Integrated STEM Education: The Nexus for Sustainable Development

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Abstract
Many initiatives have indicated the critical role of Science Technology Engineering and Mathematics (STEM) in the process of reaching a sustainable future. In an effort to make STEM education an active contributing factor in achieving sustainable development, this study is focused on the integration of stem education as a focal point for sustainable development, this paper recognizes the fact that Science, Technology, Engineering and Mathematics (STEM) Education is an enabler of national development. It examines the role of STEM Education as a tool in national development. As quality Science, Technology, Engineering, and Mathematics (STEM) education is vital for the future achievement of students. Integrated STEM education is one way to make learning more connected and relevant for students. This paper discusses STEM education, integrated STEM education and role of STEM education in sustainable development. It was concluded that the more individuals having STEM education, the more the level development of the society it then recommended that there is need for government to improve the quality of stem teaching in schools.

Keywords: STEM, STEM integration education, sustainable development

Introduction

The 21st century is characterized by advancement in science and technology. For Nigeria to realize accelerated development in the 21st century, it needs qualitative science education in schools especially in senior secondary schools. Over the last two decades, there have been repeated calls for reforms and innovations aimed at improving Science Education in Nigeria. This suggests that there are issues in science Education in Nigeria that needs to be improved upon (Ewansiha&Omorogbe, 2013). 21st century system of education is very challenging since teachers are required to teach the students to solve STEM problems in various fields of Science, Technology, Engineering and Mathematics (STEM). The problem education is facing is mainly one of productivity and efficiency. Here, efficiency means the balance between resources invested and the outcomes in terms of students' performance and equity.

In considering the requirements for twenty-first century learning, (claxton, 2007) identifies the need for a greater and different student learning capacity. He calls for an 'epistemic culture change' in schools to replace stand-alone courses in thinking skills or 'tricks of the trade' type learning. According to him, "these approaches are exploring ways in which schools as a whole, and its classrooms in particular, can become settings in which the various constitute elements of learning capacity are acknowledged, discussed, understood and systematically strengthened" Aspects of this epistemic culture will include the ways teachers and learners work together, the range of activities and methods they will engage in, the ways students can transfer thinking and how teachers can role model the attributes, dispositions, and demeanours appropriate for successful participation in future milieux.

The aims of education in secondary school should ensure that students should have knowledge and skills to be successful in college and in the workplace (O'Sullivan & Dallas, 2010). Rich (2010) explained that 21st-century learning means that students master content while producing, synthesizing, and evaluating information from a wide variety of subjects and sources with an understanding of and respect for diverse cultures. Students should not only demonstrate the three Rs, but also demonstrate the three Cs: creativity, communication, and collaboration. They should demonstrate digital literacy as well as civic responsibility. Virtual tools and open-source software create borderless learning territories for students of all ages, anytime and anywhere. Classroom learning experiences therefore need to be designed to develop students' competencies in term of collaborative, problem solving, self-control, critical thinking, and ICT skills. These learning experiences should empower students as individual and citizens as an agent of change who are responsible and creative.

Nations invest in innovation to promote sustainable economic growth. While many countries are suffering from the effects of global economic difficulties, such as rising unemployment and soaring public debt, the role of labor input is decreasing in the 21st century economy. Only innovation-driven growth has the potential to create value-added jobs and industries (Organisation for Economic Co- operation and Development [OECD], 2010a). Because it is largely derived from advances in the science, technology, engineering, and mathematics (STEM) disciplines (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2011), therefore an increasing number of jobs at all levels require STEM knowledge (Lacey & wright, 2009). As a result, nations need an innovative STEM workforce to be competitive in the 21st century.

The important contribution of STEM as an enabler for sustainable national economic growth was affirmed at the World Summit on Sustainable Development (WSSD) in 2002. According to David, Dallatu& Yusuf (2018), it is in this regard that in the framework of the New Partnership for Africa's Development (NEPAD), recognized that Science and Technology will play a major role in the economic transformation and sustainable development of any nation.

STEM education is used in research, policy issues, teaching for innovation, problem-solving and prospects. STEM is needed towards globalization demands. The complexity of today's world requires all people to be engaged with new set of core knowledge and skills, to solve difficult problems like novel the Coronavirus pandemic, gather and evaluate evidence and make sense of information they receive from varied print and digital media. It is therefore clear that the learning and doing of STEM help to develop skills and prepare students as potential and workforce where success results not just from what one knows but what one is able to do with the knowledge. STEM had been the critical instruments used to uplift not only standard of living but the economy of any nation (Wasagu, 2019).

African countries with STEM knowledge could rise above over-dependence on developed countries technological prowess. Presently, countries in the world are classified as; developed, developing and less / under developed. The difference between the developed, developing and under-developed countries however rests on the ability of the developed countries to convert scientific ideas to usable technology while the developing and under-developed countries are yet to do so effectively (Sambo, Udofiak, & Okoko, 2018).

Many educational research studies have indicated that students' interest and motivation toward Science, Technology, Engineering and Mathematics (STEM) learning has declined especially in Western countries. Concern for improving STEM education in many countries continues to grow as demand for STEM skills to meet economic challenges increasingly becomes acute (English 2016; Marginson et al. 2013; NAE and NRC 2014). Many education systems and policy makers around the globe are preoccupied with advancing competencies in STEM domains and and as a result, engaged in some education reforms. However, the views on the nature and development of proficiencies in STEM education are diverse and increased focus on integration raises new concerns and needs for further research. Recent reforms in USA (such as Next Generation Science Standards1) advocate for purposefully integrating STEM by providing deeper connections among the STEM domains. Such an approach raises issues such as competing agendas between disciplines, lack of coherent effort, locating and teaching intersections for STEM integration mainly because STEM subjects often are taught disconnected from the arts, creativity, and design (Hoachlander and Yanofsky 2011).

STEM Education

STEM education includes the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area. It is described as a STEM related individual subject, a learning package offering learning pathway for STEM elective subjects and as an integrated STEM approach (Ministry of Education, 2016). The description of STEM education as discrete STEM subjects and learning package have a long standing in the previous and current curriculums. The definition of STEM education as an integrated approach that blends the STEM content, skills and values in solving contextual problem seems to agree with that in many of the literature (eg. Jolly, 2017; Kelley & Knowles, 2016; Kennedy & Odell, 2014; Kim, Chu, & Lim, 2015; Truesdell, 2014; Vasquez, 2014; Xie, Fang, &Shauman, 2015).

This STEM perspective integrates the disciplines of Science, Technology, Engineering and Mathematics for the purpose of solving everyday science-related problems. Roehrig, Moore, Wang and Park (2012) proposed integrating the four disciplines to gain a deeper understanding of science, broaden understanding of science by relating it to technology and engineering, and develop students' interest in STEM-related professions. Teaching using a STEM perspective is a strategy aimed at improving the academic achievement of learners, as well as introducing them to skills that are important for future jobs.

For example learning in any STEM subject area, particularly Chemistry, is a cumulative process. Students' pre- existing beliefs influence how they learn new scientific knowledge and how it plays an essential role in scientific learning (Takbir, 2012). According to (Nweze, (2015), a country cannot have a strong scientific and technological enterprise without a strong foundation in chemical education.

STEM Integration

Stem integration involves the introduction of stem related activities into the school curriculum. Moore et al. (2014) defined integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real- world problems". Integrated STEM curriculum models can contain STEM content learning objectives primarily focused on one

subject, but contexts can come from other STEM subjects. Integrated STEM education could be defined as the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning.

Quality Science, Technology, Engineering, and Mathematics (STEM) education is vital for the future success of students. Integrated STEM education is one way to make learning more connected and relevant for students. The STEM model is a good starting point for teachers as they implement and improve integrated STEM education.

The research on teaching integrated mathematics and science provides a good basis for teaching integrated STEM education. Successful integration of science and mathematics depends largely on teachers' understanding of the subject matter (Pang & Good, 2000). Many teachers have shortcomings in their own subject content knowledge (Stinson et al., 2009) and asking math and science teachers to teach another subject may create new knowledge gaps and challenges (Stinson et al., 2009). What is known from research on effective practices in science and mathematics education provides insight into effective practices in STEM integration.

Zemelman, Daniels & Hyde (2005) list ten best practices for teaching math and science:
(1) Use manipulatives and hands-on learning; (2) Cooperative learning; (3) Discussion and inquiry; (4) Questioning and conjectures; (5) Use justification of thinking; (6) Writing for reflection and problem solving; (7) Use a problem solving approach; (8) Integrate technology; (9) Teacher as a facilitator; (10) Use assessment as a part of instruction.

Two important features in Science Technology Engineering Mathematics (STEM) education are integration and solving real world problems. Despite the efforts to promote STEM education awareness and interest among students and teachers, documented studies on how to explicitly integrate the existing STEM subjects' curriculum standards in solving real world problems are limited.

Therefore, educators here may subscribe to one of the given descriptions in implementing STEM education. Nevertheless, many teachers may not be familiar with integrated STEM as an approach in teaching and learning. So, guidelines and some resources are provided in order to assist educators to implement integrated STEM as an approach in classroom teaching and learning. In the Implementation Guidelines for STEM Education in Teaching and Learning by the Ministry of Education (Ministry of Education, 2016), there are general guidelines and a few teaching plan examples to assist teachers to carry out integrated STEM education during class or co-curricular activities. Further description and application of STEM education as an approach is found in the recent STEM resource modules for Physics, Chemistry, Biology, Additional Mathematics, Computer Science and Design and Invention (Rekacipta) respectively (Curriculum Development Division, 2017e, 2017d, 2017f, 2017b, 2017a, 2017c). The degree of STEM content and skills integration in each subject varies depending on the issues or problems posed for each topic. These resource modules are among some of the initial resources available for the teachers at the time of writing. They are targeted for the upper secondary school students who are in the pure science and technical classes which may not meet the needs of other students especially those in the lower secondary level. More teaching and learning materials on integrated STEM education have to be

developed for all levels of students. The design of the series also aimed to serve as a model for teachers to develop their own STEM education material for other topics in the future. Hence, teachers can plan, develop and implement their own integrated STEM lessons or programs that suit the context of their own students.

Sanders (2009) described integrated STEM education as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). Sanders suggests that outcomes for learning at least one of the other STEM subjects should be purposely designed in a course—such as a math or science learning outcome in a technology or engineering class (Sanders 2009). Moore et al. (2014) defined integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38).

One of the biggest educational challenges for secondary school education is that few general guidelines or models exist for teachers to follow regarding how to teach using or applying STEM integration approaches in their classroom. Furthermore, research into teachers' current integrated STEM teaching practices can inform STEM education stakeholders and assist in identifying barriers as well as determining best practices.

Need for integrated STEM

In recent years, the importance of providing students with a strong education in Science, Technology, Engineering and Mathematics (STEM) has been stressed. Qualified STEM professionals are needed to remain economically competitive in the global market and to fill contemporary demands such as ensuring sufficient and sustainable energy, efficient healthcare and well-considered technology development (Bøe et al., 2011). Moreover, all citizens, even non-STEM professionals, should have the skills and competences necessary to deal with the challenges of our information-based and highly technological society (National Society of Professional Engineers, 2013). STEM-literacy, that is, the awareness of the nature of science, technology, engineering, and mathematics and the familiarity with some of the fundamental concepts from each discipline, should be an educational priority for all students (Bybee, 2010; National Academy of Engineering and National Research Council, 2014). A promising approach in this regard, is the use of an integrated STEM curriculum, which provides opportunities for 'more relevant, less fragmented, and more stimulating experiences for learners' (Furner and Kumar, 2007, p.186). Real-world problems are not fragmented in isolated disciplines as they are taught in schools and to solve these problems people need skills that cut across the disciplines (Beane, 1995; Czerniak et al., 1999). Studies in a broad range of disciplines have shown that students involved in an integrated curriculum perform as well or even better than their peers in traditional instruction with separate disciplines (Czerniak et al., 1999; Hinde, 2005). Moreover, the use of an integrated curriculum has been found to improve students' non-cognitive learning outcomes, such as interest in STEM (Mustafa et al., 2016; Riskowski et al., 2009) and motivation towards STEM learning (Wang et al., 2011), which in turn could lead to increasing numbers of STEM graduates (National Academy of Engineering and National Research Council, 2014).

Engaging students in active educational programs focused on fostering STEM competencies is vital for students' future employment prospects (Bunshaft et al., 2015; Crawley, Malmqvist,

Östlund, & Brodeur, 2007; Jang, 2016). Ferrini-Mundy (2013) was more specific and noted, more hands-on, authentic STEM activities should be provided at the secondary level.

How STEM can be implemented in the classroom

Instruction is the direction of the process in teaching and learning. Among the success factors in education innovation are teachers. Previous empirical studies showed that teacher's STEM instruction have impacted on student identity development (Slavit, Nelson, &Lesseig, 2016), achievement (Henry et al., 2014) and interest (Price, 2010).

Hence, in STEM instruction, teachers need to able to break the boundaries of Science, Technology, Engineering and Mathematics and incorporate it into the lesson. There are many approach in implement STEM in teaching and learning session. In Malaysia Secondary School Standard Curriculum, there are three approach that have been emphasized in implementing STEM, i.e.: inquiry learning, problem based learning and project based learning (Curriculum Development Division, 2016b).

According to (buturlina, 2021) the main stages for implementing stem education are:
Primary Education which is carried out in preschool education institutions, primary schools, where students are engaged in primary scientific and technical creativity. The main task is to stimulate curiosity and support interest in learning, knowledge, motivation for independent research, creating simple devices, structures;

basic education which is carried out in the general secondary and out-of-school education in order to form steady interest to natural and mathematical subjects, involve in research, invention, project activity, promote such professions as an engineer, a scientist, a researcher;

Field-Specific Education is carried out on the basis of field-specific senior school of comprehensive secondary and out-of-school education institutions. The main task is to promote the conscious choice of further education of the STEM specialization, in-depth mastering of the system of knowledge and skills in STEM subjects, mastering of research methods;

Professional / Higher Education ensures forming STEM specialists; it is carried out on the basis of vocational / higher education institutions and through improving teachers' professional skills to implement new learning technologies, including STEM courses; implementation and realization of STEM projects.

STEM Education and Sustainable Development

Sustainable development is a continuous search for improving our daily life as well as a country, so that we benefit both today and, in the future, while minimizing the negative effects exerted by humans on the environment. This requires active and creative citizens who can successfully prevent problems and cooperation issues and who are ready to combine theoretical knowledge with innovations and practical ideas. The approach on teaching and learning should focus on students, encouraging them to form and develop their own ideas and values hence this approach is supported through STEM education which emphasizes on the application of knowledge to real-world problems that tends to underpin on critical thinking, problem-solving, and creativity, which is important for any national development. STEM education integrated into the school curriculum

where teachers consider students' as being an important and active factor in the learning and acquiring knowledge process.

Badejo (2005) noted that sustainable development can only be meaningful when most of the inhabitants of a country have rudimentary knowledge of Science, Technology, Engineering and Mathematics (STEM).

The importance of Science, Technology, Engineering and Mathematics (STEM) education for the attainment of sustainable development in Africa cannot be over emphasized. STEM education is fundamental to the strengthening of higher levels of education, capacity building and self-reliant development. The strategic and inimitable role of STEM education towards the development of the world is beyond doubt (Okoro, 2013). STEM education contributes to general educational development and practice. It has become a stimulating elixir, the necessary catalyst, which has engendered the spirit of sustainable development worldwide. However, the role of STEM education for achieving sustainable development for Africa is so self-evident that any country that fails to pay due credence to the development of a veritable STEM-based education at the grass root can only do so to her peril. Fafunwa (1972) observed that, "we are living in a world where science and technology have become an integral part of the world's culture and any country that overlooks this significant truism does so at its own peril". therefore, science education is a worthy platform to prepare African youths for the challenges ahead, in a highly technological world. To Akpan (2008), "the international competitiveness today is increasingly being defined in terms of ability to access, learn, adapt, utilize and innovate from available technology". This means that nations that fail to innovate lose their competitive position. Explicitly, a sound and veritable STEM based oriented education at the grass root holds the key to the answer.

Role of sustainable development can be summarized as follows

Chapter 36 of Agenda 21, adopted at the 1992 Earth Summit in Rio, identifies four major thrust of Education for Sustainable Development (Ilechukwu et al, 2014). They include:

- Promoting and improvement of basic education
- Reorienting existing education at all levels to address sustainable development.
- Develop public understanding and Awareness of sustainability
- Training

Therefore, the role of education in sustainable development can be summarized as follows:

1. Education is here regarded as an instrument of social change which could transform the society in significant ways. Education is paramount when trying to enable a change in values and attitudes towards sustainability. The report of UN's World Commission on Environment and Development (WCED) (1987) recognized that "sustainable development requires changes in values and attitudes towards environment and development" and that education plays a central role in achieving those changes in values and attitudes (Sims & Falkenberg, 2013). Education for Sustainable Development (ESD) is one of the most important tools for raising awareness about the environmental issues within a sustainable development context.

2. Education for sustainable development involves learning how to make decisions that considers the long term future of the economy, ecology and equity of all communities. UNESCO argues that education has a special responsibility to generate the knowledge needed as well as communicate

this knowledge to decision makers and the public at large. (UNESCO, 2001, 2003). As a result, the body calls on all relevant stakeholders to review the programmes and curricula of schools and universities, in order to better address the challenges and opportunities of sustainable development. Therefore, contemporary sustainable development education is expected to orient on future development, ensuring proper quality of present and future life.

3. A strong STEM education system provides the essential underpinning of an innovative and scientifically literate culture which develops the capabilities for individuals to function effectively within a science and technology based society.

4. STEM Education helps students' solve the global challenges of our generation. Engagement with science, technology, engineering, mathematics, and computer science in addition to languages, the arts or social-emotional learning should be an integral part of future-oriented education to which every child and every young person has a right.

5. It supports independent thinking and responsible action, as well as the reflective engagement with technological and societal changes for the benefit of sustainable development3

Conclusion

This paper examined the role of Science, Technology, Engineering and Mathematics education as a tool in national development. From the discourse, it can be seen that:

(i) The application of mathematical concepts has helped in advancing science, technology and engineering, thus sustaining the development of our nation;

(ii) The more the number of individuals having STEM education, the more the worth of the individuals and the level of development of the society and the result is overall national development. It is therefore concluded that with sound STEM education, national development can be achieved. For education to achieve all ends, it has to be carefully planned, the plan must take into consideration the needs of the society, the political, socio- cultural, economic, military, scientific and technological realities of the environment are very important to its development.

Recommendations

1. There is need to improve on the quality of Science, technology, engineering and mathematics teaching in schools so that learners can gain knowledge, skills and competencies needed for the gradual but lasting national development.
2. The Government should avail the general populace with sound STEM education, for in that; national development can be achieved.
4. Following the encouraging efforts made so far by curriculum development experts, governments are called upon to increase the present level of funding of these agents so that more innovations in STEM education may be enhanced.

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