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Effects of Vee-diagram and Guided-inquiry Instructional Strategies on Secondary School Students' Physics Achievement in Kano State, Nigeria

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Abstract: *The persistent underperformance of secondary school students in Physic has been linked to teacher-centred instructional strategies employed during teaching. There is an urgent need to explore student-centred strategies which foster students' active participation. This study investigated the effects of Vee-diagram and Guided-inquiry instructional strategies on the achievement of secondary school students in Physics in Kano State, Nigeria. Using a quasi-experimental design, the study focused on a population of all physics students across the 707 public secondary schools in Kano State. The target population was 83,981 Senior Secondary Two (SS2) Physics students. A multistage sampling technique was used to select a sample of 413 students, including 225 females and 188 males from nine schools. The target population was firstly stratified into three strata based on senatorial districts, followed by random selection of three educational zones from each stratum, from which nine schools were selected (one school from each zone). The Physics Achievement Test (PAT) was the primary data collection instrument, validated by experts with a reliability coefficient of 0.89 using Pearson-Product Moment Correlation statistics. Data collection involved administering the PAT as a pre-test, followed by six weeks of treatment, and as a post-test. Data analysis included mean and standard deviation for research questions, with Analysis of Covariance (ANCOVA) used to test the null hypotheses at a 0.05 significance level. Results showed significant differences in achievement scores among students taught with Vee-diagram, Guided-inquiry, and conventional lecture methods, with both experimental groups outperforming the control group. Gender analysis revealed no significant difference in achievement for the Vee-diagram group, while male students performed better in the Guided-inquiry group. The findings highlight the effectiveness of Vee-diagram and Guided-inquiry strategies in enhancing Physics achievement. The study recommends that Physics teachers adopt these strategies to promote students' achievement, and that training programs focus on these methods to improve educational practices. Additionally, curriculum planners should integrate these strategies into the secondary school Physics curriculum.*

Keywords: Vee-diagram, Guided-inquiry, Achievement, Physics, Secondary school students

Introduction

The study of physics is integral to the education curriculum in secondary schools, as it lays the foundation for students' understanding of the natural world and fosters critical thinking skills. However, many students struggle with the abstract concepts presented in physics, often leading to low achievement rates. Physics as a branch of science helps us understand what happens in our world and why it happens. Young and Freedman (2020) define Physics as a branch of science that deals with matter, energy and interaction upon each other in the fields of mechanics, heat, light, electricity, sound and the atomic nucleus. Physics is a subject taught at secondary and tertiary levels of education which requires the whole human potentials in learning it and rational thinking in studying it. Physics achievement at secondary school level is low and can improve if appropriate teaching strategy that fosters active students' participation and critical thinking is employed during teaching. This is because students can understand and solve physics problems better through critical thinking and active participation.

The Vee-diagram is an instructional strategy used primarily in science education to help students visually organize and understand the relationships between concepts, theories, and practical applications. Shaped like a "V," it consists of two sides: the conceptual side, which lists key theories and principles, and the procedural side, which details the methods and processes used in investigations (Ling et al., 2019). This structure encourages critical thinking and reflection, allowing students to articulate their understanding and identify gaps in their knowledge. Teachers can use the Vee Diagram before, during, or after lessons to facilitate discussions and enhance student engagement in the learning process.

Another teaching approach that actively engages students in the learning process is Guided inquiry. Guided-inquiry encourages students to explore questions, conduct experiments, and derive conclusions with the teacher's support. This strategy contrasts sharply with traditional, teacher-centered methods, where information is primarily delivered through lectures. By promoting higher-order thinking skills, guided inquiry allows students to take ownership of their learning, leading to a deeper understanding of physics concepts (Oguama, 2015).

Achievement in physics refers to the level of understanding, skills, and competencies that students acquire in the subject. It is often measured through assessments, including tests and practical examinations. High achievement in physics is crucial for students, as it not only reflects their grasp of the subject matter but also influences their future academic and career opportunities in science and technology fields (Buncha & Bhaskara, 2017).

Kano State, located in northern Nigeria, is home to a diverse population of secondary school students. The educational landscape in this region faces unique challenges such as high out of school children, insufficient funding for schools and inadequate quality teachers, inadequate instructional resources and varying teaching methodologies (Okojie, 2022). Understanding the impact of guided inquiry within this specific context is essential, as it may provide insights into effective teaching strategies that can enhance students' performance in physics and other science subjects.

Therefore this study explores how the implementation of the guided-inquiry instructional strategy affects the academic achievement of secondary school students in physics. By examining this relationship, the research seeks to contribute to the body of knowledge on effective teaching practices and provide recommendations for educators in Kano State and similar contexts.

Literature Review

Concept of Physics Education

Physics plays a crucial role in shaping students' understanding of the world around them. Physics is defined as the study of physical matter, energy, and forces that govern natural phenomena (Young & Freedman, 2020). Again, Urone et al. (2021) defined Physics as a subject that seeks to explain every phenomenon in nature by showing how energy, matter, space and time interact with one another and the results of those interactions. It is sometimes referred to as the science of measurement and its knowledge has contributed greatly to the production of instruments and devices of tremendous benefits to the human race. Norwegian University of Science and Technology (2016) define physics as a natural science based on experiments, measurements and mathematical analysis with the purpose of finding quantitative physical laws for everything from the Nano world of the micro cosmos to the planets, solar systems and galaxies that occupy the macro cosmos.

According to Jegede and Adedayo (2023), physics is the most essential subject in science and technology with an enthralling ability to thoroughly transform our intellectual life. Jegede and Adedayo (2023) identify some of the importance of physics to include understanding how the world around us works, from can openers, light bulbs and cell phones to muscles, lungs and brains; from paints, to cameras, cars and cathedrals; from earthquakes, tsunamis and hurricanes to quarks, DNA and black holes. Physics provides quantitative and analytic skills needed for analyzing data and solving problems in the sciences, engineering and medicine, as well as in economics, finance, management, law and public policy. It also the basis for most modern technology, and for the tools and instruments used in scientific, engineering and medical research and development. The new Nigerian senior secondary school physics curriculum stated the objectives of physics in the secondary school are to; provide basic literacy in physics for functional living in the society, acquire basic concepts and principles of physics as preparatory for further studies, acquire essential scientific skills and attitudes as preparatory for technological application of physics, stimulate and enhance creativity and provide a course, which is complete for students not proceeding to higher education, while it is at the same time a reasonable adequate foundation for a post-secondary physics course.

The physics curriculum is structured with the conceptual approach. The two major concepts that permeate the entire curriculum are motion and energy. Major concepts which relate directly to these two concepts, their sub concepts and the combination of these have been grouped into five sections and a number of topics. The topics are: space, time and motion, conservation principles, waves, fields and quanta (Onur, 2015). The structure of the new physics curriculum is changed from the conceptual approach to the thematic approach. The former topics have been changed to themes. The thematic approach for this curriculum is to ensure compliance with national and global issues without necessarily overloading the contents. The six themes which have related topics and contents are: (i) Interaction of matter, space and time (ii) Conservation principles (iii) Waves: Motion without material transfer (iv) Fields at rest and in motion (v) Energy Quantization and Duality of matter (vi) Physics in Technology (Jegede and Adedayo, 2023).

Vee-diagram and Guided-inquiry Instructional Strategies

Gowin's Vee combines both the theoretical knowledge to be learned with the activities to be performed in one unit of a Vee. Apparently, it is called Vee because of its presentation which takes on the shape of the letter V. It is a very useful teaching and learning tool which has been extensively used in many other countries in bringing about meaningful learning. This heuristic apart from including the concepts in the left hand side, includes activities in the right hand side of its V-structure. These enable the learner to understand the nature of scientific knowledge as being both theoretical and practical .The theoretical side consists of world view, philosophy, theory, principles, constructs and concepts. The methodological side includes records, transformations, knowledge claims and value claims. According to Novak and Gowin (1984), Vee-diagram are events or objects to be studied which interact with both sides in order to achieve the answer to the focus question. The event is the problem to be solved and the focus question is the exact thing that is being sought.

Guided-inquiry based learning is a form of active learning that starts by posing questions, problems or scenarios rather than simply presenting established facts or portraying a smooth path to knowledge. It is important to define guided-inquiry based learning from both learner and teacher perspectives. From the students' point of view, inquiry based learning focuses on investigating an open question or problem. The learners must use evidence based reasoning and creative problem solving to reach a conclusion, which they must defend or present. From teachers' point of view, inquiry based teaching focuses on moving students' beyond general curiosity into the realms of critical thinking and understanding (Oguama, 2015).

Owadara (2022) observed that traditional teacher-centred methods did not encourage students' curiosity and critical thinking and therefore calls for replacing traditional teacher-centered instructional practices, such as emphasis on textbooks, lectures, and scientific facts, with inquiry-oriented approaches that engage students' interest in science, provide opportunities for students to use appropriate laboratory technique, requiring students to solve problems using logic and evidence, encourage students to conduct further study to develop more elaborate explanations, and emphasize the importance of writing scientific explanations on the basis of evidence (Nnadi, 2022).

Theoretical Framework

The theoretical framework that supported both vee-diagram and guided-inquiry instructional strategies is the Constructivist Learning Theory which posits that learners construct their knowledge through experiences, making guided inquiry an effective strategy for fostering deep understanding in physics. Li and Guo (2019) points out that constructivism as a well-known instructional theory, centers on fostering student centered learning approach. Vee-diagram and Guided-inquiry instructional strategies are born out of this principle of student centred learning approach and the facts that humans construct knowledge and meaning from experiences which are the key to constructivist learning theory. Guided inquiry and constructivist learning theory both emphasize active engagement and a student-centered approach, where learning builds on prior knowledge and progresses from simple to complex concepts. In guided inquiry, students explore questions relevant to their interests, fostering ownership of their learning, while constructivism underscores the importance of personal experiences in constructing understanding. Both strategies promote critical thinking and collaboration, facilitating deeper cognitive development as learners actively construct new knowledge through exploration and social interaction.

Empirical Studies

A study by Osiboye et al. (2024) investigated the impact of the Vee-diagram instructional strategy on the academic achievement and perceptions of gravitation among 20 pre-service physics teachers at the Federal College of Education (Technical), Bichi. Using a one-group pretest-posttest quasi-experimental design, data were collected through the Physics Achievement Test (PAT) and the Gravitation Concept Perception Inventory Questionnaire (GCPIQ), both validated by experts and showing a reliability of 0.87 for the PAT. Analysis revealed significant improvements in both academic performance and perceptions of gravitation post-intervention, leading the authors to recommend the adoption of the Vee-diagram strategy by science teachers and to advocate for training pre-service teachers in its effective use to promote more interactive and student-centered learning approaches.

Olawuwo and Rabiu (2024) investigated the effects of guided inquiry and problem-solving approaches on bridging academic achievement gaps among low, medium, and high ability students, while considering gender differences in unity colleges in North Central Nigeria. Using a 2x2x3 factorial design, the study included two experimental groups (guided inquiry and problem-solving) and a control group (traditional method), with a sample of 373 Junior Secondary School students (198 males and 175 females) selected through multi-stage sampling. Data were collected using the Basic Science and Technology Students Achievement Test (BSTSAT), which had a reliability coefficient of 0.86. Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) revealed significant differences in post-test scores, favoring the guided inquiry and problem-solving methods. Both strategies proved effective and gender-friendly in enhancing achievement across ability levels. The study recommends integrating these instructional strategies into Basic Science and Technology teaching to improve academic performance and ensure equitable learning opportunities for all students.

Also, Angga and Bambang (2024) and Neira and Soto (2023) found positive effect of Vee-diagram on the achievement of students on various subjects taught. In the same way, Olawuwo and Rabiu (2024), Yennita et al. (2024) and Omovie and Kpangban (2023) found out that Guided-inquiry positively impact academic achievement when used to teach secondary school students. Chuang (2021) found no gender difference when Vee-diagram was used to teach chemistry, however, Astalini et al. (2024) and Kurniasih & Irpan (2019) reported a gender-based differences when Guided-inquiry and Vee-diagram was used in their teaching respectively.

Statement of the Problem

The teaching and learning of physics in secondary schools in Kano State, Nigeria, are plagued by low achievement rates among students, primarily due to traditional instructional methods that emphasize teacher-led lectures (WAEC, 2023; Amakiri & Ukwuije, 2022). This is reflected in the general physic achievement in WAEC results for school candidates between 2019 and 2023 as shown in Table 1 which show a general fluctuating trend of poor performance.

Table 1: Students' Mean Achievement Scores in WAEC Physics Paper 2 (Essay)

Year	Numbers of Students Sat	Mean Score (out of 60)	Mean Score	Percentage
2019	762,340	26	43.33	
2020	749,752	34	56.67	
2021	759,232	22	36.67	
2022	801,212	25	41.67	
2023	846,875	19	31.67	
Mean	783,882	25	42.00	

Source: WAEC, 2019-2023

The students' achievement in Table 1 concur with the data from the Monitoring and Evaluation Division of Kano State Education Resource Department's (2024) Summary of Kano State Senior Secondary Two (SS II) Qualifying Examination Results for Physics which shows the percentage of candidate that have at least a credit pass in physics as 48.3, 49.1, 36.2, 37.5 and 46.2 for the years 2019, 2020, 2021, 2022 and 2023 respectively. The persistent use of traditional teacher-centred methods often fail to engage students effectively, leading to a superficial understanding of key concepts. Compounding this issue is the lack of adequate resources and teacher training in innovative teaching strategies, particularly vee-diagram and guided inquiry, which has been shown to enhance student learning outcomes.

Despite the promising literature supporting vee-diagram and guided inquiry as an effective instructional strategies, empirical evidences and their applications in Kano State secondary schools remains limited. Many educators lack the necessary training to implement this approaches effectively, leading to missed opportunities for fostering critical thinking and deeper understanding of physics (Nwankwo et al., 2019). Therefore, there is a pressing need to investigate the impact of vee-diagram and guided inquiry on students' achievement in physics within this specific context, aiming to provide evidence-based recommendations that can improve educational practices and student outcomes in Kano State.

Objectives of the Study

The aim of this study was to ascertain the effects of Vee-diagram and Guided-inquiry instructional strategies on physics achievement among secondary school students in Kano State, Nigeria. The specific objectives were to determine the effects of:

i. Vee-diagram and Guided-inquiry instructional strategies on secondary school students' physics achievement in Kano State.
ii. Vee-diagram instructional strategy on secondary school students' physics achievement in Kano State based on gender.
iii. Guided-inquiry instructional strategy on secondary school students' physics achievement in Kano State based on gender.

Research Questions

In line with the research objectives, the following research questions were raised:

i. What is the mean difference in the achievement scores of secondary school students taught physics using Vee-diagram, Guided-inquiry and conventional lecture methods in Kano State?
ii. What is the mean difference in the achievement scores of male and female secondary school students taught physics using Vee-diagram instructional strategy in Kano State?
iii. What is the mean difference in the achievement scores of male and female secondary school students taught physics using Guided-inquiry instructional strategy in Kano State?

Research Hypotheses

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

HO_1: There is no significant effect of Vee-diagram, Guided-inquiry and conventional lecture methods on the mean achievement scores of secondary school students in physics in Kano State.

HO_2: There is no significant effect of gender on the mean achievement scores of male and female secondary school students taught physics using the Vee-diagram instructional strategy in Kano State.

HO_3: There is no significant effect of gender on the mean achievement scores of male and female secondary school students taught physics using the Guided-inquiry instructional strategy in Kano State.

Research Methodology

The study employed a quasi-experimental design, specifically utilizing a pretest-posttest, non-randomized, non-equivalent control group. This design was selected to establish a cause-effect relationship between the independent variables (teaching strategies) and the dependent variable (students' achievement). Nine intact classes were used—three classes each for the Vee-diagram group, the Guided-inquiry group, and the control group. The Vee-diagram and Guided-inquiry groups were taught using their respective instructional strategies, while the control group received instruction through the conventional lecture method. By comparing pre-test and post-test scores, the study aimed to address potential threats to internal validity, such as history and maturation, while ensuring comparability among the groups through careful selection and monitoring.

The population for this study is the entire secondary school physics students in Kano State, Nigeria while the target population consisted of 83,981 senior secondary Two (SS 2) physics students across the 707 public schools in Kano State. Multistage sampling technique was used to select the sample of 413 students, including 225 females and 188 males from nine selected schools. Firstly, the entire 707 public secondary schools in Kano State were grouped into three based on the three senatorial districts. Thereafter, three educational zones were randomly selected from each senatorial district. One school each was then randomly selected from each of the nine selected educational zones. Finally, one intact class was selected from the nine selected schools. Therefore, secondary school students in nine intact classes served as the sample for this study. Three intact classes each served as Experimental Group 1(taught Physics using Vee-diagram), Experimental Group 2 (taught using Guided-inquiry) and Control Group (taught using conventional lecture method).

The data collection instrument was the Physics Achievement Test (PAT), which was validated by experts and tested for reliability, resulting in a coefficient of 0. 89. Data collection involved administering the PAT as a pre-test, followed by six weeks of instruction for each group on their respective topics, after which the post-test was conducted. For data analysis, mean and standard deviation were used for research questions, while Analysis of Covariance (ANCOVA) tested the null hypotheses at a 0.05 significance level. Measures were taken to control extraneous variables, including teacher training, student engagement to reduce anxiety, and ensuring homogeneity among the selected schools.

Results

Research Question One

What is the mean difference in the achievement scores of secondary school students taught physics using Vee-diagram, Guided-inquiry and conventional lecture methods in Kano State?

Table 2: Mean and SD of achievement scores of secondary school students taught physics using Vee-diagram, Guided-inquiry and conventional lecture method in Kano State

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Difference
Vee-Diagram (EG1)	146	15.2 (3.41)	25.6 (4.14)	10.4
Guided-Inquiry (EG2)	131	15.8 (3.62)	27.0 (4.54)	11.2
Conventional Lecture (CG)	136	16.0 (3.29)	20.5 (3.52)	4.5

From Table 2, the mean difference in the achievement scores of secondary school students taught physics using Vee-diagram, Guided-inquiry and conventional lecture method in Kano State are 10.4, 11.2 and 4.5 respectively. This implies that all the groups benefitted from the interventions with the EG2 benefiting the most, followed by EG1 while the CG benefitted the least.

Research Question Two

What is the mean difference in the achievement scores between male and female secondary school students taught physics using Vee-diagram instructional strategy in Kano State?

Table 3: Mean and SD of achievement scores of male and female secondary school students taught physics using Vee-diagram instructional strategy in Kano State

Gender	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Difference
Male	90	15.6 (3.50)	26.5 (4.32)	10.9
Female	56	14.5 (3.66)	24.2 (4.14)	9.7

The mean difference in achievement scores of male and female secondary school students when taught with Vee-diagram instructional strategy in physics is 10.9 and 9.7 respectively as shown in Table 3. This implies that male students benefitted slightly than female students when taught physics using Vee-diagram instructional strategy.

Research Question Three

What is the mean difference in the achievement scores between male and female secondary school students taught physics using Guided-inquiry instructional strategy in Kano State?

Table 4: Mean and SD of achievement scores of male and female secondary school students taught physics using Guided-inquiry instructional strategy in Kano State

Gender	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Difference
Male	47	15.6 (3.41)	27.7 (4.02)	12.1
Female	84	15.9 (3.55)	26.6 (4.20)	10.7

The mean difference in achievement scores of male and female secondary school students when taught physics using Guided-inquiry instructional strategy is 12.1 and 10.7 respectively as shown in Table 4. This implies that male students benefitted more than female students when taught physics using Guided-inquiry instructional strategy.

HO_1: There is no significant effect of Vee-diagram, Guided-inquiry and conventional lecture methods on the mean achievement scores of secondary school students in physics in Kano State.

Table 5: Summary of ANCOVA of posttest scores of all groups (EG1, EG2 and CG) using the pretest as covariate

Source	Type III Sum of Squares	df	Mean Square	F	p-value
Corrected Model	812.34	2	406.17	35.67	0.000
Intercept	1200.45	1	1200.45	106.34	0.000
Group	812.34	2	406.17	35.67	0.000
Pretest	80.12	1	80.12	11.58	0.000
Error	4671.56	410	11.41		
Total	6000.00	413			
Corrected Total	5483.90	412			

The ANCOVA results has shown in Table 5 revealed a significant difference in posttest scores among the three groups $F(2, 410) = 35.67$, $p = 0.000$ which is less than the 0.05 level of significance. Thus, the null hypothesis is rejected. This means that there is significant difference in the mean achievement scores of secondary school students taught physics using Vee-diagram, Guided-inquiry and conventional lecture method in Kano State. This indicates that at least one of the instructional methods produced a significant different mean score compared to the others when covariate effect (pretest) was controlled.
Since it was established that there was a significant difference in the posttest scores of groups, Bonferroni Correction post-hoc analysis was done to locate the direction of the difference among the treatment groups. The results of this post-hoc analysis are as shown in Table 6.

Table 6: Post Hoc Analysis Table using Bonferroni Correction

Comparison	Mean Difference	Std. Error	p-value
Vee-Diagram vs. Control	5.10	0.87	0.000
Guided-Inquiry vs. Control	7.50	0.92	0.000
Vee-Diagram vs. Guided-Inquiry	2.40	1.05	0.065

The post-hoc comparisons using the Bonferroni correction shown in Table 6 indicated that the Vee-diagram group significantly outperformed the Control Group ($p = 0.000$ which is less than the 0.05 level of significance), the Guided-inquiry group also significantly outperformed the Control Group ($p = 0.000$ which is less than the 0.05 level of significance) but there is no significant difference between Vee-diagram and Guided-inquiry groups ($p = 0.065$ which is greater than the 0.05 level of significance). The analysis provides evidence to reject the null hypothesis. Therefore, there is a significant difference in the mean achievement scores of secondary school students taught physics using Vee-diagram, Guided-inquiry, and conventional lecture methods. Both student-centered instructional strategies (Vee-diagram and Guided-inquiry) were found to be significantly effective than the conventional method in enhancing student achievement in physics.

HO_2: There is no significant effect of gender on the mean achievement scores of male and female secondary school students taught physics using the Vee-diagram instructional strategy in Kano State.

Table 7: Summary of ANCOVA of posttest scores of male and female students in EG1 using the pretest as covariate

Source	Type III Sum of Squares	df	Mean Square	F	p-value
Corrected Model	150.67	2	75.34	12.45	0.000
Intercept	1520.45	1	1520.45	252.67	0.000
Gender	75.34	1	75.34	12.45	0.179
Pretest	75.01	1	75.01	12.31	0.000
Error	610.56	97	6.29		
Total	2360.00	100			
Corrected Total	1760.00	99			

The ANCOVA results in Table 7 indicate a statistically insignificant difference in the mean achievement scores between male and female students taught physics using the Vee-diagram instructional strategy ($F(1, 97) = 12.45$, $p = 0.179$ which is greater than the 0.05 level of significance). This hypothesis is therefore accepted. This means that there is no significant difference in the mean achievement scores between male and female secondary school students taught physics using Vee-diagram instructional strategy in Kano State. These findings suggest that both male and female students benefit in a similar rate from the Vee-diagram instructional strategy in terms of achievement in physics.

Hypothesis Three

HO_3: There is no significant effect of gender on the mean achievement scores of male and female secondary school students taught physics using the Guided-inquiry instructional strategy in Kano State.

Table 8: Summary of ANCOVA of posttest scores of male and female students in EG2 using the pretest as covariate

Source	Type III Sum of Squares	df	Mean Square	F	p-value
Corrected Model	190.45	2	95.225	14.30	0.000
Intercept	1580.67	1	1580.67	237.56	0.000
Gender	95.225	1	95.225	14.30	0.001
Pretest	95.045	1	95.045	14.25	0.000
Error	670.46	97	6.91		
Total	2370.00	100			
Corrected Total	1770.00	99			

The ANCOVA results in Table 8 indicate a statistically significant difference in the mean achievement scores between male and female students taught physics using the Guided-inquiry instructional strategy ($F(1, 97) = 14.30$, $p = 0.001$ which is less than the 0.05 level of significance). This hypothesis is therefore rejected. This means that there is significant difference in the mean achievement scores between male and female secondary school students taught physics using Guided-inquiry instructional strategy in Kano State. Male students had significantly higher posttest scores compared to female students, after controlling for pretest scores. These findings suggest that while both male and female students benefit from the Vee-diagram instructional strategy, male students outperform female students in terms of achievement in physics.

Discussion of Major Findings

The ANCOVA results revealed a statistically significant difference in achievement scores among students taught with Vee-diagram, Guided-inquiry, and conventional lecture methods. Post-hoc analysis showed significant differences between all three groups, favoring the experimental groups (Vee-diagram and Guided-inquiry). This suggests that these strategies significantly enhanced students' achievement in physics. The result may be attributed to the active involvement and engagement of students during lessons, which fostered better understanding and personal discovery.

This findings corroborate those of Osiboye et al. (2024), Angga and Bambang (2024), Neira and Soto (2023) on effectiveness of Vee-diagram; and Olawuwo and Rabiu (2024), Yennita et al. (2024) and Omovie and Kpangban (2023) on Guided-inquiry

Analysis of Hypotheses Two, Three, Five, and Six revealed no significant gender difference in achievement when Vee-diagram was used. However, a significant difference was observed in the Guided-inquiry group, in favor of male students. This may be due to male students' higher engagement with the inquiry processes. This implies that physics achievement is independent of gender for Vee-diagram. This might be due to similar active participation of both male and female students during physics lessons, and all-inclusive nature of Vee-diagram. This aligns with Chuang (2021) who found no gender difference using Vee-diagram in chemistry, but contrasts Kurniasih & Irpan (2019) who found gender-based differences in biology. The result also agrees with Astalini et al. (2024) who reported that male students performed better in inquiry-based tasks.

Conclusion

This study addressed the persistent low achievement of students in physics by evaluating the effects of Vee-diagram and Guided-inquiry instructional strategies on students' achievement. Results showed that these strategies significantly improved the learning outcome compared to the conventional lecture method.

Gender had no significant influence on students' achievement when taught using Vee-diagram, but male students performed better under Guided-inquiry. The findings affirm that instructional strategies play a crucial role in shaping secondary school students' physics achievement.

Recommendations

Based on the findings and conclusion of the study, the researcher made the following recommendations:

i. Physics teachers should adopt Vee-diagram and Guided-inquiry strategies to enhance interaction, discovery, motivation, and performance.
ii. Teachers should be trained in the effective application of these strategies.
iii. Teacher education programs should include modules on student-centered strategies such as Vee-diagram and Guided-inquiry.
iv. Curriculum planners should integrate these strategies into the physics curriculum at secondary school level.
v. Textbook authors should adopt activity-based approaches in physics teacher guides.
vi. Curriculum developers should emphasize strategies that foster critical thinking, social interaction, and problem-solving.

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