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Efficacy of Graphic Organizer in Enhancing Critical Thinking Skills of Senior Secondary School Chemistry Students in Niger State, Nigeria

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Abstract

The study adopted quasi-experimental of pretest posttest non-equivalent control group design. The population of the study comprised all Chemistry students in all (40) secondary school in Niger State, Nigeria. The target population for this study consisted of all senior secondary school two (SSII) Chemistry students in forty (40) school with a total number of two thousand three hundred (2300) Chemistry students, comprising 1300 males and 1000 females. Simple random sampling technique was use to select two schools from the population. The two schools were selected using balloting. One hundred (101) senior secondary school two (SSII) Chemistry students were sampled comprising forty eight (49) males and fifty two (52) females and took part in the study. A fifty (50) items ***Chemistry Critical Thinking Skills Test (CCTST)*** *was used for data collection in this study.* ***CCCTST*** *was* ***validated by two senior lecturers.*** *The reliability of the* ***Chemistry Critical Thinking Skills Test (CCTST)*** *was established using split-half reliability method and the coefficient was calculated using Spearman Brown's Formula and it was found to be 0.781. Mean and standard deviation were used to answer the research question while the hypotheses were tested at 0.05 significance level using z-test for independent sample. The findings from the study indicated that there was significant difference in the mean critical thinking skills between students taught Chemistry using graphic organizer and those taught using Lecture method in favor of experimental group.* ***It was concludes that*** *Students taught chemistry using graphic organizer possess higher critical thinking skills than their counterpart students taught using lecture method. As such graphic organizer increases the level of students' critical thinking skills.* ***On the basis of this findings, it was recommended among others*** *that secondary school Chemistry teachers in Niger State, Nigeria should employ the use of graphic organizer as a teaching strategy to enhance critical thinking skills of students.*

Keywords: Graphic Organizer, Critical Thinking Skills, Chemistry Students

Introduction

Many nations are confronted with global challenge and the need for mankind to solve problems. On the other hand, industries and employees are urged to provide innovative solutions to emerging problems by public. Critical thinking skill is considered one of the important skills that could solve those problems. The role of these critical thinking skills in economic development is seen as an important issue in assisting nations to reach higher economic empowerment and self-reliance (Yaki, 2022). There seems to be a mismatch between the skills students acquire in the classroom situation and the skills needed in the labour market. Amaal (2017) reported that critical thinking is the process of applying reasoned and disciplined thinking to a subject. Students are faced with decisions that require reasoning, understanding, interpreting and evaluation of information before them and this process involves critical thinking.

The 21st Century learning skills are a broad set of knowledge, skills, work habits, and characters require for success in today's world of information and technology (Gordon, 2021). One of these 21stcentury skills needed for 21st-century learning and work force is critical thinking skill. Critical thinking skill is the ability to examine information rationally and make reasoned decisions based on personal analyses. Martins (2021) believe that the critical thinking skills can improve data-driven, decision-making abilities and provide methodology for dealing with complex problems in science education. Research findings have shown that students' critical thinking skills requires attention like Oktariani *et al.,* (2020) who maintain that the ability of chemistry education students is still inadequate, particularly on indicators of providing explanations or making assumptions, building conclusions, and developing strategies or solutions and Suryani et al.'s (2020) who suggested that students' critical thinking skills are still at a low level. However, among the many studies that examine students' critical thinking skills, none examined students' critical thinking skills in solving problems involving the concept of moles and reaction stoichiometry.

In the process of teaching and learning, developing students' critical thinking may require engaging students meaningfully in activities that develop their creativity, independency, inference and self-evaluation. This cannot be achieved with conventional instructional strategy where classroom interaction is dominated by the teacher and knowledge acquisition during instruction is focused

on lower thinking skills that is characterized by memorization and recall. This calls for a paradigm shift from classroom instructions that are conventionally used to a new method that will enhance critical thinking skills. The new instructional strategy should emphasize active participation of students where the teacher will serve as a facilitator and guide students to learn at their own zone of proximal development **(Guo et al., 2023)**.

Graphic Organizers are visual displays that can organize ideas and conceptions to illustrate relationships among information **(Marita et al.,** 2020). They are helpful tools for learners to locate useful facts, arrange different information, explore inner relations among parts, and express their opinions and thoughts. There are many type of graphic organizer which includes **characteristics map and big question map.** Many students do not have the skills necessary for the critical thinking needed to attain high academic achievement in Chemistry. **Amaal (2017)** pointed out five different ways in which thinking skills can be used to enhance classroom instruction in Chemistry lessons.

Graphic organizers have a number of attributes that enhance students' thinking skills. They allow students to make connections among pieces of information and make information easier to recall. Furthermore, they also allow students to break information into manageable chunks, so that they can easily see the relationships among the separate idea. Finally, graphic organizers also provide a structure or framework to display the internal process of thinking in an external, visual form. In other words, they provide a means to observe and assess the students' thought processes. Graphic organizer can also be viewed as frameworks for assisting students in comprehending what is to be learned (Chauhan, 2016). There are four (4) primary ways of using graphic organizers to enhance students' thinking skills and these are compiling information, generating ideas, analyzing or evaluating ideas, and reflecting.

According to Ausubel (2018) graphic organizers as a model of instruction facilitate instruction and learning. Organizers, on the other hand, aid recall when readers must reorganize information but are ineffective when reorganization is unnecessary. As a result, the use of graphic organizers benefits all students, regardless of their reading level. Organizers are used to set up or outline the information relationship between concepts and propositions, and a cognitive map is a kind of visual road map that shows some of the ways to connect the concept's meaning. If the potentials of advance organizer are fully utilized, student's critical thinking skills could improve irrespective of gender.

In a typical classroom that is co-educational in nature, where male and female interact in the learning process; the existent of male and female is called gender. Gender is any physical and behavioral difference between male and female which are socially, culturally based. Researches on gender such as Marni, et al. (2020) found out that male and female students possess almost the same level of critical thinking skills. Anna and Franca (2022) found no significant difference between the mean critical thinking skills scores of male and female taught using scaffolding instructional strategy. There seems to be an inconsistency in the findings on gender and these needs to be filled by other studies. Also lack of critical thinking skills will negatively affect the quest to compete effectively in the global market and therefore investigate the strengths of advance organizer in enhancing Chemistry students' critical thinking skills in Niger State, Nigeria.

Statement of the Problem

Chemistry's peculiarity allows it to take pride of position in any nation's scientific and technical progress. Unfortunately, many students regard chemistry as abstract and difficult subject. This could be due to the way teachers introduced this subject to students in class utilizing the traditional lecture style, resulting in rote memorization (Chado *et al.,* 2021). Traditional teaching methods have been observed to lack adequate motivation, do not allow students to think in multiple directions, and require sufficient cooperation and interactions among students for overlearning and transfer of learning in Chemistry concepts, which are typically more difficult and abstract.

Lack of learners' engagement is a significant challenge for educators seeking to cultivate critical thinking skills among their students. Rote memorization and passive learning that characterized teaching and learning in schools hinders development of essential critical thinking abilities among students. Significantly, Science and Mathematics are key subjects with the potential of making students acquire and use relevant 21st century skills required for national development. The combination of this factors create the need for research aimed at investigating and implementing effective strategies that promote critical thinking skills basic education science and mathematics students. Specifically, the research aims to explore how scaffolding instructional strategy can be employed to bridge the gap between traditional teaching practices and contemporary, engaging learning method. Against this backdrop, the researcher's attention was drawn to investigate the strengths of advance organizer in enhancing Chemistry students' critical thinking skills in Niger State, Nigeria.

Aims and Objectives of the Study

The main aim of this study is to determine the effect of graphic organizers on the critical thinking skills of secondary school chemistry students in Niger State, Nigeria. Specifically, the objective study were set to;

1. determine the effects of graphic organizers on critical thinking skills of secondary school chemistry students.
2. find out the effects of graphic organizer on critical thinking skills of secondary school chemistry students based on gender.

Research Questions

The following research questions were raised to guide the study;

1. What is the difference in the mean critical thinking skills score between students taught chemistry using graphic organizer and those taught using lecture method?
2. What is the difference in the mean critical thinking skills score between male and female students taught chemistry using graphic organizer?

Null Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance.

HO_1: There is no significant difference in the mean critical thinking skills scores between students taught chemistry using graphic organizer and those taught using lecture methods.

HO_2: There is no significant difference in the mean critical thinking skills scores between male and female students taught chemistry using graphic organizer.

Methodology

The study adopted quasi-experimental of pretest posttest non-equivalent control group design; this is because quasi-experimental design is a type of experimental design that does not allow for full control of extraneous variable and does not give room for random assignment of subject to group (Creswell, 2012). In this design both groups were subjected to pretest and posttest before and after the treatment respectively. The population of the study comprised all Chemistry students in all (40) secondary school in Niger State, Nigeria. The target population for this study consisted of all senior secondary school two (SSII) Chemistry students in forty two (40) school with a total number of two thousand three hundred (2300) Chemistry students, comprising 1300 males and 1000 females. Simple random sampling technique was use to select two schools from the population. The two schools were selected using balloting. However, an intact class was used and assigned school into experimental and control group. One hundred (101) senior secondary school two (SSII) Chemistry students were sampled comprising forty eight (49) males and fifty two (52) females and took part in the study.

Chemistry Critical Thinking Skills Test (CCTST) was used for data collection in this study. It was developed by the researcher; it consisted of fifty (50) multiple-choice items with option ranging from A-D from which students are expected to choose the correct responses. The entire questions asked are on stoichiometry. The items of instrument were scored two mark for each correct answer and were scored zero for each incorrect answer. Marking guide was prepared in order to guide the marking of the students' script. The maximum score is 100 marks while the minimum score is 0 marks. Chemistry Critical Thinking Skills Test (CCTST) was validated by two senior lecturers from Science Education Departments, Federal University of Technology. Two schools apart from those selected for the main study were used for pilot testing of the instrument. The reliability of the Chemistry Critical Thinking Skills Test (CCTST) was established using split-half reliability method and the coefficient was calculated using Spearman Brown's Formula and it was found to be 0.781.

The researcher visited the sampled schools and sought for their permission to conduct the study and addressed the principals and all Chemistry teachers on the duration and nature of the treatment of the study. At the beginning of the study, experimental and control group were subjected to pretest to determine their level of critical thinking skills before treatment. Experimental group was taught using graphic organizer while control group was taught using Lecture method. The students in both groups were taught for five weeks. Immediately after the intervention, the researcher administered the post-test **Chemistry Critical Thinking Skills Test (CCTST)** to both experimental and control group. The data obtained from the pre-test and posttest were marked and subjected to data analysis using (SPSS v. 26.0) for both descriptive and inferential statistical tool. Mean and standard deviation were used to answer the research question while the hypotheses were tested at 0.05 significance level using z-test for independent sample statistical tool.

Data Presentation and Analysis of Result

Pre-test scores were analyzed using mean, standard deviation and z-test for data obtained from **Chemistry Critical Thinking Skills Test (CCTST)** to ascertain the homogeneity or otherwise between control and experimental group. Therefore, pre-test had no effect on students Critical Thinking Skills. The groups are therefore homogenous and suitable for the study. The result is presented in Table 2.

Table 3: Analysis of z-test of Pre-test Critical Thinking Skills Scores of the Experimental and Control Groups Prior to Treatment

Group	N	Mean	Std. Dev.	Z	Df	P-value	Decision
Experimental	50	33.80	15.894	0.561	99	0.576	Sig
Control	51	35.60	16.183				

Table 3 shows the analysis of pre-test mean critical thinking skills score of the experimental and control groups prior to treatment. The mean and standard deviation of experimental group are 33.8 and 15.89 while that of control group are 35.6 and 16.18 and from the independent sample z-test analyses for pre-test mean CTS scores of the experimental and control groups, the observed p-value is 0.576 and the alpha-value is 0.05 with df=99. Therefore, the observe p-value is greater than the alpha-value and thus indicates that the experimental and control group were comparable and suitable for the experiment since they have very close pre-requisite critical thinking skills before treatment.

Analysis of Research Question and Null Hypotheses

Research Question One: What is the difference in the mean critical thinking skills score between students taught chemistry using graphic organizer and those taught using lecture method? Mean and SD were used to answer this research question and is presented in Table 4.

Table 4: Analysis of Mean and S.D of Critical Thinking Scores of the Chemist ry Students in Experimental and Control Groups

Group	N	Mean	Std. Dev.	Mean Difference
Experimental	50	69.20	12.26	30.8
Control	51	38.40	16.33	

Table 4 presents the analysis of mean and S.D of critical thinking scores of the chemistry students in experimental and control groups. The result indicates that, students exposed to graphic organizer had a mean CTS score of 69.20 with standard deviation of 12.26 while those exposed to lecture method had a mean CTS score of 38.40 and standard deviation of 16.33. The mean difference between the groups is 30.8 and this result indicates that students taught using graphic organizer had high mean CTS than those taught using lecture method. The result shows that experimental group exposed to graphic organizer possessed better CTS than control group taught using lecture method.

$\mathbf{H_{01}}$ There is no significant difference in the mean CTS between students taught chemistry using graphic organizer and those taught using lecture methods.

Hypothesis one was tested by subjecting the posttest mean CTS of experimental and control groups to independent sample z-test using SPSS version 26 at 0.05 level of significant and is presented in table 5

Table 5 : Analysis of z -test of CTS Scores of the Chemistry Students in Experimental and Control Groups

Group	N	Mean	Std. Dev.	Z	Df	P-value	Decision
Experimental	50	69.20	12.26	10.66	99	0.000	Sig
Control	51	38.40	16.33				

Table 5 presents the result of independent sample z-test analyses for posttest mean CTS scores of the experimental and control groups. The observed p-value is 0.000 and the alpha-value is 0.05 with Df = 99. Therefore, the observe p-value is less than the alpha-value and thus the null hypothesis is hereby rejected. And concluded that, there was significant difference in the mean CTS score between students taught chemistry using graphic organizer and those taught using lecture methods in favor of experimental group (z-crit=10.66, df=99, p=0.000<0.05).

Research Question Two: What is the difference in the mean CTS score between male and female students taught chemistry using graphic organizer? Mean and SD were used to answer this research question one and is presented in Table 6

Table 6: Analysis of Mean and S.D of CTS Scores of the Male and Female Students in Experimental Groups

Gender	N	Mean	Std. Dev.	Mean Diff.
Male	30	68.67	11.66	1.33
Female	20	70.00	13.37	

Table 6: shows the analysis of mean and S.D of CTS scores of the male and female students in experimental groups. The analysis indicates that, male students exposed to graphic organizer had a mean achievement score of 68.67 and standard deviation of 11.66 while female exposed to the same method had a mean CTS score of 70.00 and standard deviation of 13.37. The mean difference between the groups is 1.33 and this result indicates that male students taught using graphic organizer had higher mean CTS scores than their female counterpart taught using the same method. The result shows that female in experimental group exposed to graphic organizer possessed better CTS than their male counterpart.

$\mathbf{H_{02}}$ There is no significant difference in the mean CTS scores between male and female students taught chemistry using graphic organizer. Hypothesis two was tested by subjecting the posttest mean CTS of experimental and control groups to independent sample z-test using SPSS version 26 at 0.05 level of significant and is presented in table 7

Table 7: Analysis of Z-test of CTS Scores of the Male and Female Chemistry Students in Experimental Groups

Gender	N	Mean	Std. Dev.	Z	Df	P-value	Decision
Male	30	68.67	11.66	0.373	48	0.711	Not Sig
Female	20	70.00	13.37				

Table 7 presents the result of independent sample z-test analyses for posttest mean CTS scores of the male and female students in experimental group, the observed p-value is 0.711 and the alpha-value is 0.05 with df=48. Therefore, the observe p-value is greater than the alpha-value and thus the null hypothesis is hereby accepted. And concluded that there was no significant difference in the mean CTS score between male and female students taught chemistry using graphic organizer (z-crit= 0.373, df=48, p=0.000>0.05).

Summary of the Findings

1. There is significant difference in the mean critical thinking skills between students taught Chemistry using graphic organizer and those taught using Lecture method in favor of experimental group.
2. There is no significant difference in the mean critical thinking skills between male and female students taught Chemistry using graphic organizer.

Discussion of the Result

The finding of this study revealed that there is significant difference in the mean critical thinking skills score between Chemistry students taught using graphic organizer and those taught using Lecture method in favor of those exposed to advance organizer. This means that the use of graphic organizer in teaching chemistry concepts enhance students' critical thinking skills in the subjects. This finding is in agreement with the findings of **Chauhan (2016) and Marita *et al.*, (2017)** whom found students that learned using graphic organizer had higher critical thinking skills than students who learned through Lecture method. The reason for this finding could be as a result of nature and process involved in the strategy used. In graphic organizer lesson students are allowed to learn and participate fully in the lesson. The learning was model by teacher followed by students and then by students individually, therefore students are allowed to learn independently and become self-evaluated. However this findings of contradict the findings of Guo et al., (2023) whom found that students that learned using graphic organizer had lower critical thinking skills than students who learned through Lecture method.

It was also observed in this study that, there is no significant difference in the mean critical thinking skills score between male and female chemistry students taught using graphic organizer. The possible reason that could be attributed to the equality in critical thinking skills across the gender in this study includes equal opportunities given to both male and female students to explore and learn at their own zone of proximal development, relating learning activities with the real life situation, allowing students to learn in group and student are allowed to learn independently and become self-evaluated. The

result of this study corroborate with the findings of **Wachanya *et al.*, (2020) and Amaal (2017)** whom reported that no significant difference in the mean critical thinking skills score between male and female was found after students received the treatment. However the results of this study disagreed with the findings of Ndola & Daks (2020) whom found that there was significant difference in the mean critical thinking skills score between male and female chemistry students taught using graphic organizer.

Conclusion

Based on the findings of this study the following conclusions were drawn:

i. Students taught chemistry using graphic organizer possess higher critical thinking skills than their counterpart students taught using lecture method. As such graphic organizer increases the level of students' critical thinking skills.
ii. Graphic organizer help in improving male and female students' critical thinking skills as indicated by insignificant difference in their mean critical thinking skills when taught using graphic organizer.

Recommendations

1. Based on the research findings, it is recommended that secondary school in Niger State, Nigeria should employ the use of graphic organizer as a teaching strategy to enhance critical thinking skills of students. Significantly, critical thinking skills empower individuals to be active and discerning learners, capable of navigating complex information landscapes, making informed choices, and contributing meaningfully to discussions and problem-solving scenarios.
2. Chemistry teachers in Niger State, Nigeria should promote interaction among male and female students, as they learn to discover knowledge themselves as this will improve their critical thinking skills.

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