and can choose the correct teaching strategy for teaching science concepts to young learners aged 6-9.

SCIENCE CONCEPT DEVELOPMENT IN YOUNG LEARNERS

Piekny and Maehler (2013) classify research on the development of scientific reasoning within two approaches, namely naïve (or intuitive) theories (the domain-specific approach; e.g. Carey, 1985, 2009) and the other the reasoning skills that are required in all inquiry processes (the domain-general approach; e.g. Kuhn and Pearsall, 2000).

Carey, (2009:29) defines intuitive theories as "theories that ground the deepest ontological commitments and the most general explanatory principles in terms of which we understand our world". She utilises intuitive theories as organising principle and explains that children are not metaconceptual theory builders – hence the qualifier *intuitive*. Young children are not metacognitive about their theories, but that does not mean that they are not theorists.

This is an important part of the design logic of the research, because we wish to see how student teachers develop an understanding of children's theorising. Foundation phase teachers' understanding of children's cognitive development in mathematics has had some influence on their discourse (Henning 2013). And so we argue that if student teachers know more about children's intuitive theories of science, that they will be better enabled to conceptualize their teaching. Understanding cognitive development is an important component of a new teacher's emergent pedagogical content knowledge.

THE STUDY

The study forms part of a programme of research on science cognition of children and of student teachers within a larger programme of research, under the auspices of the Centre for Education Practice Research hosted at the UJ Soweto Campus, where a similar inquiry is conducted in Johannesburg.

The study addresses two research questions:

First, what is the science content- (conceptual and declarative) and procedural (inquiry process skills) knowledge of B.Ed. (FP) student teachers at UNIZULU with regard to the FP school curriculum natural sciences strand, “matter and materials”?

Second, what do B.Ed. (FP) student teachers at UNIZULU know about science concept development in young learners, aged 6-9 years?

Proposed Sampling

The population of B.Ed. (FP) students of 2015-2016 will be sampled by means of non-probability sampling, asking for volunteers to answer the questionnaire on science concept development and inquiry process skills. From the respondents to the questionnaire, 10 first and fourth (final) year student teachers will be selected to be interviewed. Interviews will be conducted to measure FP student teacher understanding of science conceptual development in young children.

Proposed Data collection method

Two data collection methods will be used, namely a questionnaire for quantitative data and interviews for qualitative data.

The questionnaire will consist of multiple choice questions which test the relevant science content knowledge that is taught during the foundation phase in South African schools. Application of inquiry process skills will also be tested. The test will be conducted on-line, using Moodle, the Learning Management System available for e-learning at UNIZULU. A framework will be used for the development of the questionnaire that will be referred to as the questionnaire for “Matter and Materials Test for Foundation Phase Student Teachers”. The framework is adapted from the Educational Assessment Australia (EAA) framework which is available on their website. EAA is an education group of the University of New South Wales Global Pty Limited, a not-for-profit provider of education, training and advisory services and a wholly owned enterprise of the University of new South Wales (UNSW). EAA developed tests for schools for a number of subjects, including science, called the International Competitions and Assessments for Schools (ICAS). These tests are completed annually by learners from Australia, New Zealand Hong Kong, India, Malaysia, Singapore, South Africa and the USA. The ICAS on-line practice questions will be used to develop similar multiple choice questions suitable for the South African curriculum. An additional question category for concept knowledge is found in the MMTFPST framework but not in the ICAS framework. The MMTFPST will be designed to test science concept knowledge as well as inquiry process skills as given by the Foundation Phase Life Skills CAPS, for concepts relating to Matter and Materials.

Table 3: Framework for the Matter and Materials Test for Foundation Phase Student Teachers

	Number of questions for each category					
Sub-strands for Matter and Materials concepts	Concept knowledge	Measuring and Observing	Interpreting data	Predicting/ Concluding from Data	Investigating	Reasoning/ Problem solving
Food we eat	3	1				
Pollution	3	1				
Conservation (recycling)	3	1				
Transport (fossil fuels)	3		1			1
Poisonous substances	3		1			1
Flammable substances	3		1			1
Heat conducting substances	3			1		
Heat insulating substances	3			1		
Waterproof substances	3			1		
Water	3				1	
Soil	3				1	
Air	2				1	

The second data collection method will be individual interviews. Five students from B.Ed. (FP) year levels 1 and 4 will be interviewed in 2015 and 2016. The interviews will be semi-structured interviews. Two aspects will be discussed, firstly the student teacher's views on the nature of science, using an adapted version of the Views of the Nature of Science test (VNOS) (Abd-El-Khalick, 1998). According to Tsai (2006), the international literature suggests that many teachers still hold empiricist-aligned views about the NOS and makes clear, modern constructivist views (epistemologies) of science emphasize the progressive development of scientific understanding and recognition of technological, contextual and cultural factors that may have an effect on understanding and developing impacts on science concepts. Charlesworth and Lind (2013) point out, inquiry-oriented instruction "reflects the constructivist model of learning" and the South African Foundation Phase foundation phase curriculum implies the need for such a constructivist approach as its key science process skills are listed as inquiry skills (SA DBE , 2011a). Research is not available for the views of South African foundation phase teachers or student teachers on the NOS, even though such views affect the approach they take when teaching science in their classrooms, and therefore their PCK.

The second aspect to be discussed would be the student teachers' understanding of particular aspects of PCK (e.g. an overview of main ideas, knowledge of alternate conceptions, ways of testing for understanding, known points of confusion, effective sequencing and important approaches to the framing of ideas), using modified tools designed by Loughran et al (2004). These interviews will take place during the annual Practice teaching session which takes place during August. By using these tools, namely Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eRs), we argue that we can sensitise student teachers better regarding what learners might know about a concept, and what factors might influence conceptual understanding.

Proposed data analysis

The data collected by the study will be interpreted and conclusions will be drawn on the pedagogical content knowledge of Foundation Phase student teachers at this South African rural based university, namely UNIZULU. As teachers require pedagogical content knowledge to facilitate the learning of concepts, this study could add to the knowledge required to develop science teacher education for Foundation Phase.

Limitations of the study

The students in the study are mostly isi-Zulu home-language speakers. Questionnaires will be written and answered in English. This may not be a true reflection of the FP student teachers' conceptual understanding of the concepts being tested. After the pilot study (end 2014), we will decide whether there is a need for the test to be translated into isi-Zulu. The participants of the interviews will be able to choose whether they would like the interview to be conducted in English or isi-Zulu, and code switching will be allowed during the interview. We believe this approach will limit the effect of language on the testing of science concept development of these students and on their expression of their understanding of how young children learn science concepts.

CONCLUSION

Much needs to be done in the research field of science teacher education for young learners in South Africa. Teacher education policy (MRTEQ) (SA DoHET 2011) dictates that pedagogical content knowledge be developed by teacher education programmes, as a way to address the poor content knowledge and pedagogy of South African teachers as a whole. We contend that science education of young children aged 6-9 years forms the foundation for their interest and further science conceptual growth. This foundation can only be laid by teachers with pedagogical content knowledge, particularly knowledge of the science concepts taught during the foundation phase, and sound knowledge of science conceptual development in young children, which will impact on their choice of teaching strategies. We believe that findings from this study will add to the knowledge required to develop science teacher education for young children, aged 6 to 9 years. This conceptual paper will be followed by a paper at the next ISTE Conference, where the findings will be shared.

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THE EFFECT OF AN INTERVENTION PROGRAMME ON HOW SCIENCE TEACHERS VIEW THE NATURE OF INDIGENOUS KNOWLEDGE.

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Abstract–There is a global and national drive to include indigenous knowledge into science curricula. Most science teachers recognise the value of indigenous knowledge as well as the need to integrate it into the science classroom, but are confused on how to do so. We report on the effect of an intervention programme, based on philosophical underpinnings and science investigations, on how science teachers view indigenous knowledge. We generated a qualitative questionnaire to determine the views of science teachers on indigenous knowledge. Interventions as well as pre- and post-intervention questionnaires were administered to three groups of science teachers from different geographical settings. The results varied from a positive effect on the urban teachers' views to less promising on the rural teachers' views. The instrument developed can be used as a tool to determine the change in the views of science teachers on indigenous knowledge during professional development interventions and to identify areas in which science teachers need specific development.

Keywords: Indigenous knowledge, science teachers, professional development, nature of science, questionnaire on indigenous knowledge

1. INTRODUCTION

Currently the global focus of school science curricula is on teaching scientific literacy by making science more available and applicable to students in their daily lives. The curricula acknowledge that science content should not merely focus on facts, laws and theories, but also pay attention to the social and human aspect of science by including human activities such as investigations, attitudes and beliefs (Irez, 2006, Vhurumuku, 2010). The phrase used to refer to this type of science is the nature of science (NOS). Concurrent with the focus on the nature of science there is a worldwide drive to include indigenous knowledge into science curricula in order to make science more relevant to a diverse student body. Students from non-western backgrounds find it difficult to relate to the mostly Westernised science content taught in science classrooms (Higgens, 2014). South Africa is no exception to these initiatives and the newly implemented Curriculum and Assessment Policy Statement (CAPS) clearly states that students should "acquire and apply skills in ways that are meaningful to their own lives" and require the inclusion of indigenous knowledge in order to preserve and acknowledge "the rich history and heritage" of the country (Department of Basic Education, 2012: 3, 4). Although most science teachers recognise the value of indigenous knowledge as well as the need to integrate it into the science classroom, they are confused on how to do so in their classrooms (De Beer & Van Wyk, 2012; Ogunniyi, 2007b).

Research studies on the reasons for lack of integrating indigenous knowledge into the science classrooms indicate amongst others the perceived fear of teaching pseudo-science caused by the tension between the nature of science and the nature of indigenous knowledge, the beliefs science teachers hold about indigenous knowledge, teachers themselves being educated in western science as well as the lack of teaching strategies on the implementation of indigenous knowledge (Motwha, 2011; De Beer, 2012, Ogunniyi, 2007a). The problem that science teachers are facing is how to present indigenous knowledge and the Western science in such a way that one knowledge system is not perceived as superior to the other or in conflict with each other (Naidoo, 2010). Research by De Beer and Van Wyk (2012) revealed that 61,6% of science teachers in two provinces of South Africa view indigenous science and school science as in conflict with each other. Naidoo (2010) and Regmi and Fleming (2012) is of the opinion that indigenous knowledge and Western science should not be seen as two opposing knowledge systems, but as two alternative or complementary forms of indigenous knowledge that was developed in different cultures. Dekkers and Mnisi (2003) explain that science teachers need to be equipped with the underpinnings and values of a knowledge system if teachers have to teach different knowledge systems concurrently.

It is our belief that the philosophical underpinnings and beliefs of science teachers on both the nature of science and indigenous knowledge need to be addressed before suggesting teaching strategies to implement indigenous knowledge into the science classroom. The aim of this paper is to report on the development of a Nature of Indigenous Knowledge (NOIK) framework as well as a Views on the Nature of Indigenous Knowledge (VNOIK) questionnaire. An intervention programme based on the philosophical underpinnings of the framework and science investigations was conducted and the pre- and post-views of science teacher on indigenous knowledge were determined using the VNOIK questionnaire.

2. THE NATURE OF SCIENCE AND INDIGENOUS KNOWLEDGE

2.1 Nature of science

During the 1980s and 1990s there was a move to a more constructivist approach to science teaching and the phrase "nature of science" was being introduced in science education literature. The nature of science portrays science as a way of knowing, the activities linked to science as well as the values and beliefs embedded in science (Lederman, 2007). Introducing the nature of science into the science curricula resulted in science being viewed as tentative, open to the public domain and humanistic in nature (Abd-El-Khalick & Lederman, 2000, Ogunniyi, 2007a). The CAPS curriculum documents currently used in South Africa specifically states: "... Sciences promote knowledge and skills in scientific inquiry and problem solving, the construction and application of scientific knowledge, an understanding of the nature of science and its relationships to technology and the environment." (Department of Basic Education, 2011:8). It is very difficult to give a single definition for the nature of science as many different descriptions are available. The term nature of science in this paper will adapt the view of Dekkers (2006:82) as adapted from Abd-El-Khalick, Bell & Lederman (1998): "scientific knowledge is tentative (subject to change), empirically based (based on and derived from observations of the natural world); subjective (theory-laden); partly the product of human inference, imagination and creativity (involves the invention of explanation); and socially and culturally embedded". Added to this is that there is no single scientific method and that there is a difference between law and theory (Vhukumuru, 2010). Lederman, Abd-El-Khalick Bell and Schwartz (2002) developed a nature of science framework on which they based their views of nature of science (VNOS) questionnaire. In developing the nature of indigenous knowledge tenets we used the nature of science framework as basis, as explained in Table 1. The views on the nature of science of the following authors were also incorporated: Barnhardt and Kwagley (2005), Beauchamp (2011), De Beer and van Wyk (2011) and Vhurumuku (2010).

2.2 Indigenous knowledge

Indigenous knowledge is a way of knowing and doing what local people developed through the ages whilst busy with their everyday activities and in their struggle to survive. (Barnhardt, 2005, Senayake, 2006). Indigenous knowledge systems refer to a comprehensive group of knowledge systems and include for example language, the spiritual, philosophy, agriculture, art and science (Vhurumuku & Mokeleche, 2009). Indigenous knowledge systems is community-based, has developed over several generations, is usually orally transferred from one generation to the other and use rituals, ceremonies and songs (Aikenhead & Ogawa, 2007,Onwu & Mosimege, 2004). When referring to indigenous knowledge in this paper it will refer to the indigenous science knowledge that will be taught in the science classroom. Indigenous knowledge is still valid today to address issues for sustainable development such as hunger, under development and illnesses as it has survived the test of time (Barnhardt, 2005, Odora Hoppers, 2004, Naidoo, 2010) .

2.3 A nature of indigenous knowledge framework

We have two knowledge systems, each with its own unique characteristics that science teachers have to incorporate in one classroom. Barnhardt and Kawagley (2005) articulate the challenge clearly when they emphasise the necessity to devise a strategy that will respect the epistemology and pedagogy of both indigenous and western knowledge. This view is shared by Botha (2012) when he argues that the tensions science teachers experience between the two knowledge systems are rooted in ontological and epistemological differences. These arguments highlight the necessity to outline the epistemological and ontological structure underpinning indigenous knowledge. In an attempt to design principles for an intervention, to assist science teachers with the integration of indigenous knowledge and the nature of science in the classroom, we designed a framework for indigenous knowledge that relate to and can complement the nature of science framework of Lederman et al. (2002). There are multiple perspectives on the nature of indigenous knowledge as explained by Aikenhead & Ogawa (2007), but certain general characteristics constantly transpire from the literature. The tenets suggested in the nature of indigenous knowledge framework correspond with these general characteristics and are not seen as the fixed characteristics of indigenous knowledge, but are deemed important by the authors to take into account when integrating indigenous knowledge into the science classroom and curricula. The tenets for the nature of indigenous knowledge (NOIK) framework explained below were mainly derived from following authors: De Beer and Van Wyk (2011), Le Grange (2007), Ogunniyi (2007a & b), Senanayake, 2006. Table 1 explains the main tenets of the NOIK framework and how it relates to the NOS framework.

Table 1:NOIK framework in relation to the NOS framework

Nature of Indigenous knowledge (NOIK)	Nature of Science (NOS)
• *Empirical and metaphysical NOIK* Nature is real, partly or generally tested and observed. Needs-based experimentation. The universe is orderly, metaphysical and partly predictable.	• *Empirical NOS*: Nature is real, observable and testable. The universe is orderly and predictable.
• *Resilient yet tentative NOIK* IK has withstood the test of time, but is constantly changing as tradition is fluid and transformative – linked to people's experiences. It must be kept in mind that the elder's repository of ways of knowing is truth and not to be challenged.	• *Tentative NOS* Science is subject to change and not absolute and certain. It is challengeable by all.
• *Inferential yet intuitive NOIK* Facts are both tested and experimental observations made. Events have both natural and unnatural causes; metaphysical is important.	• *Inferential NOS* There is a clear distinction between observations made of nature and deductions or conclusions (inferences) made from observations to explain the causes. All events have natural causes.
• *Creative and mythical NOIK* Observations and experimenting are not the only sources of ways of knowing. Human creativity, imagination and myths also play a role.	• *Creative NOS* Observations and experiments are not the only sources of scientific knowledge. Human creativity and imagination also play a role.
• *Subjectivity of NOIK* Indigenous ways of knowing is based on cosmology and interwoven with culture and the spiritual. The elders can be influenced by prior ways of knowing and beliefs.	• *Subjectivity(theory-laden) of NOS* Scientists strive to be objective and culture free, but as human beings they are subjective and influenced by theoretical and disciplinary commitments, prior knowledge and beliefs.
• *Social, collaborative and cultural NOIK* Indigenous knowledge is situated in cultural tradition and within a certain historical-political context. It is the consequence of activities connected to everyday life in the natural environment of a group of people. It does not focus on the individual, but on the group and sharing. Indigenous knowledge is locally rooted and ecologically based. It is generated at a specific place by people of that place. Generilisations are relative within a certain context and can be shared amongst communities and beyond.	• *Social and cultural NOS* Scientists try to be objective, but science is a human endeavor and is therefore affected by a social and cultural milieu. Scientists do sometimes work individually. Science is generated at a specific place and thus local, but generalised scientific laws and theories have universal applications
• *Wisdom in action and NOIK*	• *Methods and NOS*

Indigenous knowledge is generated by practical engagement in everyday life through trial and error experiences. Repetition and ceremonies are methods to aid retention and reinforce ideas. New ideas are rigorously tested in the “laboratory of survival” (Senanyake, 2006:87).	Science knowledge is not generated by a single step-by-step universal method. Scientists use a variety of methods to solve problems and test theories. These methods are usually done in laboratories.
• *Functional application and NOIK* Indigenous knowledge is concerned with what and why things happen in nature, but also with what ought to happen. Emphasis is on practical or functional application and skills. Indigenous knowledge is concerned with the everyday lives of people rather than facts, theories and laws..	• *Theories and laws and NOS* Scientists use theories and laws to explain what, why and how things happen in nature. A scientific law describes what happens, while a theory explains why and how things happen. Scientific laws are causal, rational and logic.
• *Holistic approach of IK* Indigenous knowledge is “a conglomeration of knowledge systems” (Ongunniyi, 2007a: 965) including science, religion, psychology, religion and other fields. Problems and issues are solved in a holistic manner addressing all the smaller parts with no boundaries with the metaphysical world.	• *Reductionist approach of NOS* Complex phenomena can be broken down into small parts and analysed. The part to whole method is used. .

It must be clearly stated that the purpose of the philosophical framework explained in table 1 is not to compare indigenous and western science or to determine if one knowledge system is superior to the other; the framework was developed to facilitate the classroom practice of science teachers struggling to incorporate both knowledge systems in the classroom. This argument is strengthened by the views of Dekkers and Mnisi (2003) who argue that science teachers need to be equipped with the foundations and values of a knowledge system in order to teach the two knowledge systems concurrently.

3. THE PEDAGOGY REQUIRED

The problem science teachers are currently faced with is that the curricula as well as the teaching and assessment strategies are based on a western worldview and not on an indigenous worldview (Barnhardt & Kawagley, 2005). Higgins (2014, 154) argues that both the pedagogy and pedagogue needs to be de-colonised in order to introduce indigenous knowledge into the science classroom. Science teachers do realise the need to introduce indigenous knowledge into the science classroom, however the challenge is how to do it? Not much literature and research is readily available on such teaching methods (Hewson & Ogunniyi, 2011). A few teaching strategies suggested in literature will now be explained:

3.1 Cultural border crossing

Jegede and Aikenhead (1999) suggest cultural border crossing as a possible solution. Cultural border crossing involves that learners cross cultural borders when they “travel from their everyday life-world to the world of science found in their science classroom” (Jegede & Aikenhead, 1999, 49). Cultural border crossing involves collateral learning as two knowledge systems are learned simultaneously. The success of cultural border crossing depends heavily on how the students perceive the cultural divide and on the assistance they receive from the teacher acting as a cultural broker (Jegede & Aikenhead,, 1999). Naidoo (2010) highlights the fact that the own background and perceptions of the science teacher also impact on the way that indigenous knowledge is introduced when using cultural border crossing.

3.2 Indigenous education practices

Some researchers suggest an educational approach where indigenous knowledge is moved from the periphery to the centre (Barnhardt & Kawagley, 2005, Higgens, 2014). Pedagogical strategies are constructed around indigenous education practices and instruction methods can include demonstration, observation and stories. Lessons can be constructed around observing natural processes, obtaining nourishment and medicine from plant and animal material and using natural material for tools and instruments. The use of ethno-botany and medicinal plants can also be incorporated into the science classroom (De Beer & Van Wyk, 2011). A challenge to teachers might be that they do not have the necessary knowledge of these indigenous sources and practices.

3.3 Contiguity argumentation theory

Kwofi and Ogunniyi (2011) propose contiguity argumentation theory (CAT) as pedagogy to introduce indigenous knowledge in the science classroom. Their choice of method is informed by their view that indigenous knowledge and the nature of science are equal and complement each other. This method requires teachers and students to argue and debate issues relating the nature of science and indigenous knowledge. This method has the benefit that teachers learn from their students' indigenous knowledge. Challenges highlighted by teachers during application of this strategy are the lack of language skills of students, lack of prior knowledge and time constraints. Easton (2011) highlighted the fact that the argumentative strategy used in the argumentation theory is built mainly on Eurocentric types of arguing methods.

3.4 Scientific inquiry and science investigations

Scientific inquiry is advocated in most science curricula globally for an improved understanding of the nature of science (Vhurumuku, 2010). Hoffstein and Lunetta (2004, in Dudu & Vhurumuku, 2012, 580) explain scientific inquiry as " the various ways of studying the natural world, asking questions, proposing ideas, collecting evidence to justify assertions and explanations and communicating results. Inquiry practices as well as inquiry type of investigations can be used to assist students to develop an understanding of the nature of science (Dudu & Vhurumuku, 2012), but also the nature of indigenous knowledge. Scientific inquiry correlates with the indigenous educational methods suggested by Barnhardt and Kawagley (2005) as well as in the nature of science and nature of indigenous frameworks explained in table 1. Scientific as well as indigenous inquiry can complement each other as both propose the observation and studying of the natural word, collecting evidence, testing the evidence, communicating results and verifying ideas.

4. THE INTERVENTION

An intervention programme was developed to assist science teachers with the problem on how to incorporate indigenous knowledge in the science classroom. In a diverse country such as South Africa the question arises: who's indigenous knowledge to address? We therefore decided to focus on the processes and methodology rather than the content and teachers were exposed to intense hands-on activities as well as discussion and reflection sessions. Despite the fact that we focused on the processes, in order to ensure indigenous knowledge claims its rightful place in the classroom on cannot completely ignore the content. Teachers were encouraged to include local experts, their learners and resources in their own environment when applying some of the methodologies introduced. The intervention was based on both the nature of science and nature of indigenous knowledge frameworks discussed in table 1 as a well as a combination of the pedagogies described in section 3. It comprised of a three day workshops where teachers were exposed to indigenous knowledge by for example visiting the Muti market in Johannesburg, to gain first-hand experience and talk to traditional healers. The next topic covered was what indigenous knowledge and the nature of science is, combined with video recordings of interviews with elders, traditional rituals, dances and songs. The teachers had group discussions on how to address the problem of integrating the two knowledge systems using group work and applying De Bono's hat technique. The teachers visited the DNA barcoding centre to introduce them to authentic science laboratories where they could experience how indigenous plants were identified using their DNA. The teachers collected plant material available in the environment of the venue to use in experiments and to prepare herbarium vouchers. The teachers conducted science experiments applying microbiology and chemistry laboratory techniques to extract the active ingredients of the plant material they collected and that was bought from the traditional healers at the Muti market. The teachers tested whether the extracts from the plants could destroy bacteria cultures. The science teachers prepared and labeled herbarium vouchers of the collected plants also indicating their medicinal value. Although the teachers used laboratory equipment in the investigations and preparation of herbarium vouchers, it was explained or demonstrated to them how they could apply shoestring science using everyday objects in order to perform the same investigations in their own classrooms despite lack of resources. Finally teachers were introduced to the Jigsaw method, a collaborative discussion technique, where teachers were given three different case studies on how teachers integrated indigenous knowledge into their classrooms. The teachers had to critically discuss and reflect on the lessons.

5. THE VIEWS ON THE NATURE OF SCIENCE (VNOIK) QUESTIONNAIRE

We required an instrument to use as pre- and post-questionnaires to determine if the intervention did have an influence on how science teachers view indigenous knowledge. We could not find a suitable instrument and decided to develop our own instrument grounded in the nature of indigenous knowledge framework discussed in table 1 and based on the views of the nature of science questionnaire (form C) developed by Lederman et al (2002). The views on the nature of indigenous knowledge questionnaire (VNOIK) stated in figure 1 consist of ten open-ended questions. The participants are reminded that there is no right or wrong answers when answering the questionnaire.

VNOIK Questionnaire

Instructions: Please answer each of the following questions. Include relevant examples whenever possible.

There is no "right" or "wrong" answer to the questions. We are only interested in **your opinion** on a number of issues regarding indigenous knowledge.

1. In your view what is indigenous (or traditional) knowledge?
   What makes indigenous knowledge different from other types of knowledge systems (such as western knowledge)?
2. Practitioners of indigenous knowledge (e.g. elders, herbalists, traditional healers) observe nature to generate knowledge. Do they do experiments and tests in order to verify or validate this knowledge?
   If yes, explain how they test or validate their knowledge
   If no, explain why not
3. Practitioners of indigenous knowledge observe nature and give explanations about their observations. Elders in a community can, for example, explain where lightning comes from. Do the elders always use natural causes to explain their observations such as lightning, or do they sometimes include supernatural causes in their explanations?
   If they only use natural causes, explain why and give examples of some of the causes.
   If they sometimes use supernatural causes, explain why and give examples of some of the causes.
4. Indigenous knowledge is transferred from one generation to the next over many decades and centuries. Does this knowledge stay the same or does it change over time?
   If yes, explain why it stays the same
   If no, explain the causes of such changes
5. *Hoodia gordinii* is a plant that was used by Khoi-San hunters to suppress their hunger and thirst when they went on hunting expeditions. How **do you think** the Khoi-San people come to know that this particular plant has these properties?
6. Sustainable development is an emerging concept that includes topics such as hunger, poverty and underdevelopment. Globally governments and organisations struggle to find solutions for these important issues. **Do you think** indigenous knowledge can be used to alleviate some of these problems?
   If you say yes, please explain why and how indigenous knowledge can be used to solve these problems
   If you say no, please explain why it cannot be used to solve these problems
7. An athlete regularly competing in marathons struggles with pain in his legs during the last part of a marathon and can sometimes not complete a marathon due to this. The athlete decides to consult a traditional healer to determine why his legs pain during the last part of a marathon.
   What methods **do you think** the traditional healer will apply to diagnose the problem when consulting with the athlete?
   What possible treatment or advice **do you think** he will give the athlete?
8. Myths are stories that are told in different cultures by elders from one generation to the other. Do you think myths and rituals play any important role in indigenous knowledge systems? Explain your answer with examples if possible.
9. Some claim that indigenous knowledge is infused with social and cultural values. That is, indigenous knowledge reflects the social and political values, philosophical assumptions, and intellectual norms of the specific culture in which it is practiced. Indigenous knowledge is thus generated locally and can only be used in a specific area. It cannot be used universally in other contexts or globally to solve different problems.
   Explain how indigenous knowledge reflects the social and cultural values of a local community.
   Do you believe that indigenous knowledge can only be used in a specific area or do you believe it can be used in other areas or globally to solve problems? Explain your answers with examples.
10. Indigenous knowledge is passed from one generation to the other by elders. The elders are deemed very important and some people believe their ways of knowing (knowledge) is truth and cannot be challenged. Does this mean that current practitioners of indigenous knowledge must use this knowledge exactly as it was passed on to them, or can they use their creativity and imagination to modify the indigenous knowledge to solve current problems?
    If you say yes and believe that indigenous knowledge practitioners cannot change this knowledge, explain why. Use examples if possible.
    If you believe that indigenous knowledge practitioners can change and modify his knowledge, explain why. Use examples if possible.

Figure 1: The VNOIK questionnaire

6. RESEARCH METHODOLOGY

The main research questions to be answered in our research were: What are the views of science teachers on indigenous knowledge and what is the effect on an intervention in changing the perceptions on the science teachers on indigenous knowledge? A qualitative research design was adopted in order to obtain an in-depth understanding of how participants view indigenous knowledge and how the intervention could have an effect on this view.

6.1 Sampling and data collection

We used purposeful sampling as a selection method in order to see the effect on science teachers from different contexts. The VNOIK questionnaire explained in figure 1 was used as instrument. The intervention and questionnaires were administered to a group of 26 science teachers (life-, natural and physical science) who voluntarily signed up for the workshop. The teachers were from different schools in the Johannesburg area in the Gauteng province (an urban area). Participants were allowed ample time to answer the questions and reminded that there is no right or wrong answers. The participants were able to complete the questionnaire within an hour or less.

6.2 Ethics and trustworthiness

Permission was obtained from the university, the Department of Education as well as the participants. The participants were ensured that pseudonyms would be used throughout and that their results will be held confidential. The questionnaire was validated as explained in section 4.

6.3 Results

In order to ensure that the responses of the participants were coded and evaluated consistently a rubric with possible responses and a rating scale was developed using different sources of literature reporting on indigenous knowledge as well as the answers from the expert group. According to the rubric the responses to each question were coded in categories as an informed view, a partially informed view and an uninformed view on indigenous knowledge. The results of the coded questionnaires are summarised in table 2.

Table 2: Summary of results of pre- and post VNOIK questionnaires of participants

View of participants	Percentage of participants before the intervention	Percentage of participants after the intervention
Uninformed view	3.8%	0%
Partially informed view	80.8%	53.8%
Informed view	15.4%	46.2%

In order to illustrate the views of the participants on indigenous knowledge, examples of some of the responses to the VNOIK questionnaire is summarised in table 3:

Table 3: Summary of selected participants' responses on the VNOIK questionnaire to some of the questions

Question	Uninformed view	Partially informed view	Informed view
1. What is indigenous knowledge?	The things you get from nature	Knowledge that is from indigenous cultures. It has been brought from generation to generation.	Indigenous knowledge is knowledge active in a clang or tribe. They are cultural and social. This knowledge is passed on from generation to generation and the ancestors also play a role.
2. Do practitioners of indigenous knowledge do experiments?	Most just have a belief that it will work.	Yes, in an informal way they will try it out.	Yes they do. They might have tested it through trial and error and then started investigating it.
7. Methods and advice to athlete	I do not know.	Will make assumptions give him herbs to take to make the athlete stronger	The healer will first detect the cause of the pain by "throwing the bones" and get information from the ancestors. Then he will decide on the relevant mixture of plants. It may be they believe the patient is a victim of bad spiritual practice.

Some of the main misconceptions that emerged from the pre-questionnaire answers were that indigenous knowledge is limited to the use of medicinal plants that indigenous people did not execute experiments and that indigenous knowledge does not change or adapt over the years as circumstances change. The analysis of the questionnaires after the intervention indicated that the explanations for each question after the intervention was explained in more detail and displayed a richer and more in depth knowledge of indigenous knowledge. The post-questionnaires indicated a definite increase in the number of partially and informed views of the teachers on indigenous knowledge.

6.4 Discussion of results

The results indicate that some of the science teachers did adjust their view on indigenous knowledge due to the intervention. Prior to the course 3,8% of the teachers had an uninformed view of indigenous knowledge, but after the intervention none of the teachers had an uninformed view on indigenous knowledge. There was an increase of 30,8 % of teachers who now have an more informed view on indigenous knowledge. We realise that the science teachers are not yet experts on indigenous knowledge, but we believe we created a sensitivity, awareness and appreciation for indigenous knowledge systems. The teachers started to respond to indigenous knowledge. Literature informs us that a systemic longitudinal approach to professional development involving communities of practice is needed for internalisation to occur (Buyse & Winton, 2008, Steyn, 2010). We agree with this and recommend that this type of intervention be developed into different themes over an extended period of time within communities of practice. Van der Mark (2010) however indicated that positive results can be obtained with short interventions if the intervention is well designed and the target groups are considered. We believe that our intervention was well designed and the needs and profile of the target group were addressed.

7. CONCLUSION

The development of the indigenous knowledge framework and the outline of the workshops provided can assist in the planning of professional development workshops for science teachers with the integration of indigenous knowledge and the nature of science. The views on the nature of indigenous questionnaire generated can assist in identifying topics to be covered as well as the effect of an intervention on the integration of professional development. A limitation of the study is that it is very difficult to establish the validity or trustworthiness of a qualitative instrument of this nature. The theoretical underpinning of the questionnaire, the recommendations of the specialists as well as the three pilot runs and the interviews with the participants do indicate a reasonable validity. It is important to emphasise that the purpose of the questionnaire is not intended to label teachers but to determine the general view of science teachers on indigenous knowledge, identify misconceptions and to identify specific topics to be addressed during training. The questionnaire referred to South African examples of indigenous knowledge in certain of the questions, but the examples can be replaced by the examples applicable to the country or region in which the questionnaire will be used. The indigenous knowledge framework with tenets however applies to any country. We believe the framework generated in table 1 on the nature of indigenous knowledge addresses the gap identified by Barnhard and Kawagly (2005), Botha (2011) and other authors to devise a strategy that respects the epistemology and pedagogy of both indigenous and western knowledge. The framework in table 1 can also be used to equip teachers with the foundations and values of both knowledge systems in order to teach both systems simultaneously as argued by Dekkers and Mnisi (2003). The questionnaire developed as well as the outlines for an intervention fills an important gap that exists in decolonising science education curricula and providing instruments that developers of professional development programmes can use to facilitate the practice of science teachers struggling to incorporate both knowledge systems in the science classroom.

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THE USE OF MULTIPLE CHOICE QUESTIONS BY STUDENTS IN A FIRST YEAR UNIVERSITY SCIENCE EDUCATION COURSE

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Abstract–Electronic learning incorporating Multiple Choice Questions (MCQ) is essential in a modern scientific environment. The research dealt with the use of MCQ for testing and learning in a University science course. The research is done on a conventional written test and MCQ on the same course contents for 156 extended first year students in Physics. The statistical dependent sample t-test is used to decide if the MCQ can be used to test the same knowledge than a conventional written test. Results suggest that carefully constructed MCQ have the potential to enable valid and reliable assessment of depth of understanding whilst also assisting lecturers or assessors supporting through automated marking. Scores for these tests are immediately available assisting both students and lecturers in feedback. According to research, students who make informed guesses will not necessarily perform the same if they did the exact same test again. That is the concern and stimulated the interest for doing more research.

Keywords: Multiple Choice Questions**,** Learning**,** Science**,** Calculations

1. INTRODUCTION/ BACKGROUND

Electronic learning is essential in a modern academic environment.

Science education lecturers at South African Universities may use online Multiple Choice Questions (MCQ) through a Blackboard System.[6] It is used to test the knowledge of the students. Students complain about MCQ that requires calculations. In MCQ no marks are rewarded for steps followed in a calculation as is given in a traditional test. Students who make informed guesses will not necessarily perform the same in a MCQ test if they did the exact same assessment again. This raises concern and stimulates the interest for more research on this topic.

The following from an article; posted by Alejandro (The Knewton Tech Blog, 2012) summarises the interest:

A math test with 10 questions were set up, two questions are trivial, two are incredibly hard, and the rest are equally difficult. Both students achieve 90% although the first student answered an easy question incorrect and the other student answered a difficult question incorrect.

This approach illustrates a key problem with measuring student ability via testing instruments namely test questions do not have uniform characteristics.

Reflecting on this topic it occurs that by using MCQ, students can achieve personalised learning and students can be assisted to learn more effectively and efficiently. These observations are the driving force of this research.

According to Worthen (1993), MCQ can be used to assess a broad range of content in a brief period. Skilfully written items can measure higher order cognitive skills. Although it is easy to assess, MCQ, are more difficult to set up. However MCQ are mainly used to assess only knowledge in which case the correct answers can be easy to guess.

[6] Blackboard system is a virtual communication forum between lecturers and students through announcements used by Universities. It is also used to manage the course for students to access.

2. THEORETICAL FRAMEWORKS

Guessing Factor of MCQ

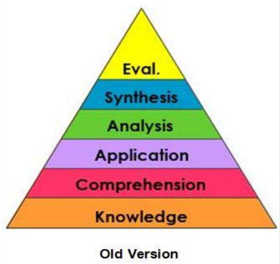
An article entitled ‘Scoring multiple choice questions’, (Christansen, 2013) indicates how different measurement theories can be used to score responses. The issue of guessing a correct answer has been an interesting topic for many years. The study shows that students rather try to make educated guesses rather than random guesses. Problems related to the classical correction for guessing are highlighted. The three-parameter ‘logistic’ item response theory (IRT) model includes a ‘guessing item parameter’ that indicates the chances that a test taker guesses the correct answer to an MCQ (Barnard, 2013).

In Christansen’s study (2013), the same MCQ were given twice to students. The study found that a large number of learners changed their answers because they were guessing. However their analysis of learner responses challenged the hypothesis substantially that learners were choosing answers at random.

Benvenuti & Cohen (2008) found that the majority of MCQ papers test only factual knowledge, with only a few questions going to the deeper level of conceptual understanding or application. This paper further reports on work done towards developing MCQ that allows both the development and assessment of deeper levels of cognitive ability (as defined in Bloom’s revised Taxonomy).

In 1956, Benjamin Bloom headed a group of educational psychologists who developed a classification of levels of intellectual behavior important in learning. During the 1990's a new group of cognitive psychologists, led by Lorin Anderson (a former student of Bloom), updated the taxonomy to reflect relevance to 21st century work. The two graphics show the revised and original Taxonomy. Note the change from nouns to verbs associated with each level.

Note that the top two levels are essentially exchanged from the traditional to the new version.



Remembering: can the student recall or remember the information?	define, duplicate, list, memorize, recall, repeat, reproduce state
Understanding: can the student explain ideas or concepts?	classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase
Applying: can the student use the information in a new way?	choose, demonstrate, dramatize, employ, illustrate, interpret, operate, schedule, sketch, solve, use, write.
Analyzing: can the student distinguish between the different parts?	appraise, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test.
Evaluating: can the student justify a stand or decision?	appraise, argue, defend, judge, select, support, value, evaluate
Creating: can the student create new product or point of view?	assemble, construct, create, design, develop, formulate, write.

Figure 1

Blooms Revised Taxonomy

Blooms Taxonomy was created in 1956 under the leadership of educational psychologist, Dr Benjamin Bloom, in order to promote higher forms of thinking in education, such as analysing and evaluating, rather than just remembering facts. The committee identified three domains of educational activities or learning

Cognitive: mental skills (*Knowledge*)

Affective: growth in feelings or emotional areas (*Attitude or self*)

Psychomotor: manual or physical skills (*Skills*)

Results from Alford and Frangenheim (2006) suggest that carefully constructed MCQ have the potential to enable valid and reliable assessment of depth of understanding and also assist lecturers or assessors through automated marking. Scores for these tests are immediately available assisting both students and lecturers in feedback.

This study found that MCQ are generally being used to assess lower level cognitive ability and are not being considered for their potential to assess higher level cognitive skills (Bloom’s taxonomy).

The second phase of the study indicates that with careful attention to question design, MCQ can be used to eliminate common misconceptions, assess higher levels of cognitive skills, and discriminate between top and bottom students. In addition, the use of MCQ allow automated testing and immediate feedback to students on their performance. Mark weighting of questions also need to be considered to ensure that students are given enough time for questions that challenge them at higher cognitive levels (Benvenuti & Cohen, 2008, p. 21).

Guidelines For Developing MCQ (McMillan J. , 2001)

The first four guidelines are to set up questions:

1. Set up the question as clearly as possible.
2. Provide the information and keep the distractors as short as possible.
3. Do not give unnecessary information.
4. Avoid negative statements.

The last five guidelines are to choose the distractors:

1. There must be only one correct option and at least two other distractors.
2. Be careful not to give more detail for the correct option.
3. Choose and test the other distractors thoroughly.
4. Avoid using none or all of above.
5. Be careful that the numbers of the correct answers don't follow a specific pattern.

Brady (2005) found in an article that the correct answer (key) of MCQ in general, is fairly distributed among the four options. The implication is that test banks need to be evaluated and used only to generate ideas. Questions in test banks may not be assessed for reliability and validity as it would be in an examination.

Good MCQ should be short, understandable and discriminating. MCQ can fulfil the criteria for effective assessment as suggested by Quinn (2000) as they can be an integral component of the teaching and learning process and can assess performance in relation to the aims of the curriculum. MCQ are efficient, objective, easy to grade and can be used to test a broad sampling of the curriculum and facilitate timely feedback and self-assessment. However, significant commitment is required in preparation to produce reliable and valid examination tools. MCQ can be combined with other assessment methods to provide an educational strategy to enhance the learning process and provide an accurate and comprehensive evaluation of student performance

Comparison Between Mcq And Essay Questions

Essays are undoubtedly easier and less time consuming to construct and can test higher order learning. Farley (1989) estimates that it requires one hour to write a good MCQ. Considerable time need to divert to the pre assessment phase of design and construction.

In an article 'Improving Multiple Choice Questions', Anon (1990) states that although many teachers believe that MCQ are only suitable for testing factual knowledge and essay type exams test higher-order cognitive skills. MCQ can test many of the same cognitive skills than essay tests if the lecturer is willing to set it up in the correct way.

Essay questions are relatively easy to write. Students cannot guess an answer. It can be used to test higher cognitive skills. Unfortunately only a limited range of content can be tested in one period (Worthen, 1993).

Comparison Between Mcq And Construct Response (Cr) Questions

According to findings done by Margit Kastner and Barbara Stangl (2011) results indicate that CR tests are equal to MCQ tests with multiple responses[7] should Number Correct scoring[8] be issued.

[7] With multiple responses more than one distractor can be correct.

[8] For Number Correct scoring only correct responses are counted i.e. no negative marking

Lukhele, Thissen, and Wainer (1994) reported on seven different advanced placement exams. It is found that the reliability of MCQ portion exceeded that of the CR section on every test.

By using CR questions many questions can be asked in a brief period of time. It is relatively easy to mark and easy to write, but limited questions can be asked to be completed in very few words.

Questions posed in terms of matching correct answers, can be written quickly and scoring can be done efficiently although higher order cognitive skills are difficult to access. True and false questions are easy to write and score but also easy to guess (Worthen, 1993).

Comparison Between Negative Marking Of Mcq And Mcq Using Hints

Negative marking and hints will decrease the temptation to guess.

If MCQ is marked negative, a student will try once. If they couldn't get the correct answer, they will rather leave the question than to loose marks.

If hints are given, the students will learn from their mistakes and redo the question until they get the correct answer even if it took a while. Therefore they can still earn some marks.

3. THE PROBLEM STATEMENT

E-learning is currently a very popular direction for teaching and learning. MCQ is a way to use E-learning.

Knowledge in Science can be tested by using MCQ as supplement for the testing of knowledge with calculations in traditional tests in Science.

4. THE RESEARCH QUESTIONS

1. What is important when setting up MCQ?
2. Can standard MCQ be used to test knowledge with calculations in Science?
3. Can lecturers use MCQ to help them with mass of marking?

5 THE AIMS AND OBJECTIVES OF THE STUDY

Aims

The aim of this study is to provide evidence that MCQ used to test the knowledge of students may be as effective as doing calculations in writing.

Specific Objectives

1. Demonstrate that testing knowledge by using MCQ can be used supplementary to testing knowledge with calculations.
2. Provide evidence that MCQ can be used by students to test calculations.
3. Indicate that MCQ testing calculations can help lecturers with mass of marking.

6. RESEARCH DESIGN AND METHODOLOGY

The quantitative, hypothesis research design is used.

Data Collection Instrument

A sample of 156 Engineering Science extended first year students were used. Five questions on heat were given to them to do in a 90 minutes period.

Research Design

The students answered the questions in writing and it were marked. The same question paper was then remarked but marks were now only allocated for correct answers. This eliminates the guessing factor.

The two averages were compared for each student. The first was the average for the written paper. The second average was calculated be awarding five marks for a correct answer and zero for an incorrect answer.

It is important in this stage to remember that the method used for calculations in writing will be marked irrespective of incorrect values used.

Research Methodology

The dependent sample t-test is used to decide if the null hypothesis (H_0) should be rejected or not. The dependent sample t-test should be used because the average scores obtained by the sample group in the same test in two different ways of assessing are compared.

Comparing averages:

H_0: There is no significant difference between the average mark for MCQ without distractors and a written test (WT).

Calculate the test statistic value:

$$T = \frac{(\bar{Y}_1 - \bar{Y}_2) - (\mu_1 - \mu_2)}{S_p\sqrt{2/n}}$$

$$S_p^2 = \frac{(n-1)(S_1^2 + S_2^2)}{2n-2}$$

Where:

$Y_{1:}$ sample mean of MCQ

Y_2: sample mean of WT

$\mu_{1:}$ population mean of MCQ

μ_2: population mean of WT

S_1: standard deviation for MCQ (calculated in Excel by STDDEVA() formula)

S_2: standard deviation for WT (calculated in Excel by STDDEVA() formula)

σ: standard deviation of the population

S_p: posted estimator

n: number of students in the survey

df = (n-1) for the group of students involved

Reject 1% if $|t| > t_{0.005} = 2.576$ (according to the table of Percentage points of the t distribution).

In a sample the average value for the written test was 63% and the average for the MCQ without distractors was 44%.

Using the t-test the following calculation is done:

$$T = \frac{(63-44)-0}{588.1596\sqrt{2/156}}$$

= 6.685719

where,

$$S_p^2 = \frac{(156-1)(457.378 + 718.9413)}{2(156)-2}$$

= 588.1596

Comparing averages with provision for guessing:

H_0: There is no significant difference between the average mark for MCQ without distractors, with provision for guessing, and a written test.

In the sample the average value for the written test is still 63% and the average for the MCQ test with provision for guessing is now 46%.

Using the t-test the following calculation for H_0 is done:

$$T = \frac{(63 - 46) - 0}{625.3769\sqrt{2/_{156}}}$$

= 5.920971

where,

$$S_p^2 = \frac{(156 - 1)(457.378 + 793.3757)}{2(156) - 2}$$

= 625.3769

Reliability

Test reliability depends upon the grading consistency and discrimination between students of differing performance levels. Well-designed MCQ are generally more valid and reliable than essay tests because (Anon. 1990):

1. they sample material more broadly,
2. discrimination between performance levels is easier to determine and
3. scoring consistency is virtually guaranteed.

MCQ should be very reliable because of the objective scoring process.

It is much more reliable to mark MCQ because the answer can't be influenced by subjectivity. This implicates more stability.

The results will increase in reliability with more questions asked in the paper. The study will also be more accurate if more questions with different difficulty can be used.

Validity

The key check determines if the answer is tested by a number of experts to be correct. A good distractor is one that is selected by those who perform poorly and ignored by those who perform well (Haladyna 1999).

A test's validity is determined by how well it samples the range of knowledge, skills and abilities that students are supposed to acquire.

The validity of MCQ depends on systematic selection of items with regard to content and level of learning. Do not develop items that require purely recognition or recall (Anon, 1990).

Limitations

To mark assessments of large groups of students can be very timeous. MCQ with hints can definitely solve this time factor. The limitation of this study is that it is very difficult to set up the online assessment. The distractors must be chosen and tested thoroughly.The standard of the chosen questions must be high to define the purpose.

Only five questions are used to ensure that the assessment can be done in one period.

Although it will be more accurate to do the study with more students, it is preferred to do this study with an existing first year extended Engineering Science class within exactly the same environment that will ensure equivalence.

7. DATA ANALYSIS AND DISCUSSION

The findings for the comparing averages test:

1. Since the calculated test statistic value of 6.685719 is greater than the critical value of 2.576 at the 1% level, the null hypothesis will be rejected at the 1% level. This means that there is a significant difference between the average mark for MCQ (when only the correct answer was marked) and the average mark for the written test with 99% confidence.
2. The group performed significantly better in the written test (average of 63%) than in the test where only the correct answer were marked (average of 44%) which is similar to a MCQ paper.

Findings up to now show that the guessing factor was eliminated. It is reality to make provision for guessing. If the answer of the written test was incorrect, there is a one out of three chance to guess the correct distractor.

The findings for the comparing averages with provision for guessing test:

These results are as follows:

1. The average for the 156 students for the written test is still 63%.
2. The average for the 156 students after making provision for guessing is now 46%.
3. Since the calculated test statistic value of 5.920971 is still greater than the critical value of 2.576 at the 1% level, the null hypothesis will still be rejected at the 1% level. This means that there is a significant difference between the average mark for MCQ (after provision for guessing) and the average mark for the written test with 99% confidence.
4. The group still performed significantly better in the written test (average of 63%) than in the MCQ test where provision for guessing is made (average of 46%).

8. CONCLUSION

E-learning and assessment by using the computer, are taking the lead in education.

To test if the students really understand the reasoning to do the work in Science, by using online assessment, is not easy. From this research, it is clear that normal calculations cannot be assessed properly online. When a written test is assessed, students get marks for reasoning which means that marks will still be allocated even if there were calculation errors.

This research was initially done without giving distractors by purpose to see the difference in the averages. Even after provision for guessing, the difference is still big.

For further research a study can be done by using hints and proper chosen distractors in MCQ. This will give the students the opportunity not to get zero if they have made some calculation errors although their reasoning were correct.

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GLOSSARY

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