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Enhancing Students' Critical Thinking in Physics Using Graphic Organizer-Enhanced and Context-Based Learning Strategies

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Abstract

Purpose: This study focused on fostering critical thinking in physics using graphic organizer-enhanced and context-based learning strategies among secondary students in Taraba State, Nigeria. **Methodology:** Five objectives guided the study using a quasi-experimental design. The sample comprised 225 students (males=113, females= 112). Data were collected using the Test of Critical Thinking Skill Acquisition (TOCTSA). The Kendal Tau-b inter-rater formula was used to determine the reliability of TOCTSA. Mean, standard deviation, and ANCOVA were the statistical methods employed. **Findings:** The study revealed a significant difference in the mean critical thinking scores in physics for students taught using the graphic organizer-enhanced learning strategy compared to those taught using the conventional strategy ($F_{1,172} = 174.230$; $p = 0.000 < 0.05$), as well as for those taught using the context-based learning strategy compared to the conventional strategy ($F_{1,169} = 7.772$; $p = 0.006 < 0.05$). However, there was no significant difference in the mean score of critical thinking in physics between male and female students taught using the graphic organizer-enhanced strategy ($F_{1, 50} = 2.897$; $p = 0.095 > 0.05$). Conversely, there was a significant difference in the mean score of critical thinking in physics between male and female students taught using the context-based learning strategy ($F_{1,47} = 17.578$; $p = 0.000 < 0.05$). **Significance:** These strategies have the potential to enhance the academic achievement of both male and female students and promote the acquisition of critical thinking skills in physics.

Keywords: critical thinking, physics teaching, graphic organizer strategy, enhanced strategy, context-based learning strategy, gender.

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Introduction

Physics plays an extra ordinary and prominent role in shaping what is presently branded a modern society, making it almost mandatory for science students to have a basic understanding of the subject. Physics as a discipline offers knowledge in the study of matter and energy and their interaction in the field of mechanics, acoustics, optics, heat, electricity, magnetism, radiation, atomic structure and nuclear phenomena. As a branch of natural science, physics is the bedrock of engineering, medicine, scientific and technological advancements.

Physics has many uses in the communication, transportation, information and health sectors. Knowledge and principles of physics are applied in the design of devices for monitoring, measuring, regulating, power generating as well as developing machines and equipment used in health, military, industrial and agricultural organizations. The focus of physics education has been to guide students develop critical thinking and by extension to the understanding of physics concepts which enhance good academic achievement.

Critical thinking, as a process of analysing issues in order to form reasonable judgment in whatever career one chose to pursue, is always deemed essential for successful outcome. Critical thinking skill affect students' learning process, for it enables them to reason in depth that leads to academic achievement (Abbasi & Izapanah, 2018; Pozhham et al, 2019). The importance of critical thinking is recognized in every endeavour of life due to its problem-solving attributes which account for positive changes.

While physics has many potential benefits including scientific and technological advancements, there has been a growing concern in the academic community about the strategy teachers employ in teaching physics. Research has reported that teacher's in-adequate training in the use of appropriate instructional strategies results to students' poor achievement in physics and lack of critical thinking to apply knowledge in dealing with challenges (Browne & Keeley, 2010; Brookfield, 2012; Achor, 2020).

In bid to enhance learning, researchers are continuously searching for strategies for effective content delivery. Towards this direction government and other professional bodies such as science teachers Association of Nigeria (STAN) have been organizing training and retraining workshops for science teachers with the aim of enhancing their instructional delivery capability and by extension improve students' academic achievement and critical thinking in physics. However, these efforts are still far from recording tangible improvement in students' achievement in physics (Samba, et al, 2020).

Despite these concerns, there is also evidence to suggest that strategies such as graphic organizer-enhanced and context-based learning strategies can have positive effect on students' critical thinking in physics. For example, graphic organizer is an instructional strategy that organizes information in pictorial format. The graphical arrangement allows the students to identify the missing information or connecting link in their critical thinking. Effect of graphic 2ategoriz on improving learning outcome has been investigated and found useful in structuring students' critical thinking about a topic, linking materials students are learning with what they already know and in assisting students with organization and attention challenges (Oswalt, 2020).

Characteristic features that make graphic organizer a unique tool that can facilitate learning, are the visual displaying of key information, organizing information for easy comprehension, showing how ideas are connected within a text or surrounding a concept, providing students with a structure for grasping abstract ideas. Other characteristics of graphic organizer include, allowing to put into practice different skills such as comparing data, ordering events and structuring the information, combining traditional note

taking or outlining with the visuo-spatial benefits of diagram, helping students' to both physically see and conceptually understand relationships between their ideas. Benefits of the use of graphic organizer in the classroom is that it helps visualize or present information in a way that is easier to comprehend by breaking down larger or complex concepts into smaller and simpler parts. It provides students the opportunity to actively contribute and participate in the learning process. Graphic organizer helps to develop cognitive skills such as brainstorming, categorizing and prioritizing of content. As a learning tool, graphic organizer may help in recalling prior knowledge about a subject and quickly connect it to new information. It provides self-learning: by using graphic organizer for note-taking, analysing, and in studying, students can familiarize themselves with a lesson far more easily.

Context-based learning strategy for, an instance is unique and important in connecting content to real world experience of the students. The strategy links physics concepts to real world; life experiencing of the students in a learning environment for learning goes with experiencing. Learning occurs only when students process new information or knowledge in such a way that it makes sense in their frame of reference (Davtyan, 2014). When students are informed, especially of the why they are learning physics concepts and how such concepts can be applied in real world situations, their interest increase significantly in commitment to their school work. Context-based learning strategy enables students develop multiple skills and career experiences that strengthen academic and professional knowledge (Pham, 2011)

Contextual learning strategy does not only help students remember specific information, but also helps them to apply this information in their daily lives using critical thinking (Sabramowicz, 2016). The characteristic features of context-based learning strategy that makes it to enhance learning are, the emphasizing of problem solving, recognizing that teaching and learning need to occur in multiple contexts, assisting students in learning how to monitor their learning to become self-regulated learners. Other features include, anchoring teaching in the diverse life context of students, encouraging students to learn from each other and employing authentic assessment.

Given the potential benefits of graphic organizer-enhanced and context-based learning strategies use, for facilitating students' achievement and critical thinking, it would be important to gain a better understanding of the mechanism underlying these effects. This study aimed to investigate the relationship between graphic organizer-enhanced and context-based learning strategies use and academic achievement and critical thinking, with a particular focus on the role of graphic organizer-enhanced and context-based learning strategies comparison processes in teaching physics. By doing so, the researcher hope to shed light on the potential benefits of graphic organizer-enhanced and context-based learning strategies use for academic achievement and critical thinking and to provide insights that can inform interventions and policies aimed at promoting graphic organizer-enhanced and context-based learning strategies use in physics content delivery.

Although the focus of the research was to investigate whether two instructional approaches: graphic organizer-enhanced and context-based learning strategies lead to different improvements in students' critical thinking in physics, however, gender was considered a moderator variable, because as independent variable it might affect the dependent variable (critical thinking), since normal classes usually consist of male and female students. Gender refers to the socially determined ideas and practices of what it is to be male or female including attitudes and behaviour that depend upon the expectations from society.

Statement of the Problem

Students' achievement in physics over the years in external examination has not been encouraging. The trend is not different from secondary schools in the study area. A percentage table reflecting WASSCE results from 2011-2020 in Taraba State (Taraba State WASSCE Results, 2020) is evidence of poor performance. During these years percentage passes did not exceed twenty, while failures were above fifty percent, indicating poor achievement.

Persistent under-achievement of students in physics external examinations in the study area is worrisome. Majority of students hardly can apply what they have learnt. A situation that had not only brought delayed, but equally denial of opportunity to students opting to study engineering, technology, medicine and other physics-based courses in higher schools. This ugly situation is not only frustrating to the students and parents, but equally negative on the society's advancement. Though investigations have been conducted on effectiveness of instructional strategies for improving students' critical thinking in physics, yet more need to done especially in the study area.

Purpose of the Study

The purpose of the study is to investigate if graphic organizer-enhanced and context-based learning strategies foster physics students' critical thinking better than the conventional teaching strategy. Specifically, it aims to achieve the following objectives.

1. To find out the effect of graphic organizer-enhanced learning strategy and the conventional strategy on students critical thinking in physics.
2. To find out the effect of context-based learning strategy and the conventional strategy on students critical thinking in physics.
3. To determine the effect of graphic organizer-enhanced learning strategy on male and female students' critical thinking in physics.
4. To determine the effect of context-based learning strategy on male and female students' critical thinking in physics.
5. To ascertain the interaction effect of strategies and gender on students' critical thinking in physics.

Method

Research Design

Quasi-experiment, specifically the pretest-posttest, non-equivalent control group design was adopted for the study. A quasi-experiment is the type of experimental design that does not have randomly assigned groups. The researcher collects participants in a group that cannot or should not be divided up, such as existing groups. Common attribute of quasi-experimental design is that it tries to identify the effect of a variable (independent variable) on another variable (dependent variable) in which an intervention is introduced to one group and the other is treated as control group.

The quasi-experimental design was adopted because it was not possible to have complete randomization of the participating students due to the avoidance of disrupting the already existing setting

(streaming of classes) in the schools. In addition to the earlier stated reason for the choice of the design, is the fact that intact classes were used. To justify the choice for the use of intact classes for the study, studies (Nworgu, 2010; Emaikwu, 2013) suggest that intact class should be used when it is not possible to assign subjects to experimental and control groups. The students in their intact classes were assigned to three groups namely the experimental group$_1$ (EG_1), experimental group$_2$ (EG_2) and the control group (CG). In implementing the design, experimental group$_1$ and experimental group$_2$ were given a pre-test on linear momentum, then received treatment (GOLS & CBLS respectively) and after, given a post-test. At the same time the control group (CTS) was given a pre-test on linear momentum and did not receive treatment and then given a post-test.

Population, Sample and Sampling

The population of 2,105 SS2 students studying physics in Jalingo education zone in Taraba State (Taraba State Post-Primary Education Management Board, 2022) comprising of 1,158 males and 947 females was the target for the study. Names of secondary schools offering physics within Jalingo education zone, the population of SS2 Students offering physics as well as the breakdown into male and female gender was presented.

Sample size of 225 SS2 students drawn from secondary schools offering physics in jalingo education zone was used for the study. The sample was obtained using hat and draw simple random sampling technique and intact sampling technique also. The hat and draw method of simple random sampling technique involves putting names in a hat and drawing a certain number of names out. While intact class sampling technique involves selecting an already existing group in which case entire group is used to represent some large population, hence requires no procedure for selection (Hendrika, 2016).

Applying the techniques in the study, names of secondary schools each in the local government areas were written, put into a hat, reshuffled and one school picked only. The procedure was repeated to select one school each from the secondary schools in the local government areas that constitute Jalingo education zone. Thereafter, intact class sampling technique applied to select the experimental groups and the control group.

Instrumentation, Validation and Reliability

Test of Critical Thinking Skills Acquisition (TOCTSA) with scoring guide was the instrument used in this study. In addition, three sets of lesson plans were also provided for the experimental groups and control group respectively. Test of Critical Thinking Skill Acquisition instrument contained 10 essay-type questions that required the test takers to demonstrate their domain-specific critical thinking proficiency in linear momentum in physics through written response. The elaboration of domain-specific critical thinking outcomes students should demonstrate after completion of the linear momentum content topics were identified. The linear momentum learning outcomes were formulated in terms of how successful physics students could perform when confronted with critical thinking task specific to linear momentum. Essay-type question item format was used to measure critical thinking skills because multiple choice question items do not directly and efficiently test for critical thinking features such as drawing warranted conclusions, analyzing arguments and systematically solving problems (Tiruneh, et al, 2016). The scoring guide for the TOCTSA is provided. The essay-type test questions covered ten categories of critical thinking skills such as observation, analysis, and explanation, communication, drawing inference, recognizing assumption, evaluation, interpretation, problem solving and deduction. The critical thinking categories to be assessed

and their corresponding scoring weight are provided.

Two types of validation, namely face and content validation were implemented. Being aware that validation of instruments is best handled by experts, three professors in Taraba State University, Jalingo were consulted. The three experts, two from science education department and one from educational foundations, were each presented with a copy of letter, requesting for validation of 10 essay question (test of critical thinking skill acquisition) item instruments. In addition, three sets of lesson plan for both the experimental groups and control group, as well were attached with the instrument, which was reviewed.

The main purpose of the test which was to measure critical thinking of students in linear momentum in physics was initially explained to the validators and subsequently requested to review each item in relation to the overall purpose of the test. Specifically, the experts were requested to review each item based on the following criteria (a) appropriateness of the items to the purpose of the test (b) accuracy of the information presented in the items and (c) clarity of the words/phrases/diagrams.

The validators after going through the instruments, unanimously, though separately stated that the instruments appeared to measure the target variables. Further, the experts' suggested that most of items were appropriate and relevant in measuring the targeted achievement and critical thinking in momentum in physics. However, they observed that the instruments did not cover every form of linear momentum that was stated in the lesson plan. They noted that, if some types of linear momentum as mentioned in lesson plan are left out, then the results may not be an accurate indication of students understanding of the subject.

Based on the validators' observation, comment and useful feedback on a few of the items they thought that required revision, the researcher developed a comprehensive table of specification covering the subtopics in linear momentum for the physics achievement test (PAT). The specification contained every form of linear momentum and the objectives. The table served as a large pool of items that covered a broad range of topics in linear momentum from which individual test questions were drawn. Afterwards, on presenting the comprehensive table of specification to the validators, it was confirmed that the items on the test represent the entire range of possible items that the test should cover, hence the affirmation of content validity of the test instrument.

For the test of critical thinking skill acquisition instrument, where the test measured a trait (critical thinking) that was difficult to define, the experts advised that two independent judges rate the test separately. Thereafter items that were rated strongly relevant by both judge be included in the final test. This advice was implemented to arrive at the content validity of the test of critical thinking skill acquisition.

The instrument was pilot tested to a small group of SS2 physics students (n=20) in Danbaba science secondary school in Bali Local Government Area Taraba State Nigeria, which is not within the education zone in which the actual research will be carried out. The choice of the school was made on the assumption that it was comparable in terms of staff strength, population and administrative competence of the schools that were used for the actual study.

The calculated reliability index for Test of Critical Thinking Skill Acquisition (TOCTSA) was determined using Kendall's Tau-b Inter Rater statistics and the reliability index of 0.61 was obtained. The formula was used because the items in the (TOCTSA) instrument were essay-type, of which students' answers might likely not be the same. Since two independent raters were involved in rating the students, there was need to determine the extent to which the two raters/scorers agreed, in order to address the issue of consistency in the implementation of the instrument.

According to Nworgu, (2010) reliability coefficient standard ranges from 0.5 and 0.99. Since these

calculated reliability value fell within this range, it was therefore considered acceptable for the study. In addition to extent to which the instruments were reliable, Dingley (2014) maintained that reliability value greater than 0.5 shows acceptable level of internal consistency. Administration of the test lasted between 60 and 80 minutes for PAT and TOCTSA respectively.

Administration and Data Collection Procedure

The researcher obtained from the department an introductory letter seeking for permission of the secondary school authorities whose students, teachers and facilities were used for the period of eight weeks of the study. The participating teachers for the study included the regular physics teachers that handled the intact class of each of the selected secondary school. The teachers were trained for four days using a training schedule manual during the training the graphic organizer-enhanced learning strategy, context-based learning strategy and the conventional teaching strategy were explained to the teachers verbally.

Three intact classes selected for study, two were designated experimental group$_{1,}$ and experimental group$_2$ while the third was control group. The experimental group$_1$ received graphic organizer-enhanced learning strategy treatment, similarly experimental group$_{2,}$ received context-based learning strategy treatment while the control group received no treatment (CTS). Three sets of lesson plan on linear momentum, prepared based on Graphic Organizer-Enhanced Learning Strategy (GOLS), Context-Based Learning Strategy (CBLS) and the Conventional Teaching Strategy (CTS) were used to deliver the physics content to experimental group$_{1,}$ experimental group$_2$ and control group respectively.

At the beginning of the study, using the physics achievement test (PAT) and tests of critical thinking skill acquisition (TOCTSA) as data gathering instruments, pre-test was administered to experimental group$_{1,}$ experimental group$_2$ and the control group. At the end of the study, PAT and TOCTSA were used again as data gathering instrument to administer post-test to experimental group$_{1,}$ as well as experimental group$_2$ and the control group.

Data Analysis

The data collected for the study were subjected to analysis at two different statistical levels: descriptive and inferential statistics. At the descriptive level, the descriptive statistics of mean and standard deviation were used in order to respond to the research questions. At the inferential level, the Analysis of Covariance (ANCOVA) was used to test the hypotheses and the Covariate prê-test. All hypotheses were tested at $P<0.05$ level of significance. The inferential statistics permit decision making whether or not to reject null hypotheses after being tested. The researcher used ANCOVA statistics in the analysis because it agrees with the opinion of Emaikwu (2013) which stated that ANCOVA is appropriate in taking care of initial group differences statistically to compare in experimental research, effectiveness of pedagogical instructions where intact classes may differ in intelligence as it is similar to the current study.

Results

Objective 1: Find out the effect of graphic organizer-enhanced learning strategy and the conventional strategy on students critical thinking in physics

Table 1. *Mean Score Critical Thinking in Physics of Students Taught Using Graphic Organizer-Enhanced Learning Strategy and Conventional Strategy*

Strategies		PreTOCTSA	PostTOCTSA	Mean Gain
Graphic organizer-enhanced learning strategy	Mean	6.79	22.90	16.11
	N	53	53	
	Std. Deviation	4.73	6.54	
Conventional Strategy	Mean	7.58	10.63	3.05
	N	122	122	
	Std. Deviation	4.07	5.24	
Mean difference				13.06

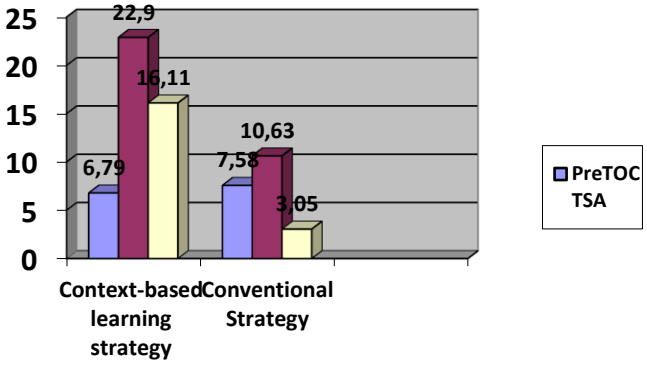

Figure 1. *Pretest, Posttest and Mean Gain in Critical Thinking in Physics of Students Taught Using Graphic Organizer-Enhanced Learning Strategy and Conventional Strategy*

Table 2. *ANCOVA of Critical Thinking in Physics of Students Taught Using Graphic Organizer-Enhanced Learning Strategy and Conventional Strategy*

Dependent Variable: postTOCTSA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5595.867[a]	2	2797.934	87.116	.000	.503
Intercept	11124.866	1	11124.866	346.383	.000	.668
preTOCTSA	36.492	1	36.492	1.136	.288	.007
Strategies	5595.774	1	5595.774	174.230	.000	.503
Error	5524.167	172	32.117			
Total	47178.000	175				
Corrected Total	11120.034	174				

a. R Squared = .503 (Adjusted R Squared = .497)

Table 1 shows the mean score critical thinking in physics of students taught using graphic organizer-enhanced learning strategy and those taught using the conventional strategy. The table shows that 53 students were taught using graphic organizer-enhanced learning strategy and 122 students were taught using conventional strategy. The table reveals that the mean score critical thinking in physics of students taught using graphic organizer-enhanced learning strategy is 6.79 with a standard deviation of 4.73 during pre-test and 22.90 with a standard deviation of 6.54 in post-test while the mean score critical thinking in physics of students taught using conventional strategy is 7.58 with a standard deviation of 4.07 during pre-test and 10.63 with a standard deviation of 5.24 in post-test. The table further shows that the mean gain for graphic organizer-enhanced learning strategy is 16.11 and conventional strategy is 3.05. The difference in the mean score critical thinking in physics of students taught using graphic organizer-enhanced learning strategy and those taught using the conventional strategy is 13.06 in favour of students in graphic organizer-enhanced learning strategy class. The summary of the pretest, posttest mean critical thinking as well as the mean gain in the mean critical thinking of students in graphic organizer-enhanced learning strategy and conventional strategy is as shown in Figure 2.

Table 2 reveals that $F(1,172) = 174.230$; $p = 0.000 < 0.05$. Thus, the null hypothesis is rejected. This implies that there is significant difference in the mean score critical thinking in physics of Students taught using graphic organizer-enhanced learning strategy and those taught using the conventional strategy. Therefore, there is significant difference in the effect of graphic organizer-enhanced learning strategy and conventional strategy on the mean score critical thinking in physics of Students. The partial Eta square of 0.503 obtains for strategies imply that 50.3 percent of the mean score critical thinking in physics of Students can be attributed to the strategies.

Objective 2: Find out the effect of context-based learning strategy and the conventional strategy on students critical thinking in Physics

Table 3. *Mean Score Critical Thinking in Physics of Students Taught Using Context-Based Learning Strategy and Conventional Strategy*

Strategies		**PreTOCTSA**	**PostTOCTSA**	**Mean Gain**
Context-based learning strategy	Mean	10.94	14.82	3.88
	N	50	50	
	Std. Deviation	7.45	11.33	
Conventional Strategy	Learning Mean	7.58	10.63	3.05
	N	122	122	
	Std. Deviation	4.07	5.24	
Mean difference				0.83

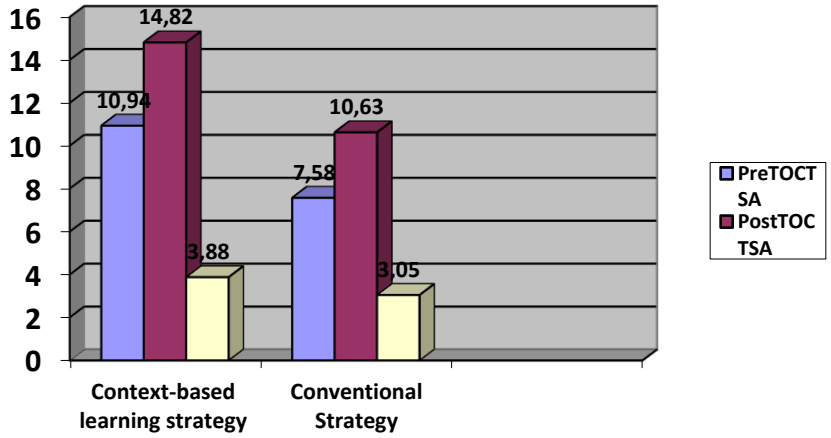

Figure 2. *Pretest, Posttest Mean Gain in Critical Thinking in Physics of Students Taught Using Context-Based Learning Strategy and Conventional Strategy*

Table 4. *ANCOVA of Critical Thinking in Physics of Students Taught Using Context-Based Learning Strategy and Conventional Strategy*

Dependent Variable: postTOCTSA

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	734.650[a]	2	367.325	6.526	.002	.072
Intercept	5061.335	1	5061.335	89.918	.000	.347
preTOCTSA	114.795	1	114.795	2.039	.155	.012
strategies	437.498	1	437.498	7.772	.006	.044
Error	9512.716	169	56.288			
Total	34419.000	172				
Corrected Total	10247.366	171				

a. R Squared = .072 (Adjusted R Squared = .061)

Table 3 shows the mean score critical thinking in physics of students taught using context-based learning strategy and those taught using the conventional strategy. The table shows that 50 students were taught using context-based learning strategy and 122 students were taught using conventional strategy. The table reveals that the mean score critical thinking in physics of students taught using context-based learning strategy is 10.94 with a standard deviation of 7.45 during pre-test and 14.82 with a standard deviation of 11.33 in post-test while the mean score critical thinking in physics of students taught using conventional strategy is 7.58 with a standard deviation of 4.07 during pre-test and 10.63 with a standard deviation of 5.24 in post-test. The table further shows that the mean gain for context-based learning strategy is 3.88 and conventional strategy is 3.05. The difference in the mean score critical thinking in physics of students taught using context-based learning strategy and those taught using the conventional strategy is 0.83 in favour of students in context-based learning strategy class. The summary of the pretest, posttest mean critical thinking as well as the mean gain in the mean critical thinking of students in context-based learning strategy and conventional strategy is as shown in Figure 2.

Table 4 reveals that F (1,169) = 7.772; p = 0.006 < 0.05. Thus, the null hypothesis is rejected. This implies that there is significant difference in the mean score critical thinking in physics of students taught using context-based learning strategy and those taught using the conventional strategy. Therefore, there is significant difference in the effect of context-based learning strategy and conventional strategy on the mean score critical thinking in physics of students. The partial Eta square of 0.044 obtains for strategies imply that only 4.4 percent of the mean score critical thinking in physics of students can be attributed to strategies**.**

Objective 3: Determine the effect of graphic organizer-enhanced learning strategy on male and female students' critical thinking in physics

Table 5. *Mean Score Critical Thinking in Physics of Male and Female Students Taught Using Graphic Organizer-Enhance Learning Strategy*

Gender		PreTOCTSA	PostTOCTSA	Mean Gain
Male	Mean	6.96	24.40	17.44
	N	27	27	
	Std. Deviation	5.14	3.20	
Female	Mean	6.61	21.34	14.73
	N	26	26	
	Std. Deviation	4.37	8.56	
Mean difference				2.71

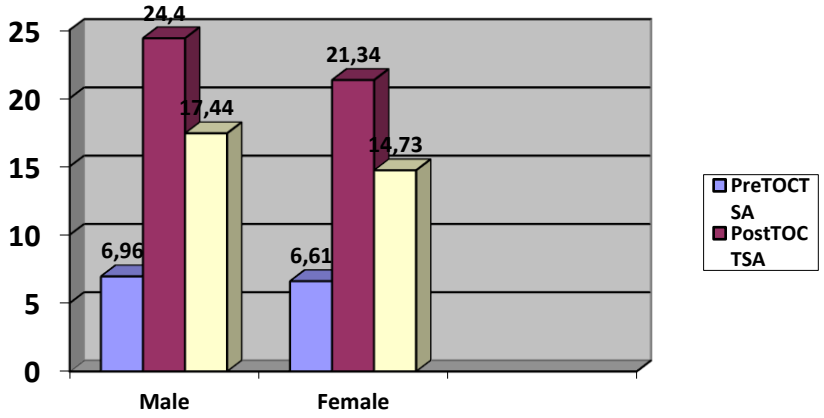

Figure 3. *Pretest, Posttest Mean Gain in Critical Thinking in Physics of Male and Female Students Taught Using Graphic Organizer-Enhance Learning Strategy*

Table 6. *ANCOVA of Critical Thinking in Physics of Male and Female Students Taught Using Graphic Organizer-Enhanced Strategy*

Dependent Variable: postTOCTSAGO

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	136.253[a]	2	68.126	1.630	.206	.061
Intercept	8421.875	1	8421.875	201.454	.000	.801
preTOCTSAGO	12.127	1	12.127	.290	.593	.006
genderGO	121.100	1	121.100	2.897	.095	.055
Error	2090.276	50	41.806			
Total	30034.000	53				
Corrected Total	2226.528	52				

a. R Squared = .061 (Adjusted R Squared = .024)

Table 5 shows the mean score critical thinking in physics of male and female students taught using graphic organizer-enhanced learning strategy. The table shows that 27 male and 26 female students were taught using graphic organizer-enhanced learning strategy. The table reveals that the mean score critical thinking in physics of male students taught using graphic organizer-enhanced learning strategy is 6.96 with a standard deviation of 5.14 during pre-test and 24.40 with a standard deviation of 3.20 in post-test while the mean score critical thinking in physics of female students taught using graphic organizer-enhanced learning strategy is 6.61 with a standard deviation of 4.37 during pre-test and 21.34 with a standard deviation of 8.56 in post-test. The table further shows that the mean gain for male students is 17.44 and female students is 14.73. The difference in the mean score critical thinking in physics of male and female students taught using graphic organizer-enhanced learning strategy is 2.71 in favour of male students in graphic organizer-enhanced learning strategy class. The summary of the pretest, posttest mean critical thinking as well as the mean gain in the mean critical thinking of male and female students in graphic organizer-enhanced learning strategy is as shown in Figure 3.

Table 6 reveals that $F(1,50) = 2.897$; $p = 0.095 > 0.05$. Thus, the null hypothesis is not rejected. This implies that there is no significant difference in the mean score critical thinking in physics of male and female students taught using graphic organizer-enhanced strategy. Therefore, there is no significant difference in the effect of graphic organizer-enhanced strategy on the mean score critical thinking in physics of male and female students. The partial Eta square of 0.055 obtained for gender means that only 5.5 percent of the mean score critical thinking in physics of male and female students can be attributed to gender**.**

Objective 4: determine the effect of context-based learning strategy on male and female students' critical thinking in physics

Table 7. *Mean Score Critical Thinking in Physics of Male and Female Students Taught Using Context-Based Learning Strategy*

Gender		PreTOTCSA	PostTOCTSA	Mean Gain
	Mean	12.68	20.80	8.12
Male	N	25	25	
	Std. Deviation	8.15	7.95	
	Mean	8.80	9.20	0.40
Female	N	25	25	
	Std. Deviation	6.36	1.15	
Mean difference				7.72

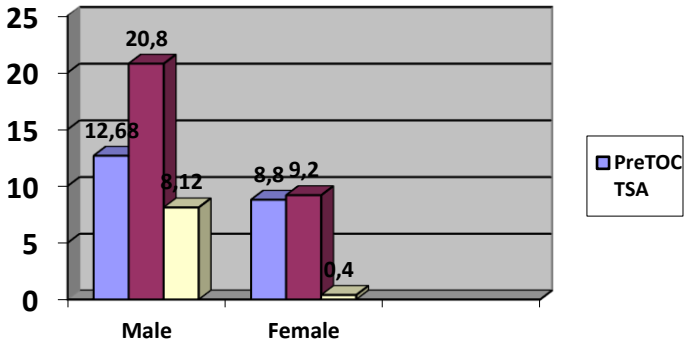

Figure 4. *Pretest, Posttest Mean Gain In Critical Thinking in Physics of Male and Female Students Taught Using Context-Based Learning Strategy*

Table 8. *ANCOVA of Critical Thinking in Physics of Male and Females Students Taught Using Context-Based Learning Strategy*

Dependent Variable: postTOCTSACB

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1788.053[a]	2	894.026	9.327	.000	.284
Intercept	3281.377	1	3281.377	34.232	.000	.421
preTOCTSACB	.033	1	.033	.000	.985	.000
genderCB	1685.022	1	1685.022	17.578	.000	.272
Error	4505.327	47	95.858			
Total	17275.000	50				
Corrected Total	6293.380	49				

a. R Squared = .284 (Adjusted R Squared = .254)

Table 7 shows the mean score critical thinking in physics of male and female students taught using context-based learning strategy. The table shows that 25 male and 25 female students were taught using context-based learning strategy. The table reveals that the mean score critical thinking in physics of male

students taught using context-based learning strategy is 12.68 with a standard deviation of 8.15 during pre-test and 20.80 with a standard deviation of 7.95 in post-test while the mean score critical thinking in physics of female students taught using context-based learning strategy is 8.80 with a standard deviation of 6.36 during pre-test and 9.20 with a standard deviation of 1.15 in post-test. The table further shows that the mean gain for male students is 8.12 while female students is 0.40. The difference in the mean score critical thinking in physics of male and female students taught using context-based learning strategy is 7.72 in favour of male students in context-based learning strategy class. The summary of the pretest, posttest mean critical thinking as well as the mean gain in the mean critical thinking of male and female students in context-based learning strategy is as shown in Figure 4

Table 8 reveals that $F(1,47) = 17.578$; $p = 0.000 < 0.05$. Thus, the null hypothesis is rejected. This implies that there is significant difference in the mean score critical thinking in Physics of male and female students taught using context-based learning strategy. Thus, there is significant difference in the effect of context-based learning strategy on the mean score critical thinking in Physics of male and female students. The partial Eta square of 0.272 obtain for gender implies that 27.2 percent of the mean score critical thinking in Physics of male and female students can be attributed to gender.

Objective 5: Ascertain the interaction effect of strategies and gender on students' critical thinking in Physics

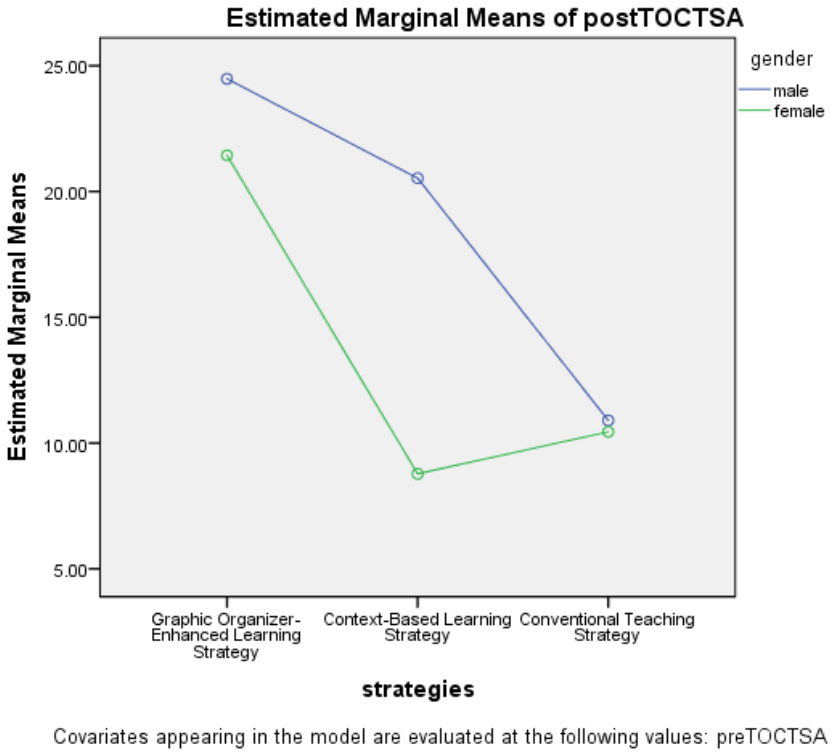

Figure 5. *Interaction Effect of Strategies and Gender on Students' Critical Thinking in Physics*

Table 9. *ANCOVA of Interaction Effect of Strategy and Gender on Students' Critical Thinking in Physics Dependent Variable: postTOCTSA*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7505.804[a]	6	1250.967	27.502	.000	.431
Intercept	13821.079	1	13821.079	303.850	.000	.582
preTOCTSA	20.308	1	20.308	.446	.505	.002
Strategies	5560.559	2	2780.279	61.123	.000	.359
Gender	1221.585	1	1221.585	26.856	.000	.110
strategies * gender	1110.535	2	555.268	12.207	.000	.101
Error	9916.045	218	45.486			
Total	64453.000	225				
Corrected Total	17421.849	224				

a. R Squared = .431 (Adjusted R Squared = .415)

Figure 5 shows the profile graph of the interaction effect of strategies and gender on students' critical thinking in physics. The interaction pattern shows that the plots for male and female tend to intersect at conventional strategy and also tend to intersect at graphic organized-enhanced learning strategy. This indicates that there is interaction effect of strategies and gender on students' critical thinking in physics.

Table 9 reveals that $F(2, 218) = 12.207$; $p = 0.000 < 0.05$. Thus, the null hypothesis is rejected. This implies that there is significant interaction effect of strategies and gender on students' critical thinking in physics. Thus, strategies and gender have significant interaction effect on students' critical thinking in physics. The partial Eta square of 0.101 obtain for strategies and gender implies that 10.1 percent of students' critical thinking in physics can be accounted for by the interaction effect of strategies and gender.

Discussion

Findings arrived at in this study are discussed in this section. The study investigated if graphic organizer-enhanced and context-based learning strategies foster physics students' critical thinking and academic achievement better than the conventional teaching strategy. The sample comprised male and female students therefore gender was incorporated as a moderator variable. Discussion of findings was tailored along the variables in the study as guided by the results of research questions and hypotheses.

The mean score critical thinking in physics of students taught using graphic organizer-enhanced learning strategy was higher than those taught using the conventional strategy. There was significant difference in the mean score critical thinking in physics of Students taught using graphic organizer-enhanced learning strategy and those taught using the conventional strategy. This means that the use of graphic organizer-enhanced learning strategy fosters critical thinking in physics better than the use of conventional strategy. The finding agrees with Aslami et al. (2021) that the increase in critical thinking skills' mean score of the experimental group of the medical students demonstrated the effectiveness of concept mapping strategy over the lecture-based strategy in teaching anatomy course. The finding agrees with Gehan and Nahed (2020) that the increase gain in mean score after teaching students using mind mapping which is a type of graphic organizer, signified the effectiveness of the strategy. The finding agrees

with Tiruneh et al. (2018) that participants in the immersion and infusion conditions significantly outperformed those in the control condition on domain-specific critical thinking proficiency.

The finding agrees with Wartono et al. (2017) that there was significant difference in the mean critical thinking skills between the experimental group and the control group. The finding agrees with Lust (2014) that the group of students that were taught using graphic organizer was greater, indicating that graphic organizer strategy was more effective in teaching critical thinking to students in the special education setting. However, the finding disagrees with Samba et al. (2020) that graphic organizer teaching with feedback was not significantly different with experiential learning with feedback effect on students' critical thinking mean score in CTT. The finding also disagrees with Rimigio et al. (2020) that there was no significant difference between the pretest mean score of the experimental group and the control group. Also, no significant difference was found between the pretest and posttest mean scores of the two groups.

The use of graphic organizer-enhanced learning as an experimental strategy provides three ways to chunk information. These are grouping, patterning and organizing. The graphic organizer-enhanced learning strategy has been effectively utilized as the basis for dividing a group of information into multiple categories based on meaning. Graphic organizer-enhanced learning is useful in structuring students' critical thinking about a topic, linking materials learners are learning with what they already know and in assisting students with organization and attention challenges. This may be responsible for the significant difference found in the mean score critical thinking in physics of Students taught using graphic organizer-enhanced learning strategy and those taught using the conventional strategy. This means that meaningful learning can be assisted using graphic organizer-enhanced learning strategy.

The mean score critical thinking in physics of students taught using context-based learning strategy was higher than those taught using the conventional strategy. There was significant difference in the mean score critical thinking in physics of students taught using context-based learning strategy and those taught using the conventional strategy. This means that the use of context-based learning strategy fosters critical thinking in physics better than the use of conventional strategy. The finding agrees with Abebe et al. (2023) that there was significant difference between the mean scores of the two groups in favour of the experimental group. The finding agrees with Pursitasari et al. (2020) that there was significant difference between the mean score critical thinking in physics of students taught using context-based learning strategy and those taught using inquiry learning strategy with those taught with context-based learning strategy higher than those with inquiry learning strategy.

The finding agrees with Bakhsha et al. (2019) that context-based learning strategy improved students' critical thinking skill in anesthesiology course better than the lecture strategy. The finding agrees with Hasruddin et al. (2015) that context-based learning strategy had greater improvement on the biology students' critical thinking ability. The finding agrees with Sabiha (2013) that there was significant difference between the mean score of the students taught using context-based instruction integrated with learning circles and those taught using the conventional teaching method in favour of context-based instruction integrated with learning cycle model. However, the finding disagrees with Bustami et al. (2018) that there was no significant difference between the mean score critical thinking skills of students taught using context-based learning strategy and those taught using expository learning strategy.

The use of context-based learning strategy enable students' learning in the context of exploration of real world situations, events or conditions associated with the physics content. Learning through context-based provides practical contact with an observation of facts or events, which can spur students to discover evidence and build competence in terms of knowledge and critical thinking to tackle future similar

problems with confidence. The teacher provides the students with procedure or activity for discovering new knowledge. This may be responsible for the significant difference found in the mean score critical thinking in physics of students taught using context-based learning strategy and those taught using the conventional strategy.

The mean score critical thinking in physics of male students taught using graphic organizer-enhance learning strategy was higher than that of female students taught using graphic organizer-enhance learning strategy. There was no significant difference in the mean score critical thinking in physics of male and female students taught using graphic organizer-enhanced strategy. This implies that the use of graphic organizer-enhanced learning strategy is gender friendly with respect to critical thinking in physics of male and female students. The finding agrees with Remya and Chetan (2022) that there was no significant difference between the mean score critical thinking of the male and female students. However, the finding disagrees with Bart et al. (2015) that there was significant difference between the mean scores of the male and female in favour of the females.

Gender stereotyping permeates physics class when graphic organizer-enhanced learning strategy was used. The present study found no significant difference in the mean score critical thinking in physics of male and female students taught using graphic organizer-enhanced strategy. This means that the use of graphic organizer-enhanced learning strategy is gender friendly with respect to critical thinking in physics of male and female students. The use of graphic organizer-enhanced learning strategy deals with graphical information processing and linguistic processing. This is because if the information to be processed is coded both visually and verbally, the chances for male and female students in understanding the message would be double irrespective of gender, for the fact that the information is presented physically as a whole.

The mean score critical thinking in physics of male students taught using context-based learning strategy was higher than that of female students taught using context-based learning strategy. There was significant difference in the mean score critical thinking in Physics of male and female students taught using context-based learning strategy. This means that the use of context-based learning strategy is gender sensitive with respect to critical thinking in physics of male and female students. The finding agrees with Ramdani et al. (2021) that there was significant difference in the male and female posttest mean scores critical thinking in favour of the male students. However, the finding disagrees with Supriyati (2021) that there was no significant difference between the mean scores critical thinking in biology of the male and female students. The finding also disagrees with Fernandi et al. (2018) that students' critical thinking did not differ by gender.

Gender is equally important in this study with the use of context-based learning strategy. The present study found significant difference in the mean score critical thinking in Physics of male and females students taught using context-based learning strategy. This means that the use of context-based learning strategy is gender sensitive with respect to critical thinking in physics of male and female students. The use of context-based learning strategy allows students to perform activities related to real-world situations using the new knowledge or skill acquired from the concept learned with respect to their gender. This is because learning by using new concept and information in useful context in physics allows students to visualize future success careers and post-secondary education.

Finding on the interaction pattern of strategies and gender on students' critical thinking in physics revealed that the interaction plot for strategies and gender tends to cross at graphic organizer-enhanced learning strategy and conventional strategy but not at context-based learning strategy. There was

significant interaction effect of strategies and gender on students' critical thinking in physics. This interaction could come from the gender sensitivity of context-based learning as an experimental strategy.

Conclusion

The study has established that the use of graphic organizer-enhanced and context-based learning strategies in teaching physics content foster students' critical thinking skill acquisition in physics better than conventional strategy. It was equally established that graphic organizer and context-based learning strategies are gender sensitive with reference to students' critical thinking in physics. The interaction plot for strategies and gender tends to cross at graphic organizer-enhanced and conventional strategies, but not context-based learning strategy. This interaction could come from gender sensitivity of context-based learning as an experimental strategy. It was concluded that concepts in physics are better taught via graphic organizer-enhanced and context-based strategies, since the students find themselves reassessing the importance of physics and develop interest that encourage understanding of physics concepts, acquire critical thinking skills and perform better in physics. However, gender of students does not interact with strategies to affect students' critical thinking skill acquisition and academic achievement in physics.

Recommendations

The following recommendations were made in the light of the findings of this study:

1. Physics teachers should employ graphic organizer-enhanced and context-based learning in their interaction when teaching physics as the strategies have the capacity to enhance male and female students' critical thinking skill acquisition in physics.
2. Physics teachers should regularly provide the structure and opportunity for students to employ graphic organizer-enhanced and context-based strategies in their learning process.
3. In-service training programmes, seminars, work-shops and symposia should be organized by the state and federal governments to train physics teachers in the use of graphic organizer-enhanced and context-based strategies in teaching physics.
4. Graphic organizer-enhanced and context-based learning strategies should be included in the training package of teacher education programme both in colleges and at university level to ensure that teacher-trainees acquire necessary skills to effectively implement the techniques.

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