Effects of Vee-Diagram and Guided-Inquiry Instructional Strategies on Achievement in Physics among Secondary School Students in Akwa Ibom State, Nigeria

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Abstract

The persistent poor performance in Physics among secondary students in Akwa Ibom State has been linked to teacher centered instructional strategies employed during teaching. There is an urgent need to explore student centered strategies which foster students' active participation. This study investigated the effect of Vee-Diagram and Guided Inquiry Instructional Strategy on achievement in Physics among the senior secondary school student in Akwa Ibom State. A sample of 146 (66 females and 80 males) senior secondary school (SS2) Physics students were draw from the population of 43,981 comprising of 25,900 males and 18,081 females SS2 Physics students in all the 256 public secondary schools of (2024/2025) in Akwa Ibom State. The study was guided by 3 specific objectives, 3 research questions and3 null hypotheses tested at 0.05 level of significance. The study adopted the quasi-experimental research design involving two experimental groups and one control group. The experimental group were taught using Vee–Diagram and Guided Inquiry while the control group were taught using the conventional method. The instrument used for data collection was Physics Achievement Test (PAT).PAT was subjected to face and content validation by three experts from the Department of Science Education of Michael Okpara University of Agriculture ,Umudike.The reliability of the instruments was established using Kuder-Richarson 20 formula ($K - R_{20}$).The reliability index was 0.89.Mean and standard deviation were used to answer the research questions while the hypotheses were analyses using (ANCOVA) analysis of covariance at a p-value of 0.05. Results indicated that students taught with the Vee–Diagram had significantly higher mean scores compared to those in the other groups. While male students showed higher gains, no significant gender differences were found across teaching methods. In conclusion, the Vee–Diagram significantly enhances academic achievement in Physics without gender bias. Recommendations include adopting the Vee–Diagram approach in teaching of Physics and providing necessary resources for its effective implementation in public secondary schools

Keywords: Vee – Diagram, Guided Inquiry, Academic Achievement, Physics. .

Introduction

Physics is a crucial component of the science curriculum in Nigerian secondary schools, essential for technological advancement of any nation. Young & Freedman (2020) describe Physics as the study of matter, energy, and their interactions across various domains, including mechanics, heat, light, electricity, sound, and atomic structure. It is taught at both secondary and tertiary education levels, demanding full engagement and critical thinking from students. Mastery of Physics concepts and problem-solving requires rational thought, positioning Physics as a crucial subject that underpins advancements in Science and Technology. Oguama (2015) emphasized that Physics plays a vital role in equipping students with essential scientific skills necessary for a progressive society. Obviously, Science and Technology would be incomplete without Physics. This is because the knowledge gained from Physics is applied to almost every human activity and every profession involves some elements of Physics. For instance, the principles of electromagnetism have been widely used for various economic, scientific and technological inventions such as in the manufacture of electrical appliances as well as in information and communication technology, which has transformed the world into a global village through the use of computers and satellite. Also, knowledge of Physics is used to manufacture nuclear weapons, scan the internal organs of our body, study the motion of aeroplanes and rockets in the air, and several other applications. It is an undeniable fact that Physics should be a top priority for stakeholders in Science Education. However, two significant challenges exist regarding student engagement with Physics namely, performance and enrollment. According to Obialor and Osuafor (2019), despite its importance for national development, Physics is the least popular science subject among secondary school students. This is evident in the low enrollment in Physics courses in both secondary schools and tertiary institutions, as well as students' poor performance in the subject

Similarly, Buncha and Bhaskara (2017) noted that, despite its crucial contributions to scientific progress, Physics is often the least preferred subject among students, due to the abstract nature of many Physics concepts, which demand strong critical thinking and Mathematical skills. Many students not only find Physics difficult but also tend to avoid it. To equip students with the necessary mathematical and critical thinking abilities, it is vital to carefully select instructional strategies for teaching Physics. These strategies determine how students are taught and the approaches teachers use to help students acquire the desired knowledge, skills, and attitudes. Although lecture and demonstration methods are common due to their effectiveness in conveying information to large groups, they often result in passive learning among students. Wuryani and Yufiarti (2017) describe conventional teaching methods as teacher-centered, where the instructor is the primary source of information, focusing solely on covering the syllabus without ensuring that students have acquired the necessary competencies.

One seemingly effective method is the Vee-diagram, developed by Novak and Gowin in 1978 (Gülhan & Ahmet, 2016). This learner-centered strategy enhances understanding by

connecting theoretical concepts with practical applications, promoting deeper learning in subjects like Physics. The Vee-diagram serves as a graphic organizer that helps students structure their knowledge around problem-solving, illustrating the relationship between theoretical knowledge and practical application. Its left side focuses on the conceptual framework—principles, concepts, and theories—while the right side emphasizes methodological aspects, such as observations, data collection, and interpretations. This approach is particularly beneficial for helping students to relate theory to practice, fostering critical thinking and reflective learning as they analyze what they know and how they acquired that knowledge (Kayacan, 2018).

Another effective student-centered strategy that promotes active learning and critical thinking is Guided-inquiry. This approach encourages students to explore and investigate Physics concepts with support from the teacher (Fatokun & Yalams, 2018). In Guided-inquiry, the teacher provides a framework or guiding questions to assist students as they conduct experiments, gather and analyze data, and draw conclusions. Unlike traditional methods where knowledge is directly transmitted, Guided-inquiry allows students to uncover principles through structured exploration (Akuma, 2019).

Students' achievement in Physics is reflected in their performance over time, indicating whether they have succeeded or failed. Sinha and Mishra (2015) pointed out that achievement does not have a fixed definition; it is typically assessed through students' test scores and examination results. Kristiyani & Faturochman (2018) emphasized that achievement is measured by goal attainment and visible development, which are influenced by the students' input, abilities, and the learning process.

Neira and Soto (2023) researched on Creativity and Physics Learning as product of the intervention with Conceptual Maps and Gowin's Vee Diagram. The population consisted of all first-year students of Civil Engineering at the University of Bíobío Chile. The design for the study is quasi-experimental. The sample is composed of first-year students participating in the modular course Physics I which are 74 students in Civil Engineering at the University of Bíobío, Concepción, of which (20.3%) were female and (79.7%) male. The sampling technique is the simple random type, where all subjects have the same probability to be part of the experimental or control group. The data collecting instrument used were (A) Interest and Creative Performance Questionnaire (ICPQ): test that identifies creative abilities of students. It has 60 items grouped into five criteria and (B) Academic performance was measured by a test, the validity of content is ensured to have been built by experts. The ICPQ's content validity was ensured through expert evaluation, and the academic performance test was also validated by subject matter experts. ICPQ showed Cronbach's Alpha values ranging from $\alpha = .694$ to $\alpha = .832$ for its subscales, with an overall reliability of $\alpha = 0.9$ while the reliability of the academic performance test was ensured through expert input.

The results indicate that the proposed methodological innovation based learning on concept maps and Gowin's Vee diagram to address the contents of Physics I with Civil Engineering students, can promote the construction of knowledge and some characteristics of creative thinking. It also promotes academic success as students from the experimental group obtained higher scores. The effectiveness of the Vee-based learning and concept maps can be seen.

Olawuwo and Rabiu (2024) investigating the effects of Guided inquiry and Problem-solving approaches on bridging the gap in academic achievement among low, medium, and high ability students, considering gender differences in unity colleges in North Central Nigeria. It employed a 2x2x3 factorial research design with two experimental groups (guided inquiry and problem-solving) and a control group (traditional method). The population consisted of Junior Secondary School (JSS) students, with a sample of 373 participants (198 males and 175 females) selected through a multi-stage sampling technique. The Basic Science and Technology Students Achievement Test (BSTSAT) was utilized for data collection, with a reliability coefficient of 0.86 confirmed through the Pearson Product Movement Correlation. Data analysis involved using Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) to assess the differences in achievement scores among the groups. The results indicated significant differences in post-test mean scores, favoring the guided inquiry and problem-solving methods over the traditional approach. Furthermore, the findings showed that both instructional strategies were gender-friendly and effective in improving student achievement across different ability levels. Based on these results, the study recommends the incorporation of guided inquiry and problem-solving strategies in teaching Basic Science and Technology to enhance academic performance and provide equitable learning opportunities for all students, regardless of their ability or gender.

Kurniasih and Irpan (2019) carried out a study which aimed to compare the effectiveness of two instructional media (Vee Diagram and mind mapping) on students' conceptual understanding of plant reproduction in a biology education context. Conducted as a quasi-experimental research design, the study involved second-year students from the Biology Education Study Program at Pakuan University. The selected participants were from two classes (IVB and IVC), with IVB using the Vee Diagram and IVC employing mind mapping. Data collection methods included paper-and-pencil tests, observations, and documentation, allowing for a comprehensive evaluation of student understanding. The study's results indicated that students using the Vee Diagram achieved a higher average conceptual understanding score compared to those using mind mapping, suggesting that the Vee Diagram facilitated better learning outcomes.

Statement of the Problem

The teaching of Physics in secondary schools in Akwa Ibom State, Nigeria. Had faced significant challenges, particularly in fostering positive student attitudes toward the subject. Despite the crucial role Physics plays in understanding scientific concepts and technological

advancement of any nation. Many students exhibit a lack of interest and this lead to poor performance. Ogunneye (2018) found out that over half of the Physics concepts are perceived as difficult, contributing to students' low performance. The WAEC Chief Examiners' Reports (2020) identified several weaknesses, including poor problem-solving skills, difficulties in accurately plotting and interpreting graphs, lack of attention to instructions, and challenges in solving mathematical problems within a Physics context. The ongoing low achievement levels in Physics (Amakiri & Ukwuije, 2022; WAEC Chief Examiners' Reports, 2020) gives much concerns and require immediate intervention to prevent declines in technological innovation, stagnation in industrial growth, and reduced competence in STEM fields, which could have significant economic repercussions.

Student-centered instructional strategies, such as Vee-diagrams and Guided-inquiry, emphasize practical activities that create connections between theory and real-life situations. These approaches may lead to a better understanding of the concepts taught, enhance students' problem-solving skills, and address specific weaknesses identified in the WAEC Chief Examiners' Reports, such as graph plotting and mathematical problem-solving. By effectively addressing these weaknesses, students' achievement in Physics are likely to improve. Therefore, the problem statement of this study is to examine the effect of Vee-diagram and Guided-inquiry instructional strategies on achievement of secondary school Physics students in Akwa Ibom State, Nigeria.

Purpose of the Study

The general purpose of this study was to ascertain the effects of Vee-diagram and Guided-inquiry instructional strategies on achievement in Physics among senior secondary school students in Akwa Ibom State, Nigeria. Specifically, the study tended to ascertain the:

1 Vee-diagram instructional strategy, Guided inquiry and lecture method on students' achievement in Physics.
2 Vee-diagram instructional strategy on students' achievement in Physics based on gender.
3 Guided inquiry instructional strategy on students' achievement in Physics based on gender.

Research Questions

The following research questions were raised to guide the study:

1 What are the mean achievement scores of students in Physics when taught with Vee-diagram, Guided-inquiry instructional strategy and Conventional method?
2 What are the mean achievement scores of male and female students in Physics taught with Vee - diagram instructional strategy?
3 What are the mean achievement scores of male and female students in Physics taught with Guided inquiry instructional strategy?

Research Hypotheses

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

Ho_1: There is no significant difference among the mean achievement scores of students in Physics taught with Vee-diagram, Guided inquiry and Conventional method?

Ho_2: There is no significant difference between the mean achievement scores of male and female student taught Physics using Vee-diagram instructional strategy?

Ho_3: There is no significant difference between the mean achievement scores of male and female student taught Physics using Guided inquiry instructional strategy?

Research Methodology

The study utilized a quasi-experimental design, specifically a non-equivalent control group approach, involving pre-test, treatment, and post-test measures. This design was chosen to establish a cause-effect relationship between the independent variables (teaching methods) and the dependent variables (students' achievement).Three Intact classes were used, by comparing pretest and posttest scores, the study aimed to mitigate threats to internal validity such as history and maturation while ensuring that the groups remained comparable.

The research was conducted in Akwa Ibom State, Nigeria, focusing on Senior Secondary Two (SS2) Physics students across 256 public secondary schools. The total population was 43,981 comprising of 25,900 males and 18,081 females from which a sample of 146 students was purposively selected. Multistage sampling procedure was used to select the three intact classes, two experimental groups and one control group. The experimental group were taught using Vee – Diagram and Guided Inquiry while the control group were taught using the conventional method. The instrument used for data collection was Physics Achievement Test (PAT).PAT was subjected to face and content validation by three experts from the Department of Science Education of Michael Okpara University of Agriculture ,Umudike.The reliability of the instruments was established using Kuder-Richarson 20 formula ($K - R_{20}$).The reliability index was 0.89.Mean and standard deviation were used to answer the research questions while the hypotheses were analyses using (ANCOVA) analysis of covariance at a p-value of 0.05. Measures were taken to control extraneous variables, including training for teachers, engaging with students to minimize anxiety, and ensuring homogeneity among the selected schools.

Results

Research Question 1: What are the mean achievement scores of students in Physics when taught with Vee-diagram, Guided-inquiry instructional strategy and Conventional method?

Table 1: Mean pre-test and post test scores of students in Physics when taught with Vee-diagram, Guided-inquiry instructional strategy and lecture method

S/n	Group	N	Pre-test		Post test		Mean
			$\bar{X}$	SD	$\bar{X}$	SD	gain
1	Vee-diagram	50	22.32	1.15	32.44	2.48	10.12
2	Guided-inquiry	48	22.46	1.53	32.31	2.36	9.85
3	lecture method	48	22.43	1.67	28.57	3.71	6.14

Table 1 is a summary of the mean pre-test and post-test scores of students in Physics when taught using Vee-diagram, Guided-inquiry instructional strategies and lecture method. The students were divided into three groups based on teaching method. The result shows that the mean pretest and post-test scores of students in experimental group one who were taught with Vee-diagram instructional strategy are 22.32 and 32.44 respectively with standard deviations of 1.15 and 2.48 respectively making a mean gain of 10.12. The corresponding figures for students in experimental group two who were taught with Guided-inquiry instructional strategy are 22.46 and 32.31 respectively with standard deviations of 1.53 and 2.36 making a mean difference of 9.85. Students in the control group who were taught with the lecture method scored 22.43 and 28.57 respectively in the pre-test and post-test with standard deviations of 1.67 and 3.71 respectively making a mean difference of 6.14. It could be observed that students who were taught using Vee-diagram instructional strategy obtained the highest mean gain of 10.12 as against 9.85 and 6.14 obtained by those who were taught using Guided-inquiry strategy and lecture methods respectively. The standard deviation of the scores ranged between 1.15 and 3.71 indicating that the scores of students in the three groups were not too far from the group mean. This result suggests that teaching Physics using Vee-diagram instructional strategy enhances students' achievement in physics than using Guided-inquiry strategy and lecture method.

Table 2 Summary of Turkey's post hoc pairwise comparison of the mean difference in the post-test scores of students in the three groups. *Dependent Variable: Post-Test Scores*

Groups	Mean Difference*	Standard Error	Sig	Remarks
1 Vs 2	.1275	.58929	.975	NS
1 Vs 3	3.8686***	.58929	.000	S
2 Vs 1	-.1275	.58929	.975	NS
2 Vs 3	3.7411*	.58929	.000	S
3 Vs 1	-3.8686***	.58929	.000	S
3 Vs 2	-3.7411*	.58929	.000	S

*Based on observed means (raw scores). The error term is Mean Square (Error) = 47.519.

**. The mean difference is significant at the .05 level.

Table 2 presents the summary of Turkey's post hoc pairwise comparison of the mean difference in the post-test scores of students in the three groups. The result shows that the mean difference between groups 1 (Vee-diagram) and group 2 (Guided-inquiry) was not significant at 0.05 level of significance. Likewise, the mean difference between groups 2 and 1, was also not significant at 0.05 level of significance. However, the mean difference between groups 1 (Vee-diagram) and group 3 (lecture method), groups 2 and 3 as well as between groups 3 and 2 were found to be significant. This result implies that the mean post test scores of students in experimental group 1 (Vee-diagram) was significantly better than those in the other two groups. The significant difference was therefore attributed to the Vee-diagram group which recorded the highest mean gain in the post test score as seen in Table

Research Question 2: What are the mean achievement scores of male and female students in Physics taught with Vee - diagram instructional strategy?

Table 3 Mean Achievement scores of male and female students in Physics taught with Vee - diagram instructional strategy

S/n	Group	N	Pre-test		Post test		Mean
			$\bar{X}$	SD	$\bar{X}$	SD	gain
1	Male	28	22.18	1.06	33.75	1.76	11.57
2	Female	22	22.50	1.26	30.77	2.27	8.27

Table 3 is a summary of the mean pre-test and post -test scores of male and female students in Physics when taught using Vee-diagram instructional strategy. The result shows that the mean pre-test and post-test scores of male students are 22.18 and 33.75 respectively with standard deviations of 1.06 and 1.76 respectively making a mean gain of 11.57. The corresponding figures for female students are 22.50 and 30.77 respectively with standard deviations of 1.26 and 2.27 making a mean gain of 8.27. It could be observed that male students who were taught using Vee-diagram instructional strategy obtained a higher mean gain of 11.57 as against 8.27 obtained by their female counterparts. The standard deviation of the scores ranged between 1.06 and 2.27 indicating that the scores of students in the group were not too far from the group mean. This result suggests that teaching Physics using Vee-diagram instructional strategy enhance male students' achievement more than the female students.

Research Question 3: What are the mean achievement scores of male and female students in Physics taught with Guided inquiry instructional strategy?

Table 4 Mean Achievement scores of male and female students in Physics taught with Guided inquiry instructional strategy

S/n	Group	N	Pre-test			Post test	Mean
			$\bar{X}$	SD	$\bar{X}$	SD	gain
1	Male	28	22.18	1.54	32.46	2.22	10.28
2	Female	20	22.85	1.46	32.10	2.59	9.25

Table 4 is a summary of the mean pre-test and post -test scores of male and female students in Physics when taught using Guided inquiry instructional strategy. The result shows that the mean pre-test and post-test scores of male students are 22.18 and 32.46 respectively with standard deviations of 1.54 and 2.22 respectively making a mean gain of 10.28. The corresponding figures for female students are 22.85 and 32.10 respectively with standard deviations of 1.46 and 2.59 making a mean gain of 9.25. It could be observed that male students who were taught using Guided inquiry instructional strategy obtained a higher mean gain of 10.28 as against 9.25 obtained by their female counterparts. The standard deviation of the scores ranged between 1.46 and 2.59 indicating that the scores of students in the group were not too far from the group mean. This result suggests that teaching physics using Guided inquiry instructional strategy enhance male students' achievement more than the female students.

Research Hypothesis1: There is no significant difference among the mean achievement scores of students in Physics taught with Vee-diagram, Guided inquiry and Lecture method?

Table 5: Analysis of Covariance test for significant difference in the mean post test scores of students in Physics when taught using Vee-diagram, Guided-inquiry instructional strategy and lecture method

Dependent Variable: POSTEST

Source	Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	476.180[a]	3	158.727	18.573	.000	
Intercept	517.818	1	517.818	60.592	.000	
PRETEST	2.554	1	2.554	.299	.585	
GROUP	474.532	2	237.266	27.763	.000	S
Error	1222.078	143	8.546			
Total	143959.000	147				
Corrected Total	1698.259	146				

*S = Significant at 0.05 level of significance

Table 5 shows the result of the Analysis of Covariance conducted to test for significant difference in the mean post-test scores of students in Physics when taught using Vee-diagram and Guided-inquiry instructional strategies as well as lecture method. The students were divided into three groups based on teaching strategies namely Vee-diagram, Guided-inquiry instructional strategy and lecture method. The F -value for group or teaching method is 27.76 with p- value (probability value) being 0.00. Since the obtained p- value is less than the stipulated probability level of 0.05, it implies that the value of F is significant at 0.05 level of significance. On this basis, the null hypothesis is rejected implying that there is significant difference among the mean test scores of students in Physics taught with Vee-diagram, Guided inquiry and Lecture method.

Research Hypothesis 2: There is no significant difference in the mean achievement scores of male and female students in Physics taught with Vee-diagram instructional strategy

Table 6: Analysis of Covariance test for significant difference in the mean post test scores of male and female students in Physics when taught using Vee-diagram instructional strategy

Source	Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	126.069[a]	2	63.034	17.002	.000	
Intercept	54.786	1	54.786	14.777	.000	
PRETEST	16.862	1	16.862	4.548	.038	
GENDER	119.297	1	119.297	32.178	.000	S
Error	174.251	47	3.707			
Total	52918.000	50				
Corrected Total	300.320	49				

*S = Significant at 0.05 level of significance

Table 6 presents a summary of the Analysis of Covariance conducted to test for significant difference in the mean post test scores of male and female students in physics when taught using Vee-diagram instructional strategy. The F -value for gender is 32.18 with p- value (probability value) being 0.00. Since the obtained p- value is less than the stipulated probability level of 0.05, it implies that the value of F is significant at 0.05 level of significance. On this basis, the null hypothesis is rejected implying that there is a significant difference in the mean post test scores of male and female students in Physics taught with Vee - diagram instructional strategy. The difference is in favour of male students who obtained a higher mean gain than their female colleagues as shown in Table 1

Research Hypothesis 3: There is no significant difference in the mean achievement scores of male and female students in Physics taught with guided inquiry instructional strategy.

Table 7: Analysis of Covariance test for significant difference in the mean achievement scores of male and female students in Physics when taught using Guided Inquiry instructional strategy

Source	Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	56.769[a]	2	28.385	6.214	.004	
Intercept	486.244	1	486.244	106.454	.000	
PRETEST	55.221	1	55.221	12.090	.001	
GENDER	.169	1	.169	.037	.848	NS
Error	205.543	45	4.568			
Total	50379.000	48				
Corrected Total	262.312	47				

*NS = Not Significant at 0.05 level of significance

Table 7 presents a summary of the Analysis of Covariance conducted to test for significant difference in the mean post test scores of male and female students in Physics when taught using guided inquiry instructional strategy. The F -value for gender is 0.037 with p- value (probability value) being 0.85. Since the obtained p- value is greater than the stipulated probability level of 0.05, it implies that the value of F is not significant at 0.05 level of significance. On this basis, the null hypothesis is upheld implying that there is no significant difference in the mean post test scores of male and female students in Physics taught with guided inquiry instructional strategy.

Discussion of the Major Findings

The study found that students who were taught Physics using Vee-diagram instructional method had the highest mean gain in the post-test than those who were taught using Guided inquiry and lecture methods. The ANCOVA result 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 difference between all the three groups favoring the experimental groups (Vee-diagram and Guided inquiry).This suggests that these strategies significantly enhance students' achievement in Physics. The result may be attribute to the active involvement and engagement of students during lessons, which fostered better understanding and personal discovery.

This findings corroborate those of Neira and Soto (2023) on effectiveness of Vee-diagram and Olawuwo & Rabiu (2024), Kurniasih &Irpan (2019) on effectiveness of Guided inquiry.Analysis of hypotheses two revealed that there is a significant difference in the mean post test scores of male and female students in Physics taught with Vee - diagram instructional strategy. The difference is in favour of male students who obtained a higher mean gain than their female also analysis of hypotheses three revealed that there is no significant difference in the mean post test scores of male and female students in Physics taught with guided inquiry instructional strategy.

Conclusion

This study addressed the persistent low achievement of student in Physics by evaluating the effects of Vee-diagram and Guided inquiry instructional strategies on students 'achievement. Result showed that these strategies significantly improved the learning outcome compared to the conventional 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 of the study, the researcher made the following recommendations:

1. Physics teachers in secondary schools in Akwa Ibom state should henceforth adopt Vee-diagram instructional strategies as this would enhance the students motivation and achievement in Physics
2. Physics teachers in secondary schools in Akwa Ibom state should also use Guided inquiry as one of the instructional strategies as this would enhance the students retention of concepts in Physics
3. Workshops, symposia and seminars should be organized by the federal and Akwa Ibom state ministries of education to sensitize Physics teachers on how to effectively use Vee diagram and guided inquiry instructional strategies in their teaching.

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