Equity Journal of Innovative Research in Education
2026, Vol. 3 No. 2
ISSN 2814-2187

OPEN ACCESS
https://ejire.org.ng
An Official Publication of Faculty of Education, AFUSTA

Effect of Inquiry Oriented Instructional Approach on Academic Performance of Undergraduate Students in Partial Differential Equations in Kebbi State

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Citation: Buhari, U. A., Julius, Elizabeth, Samaila, K. (2026). Effect of Inquiry Oriented Instructional Approach on Academic Performance of Undergraduate Students in Partial Differential Equations in Kebbi State. *Equity Journal of Innovative Research in Education*, 3(2), 23-32: ISSN 2814-2187

ABSTRACT

This study investigated the effect of inquiry oriented instructional approach on academic performance of undergraduate students in partial differential equations in Kebbi state, Nigeria. The study focused on 300 Level undergraduate students of mathematics department and education mathematics unit in Abdullahi Fodio University of Science and Technology, Aliero (AFUSTA) and Federal University Birnin Kebbi (FUBK). The research adopts quasi experimental design. The population of this study consist of 216 students while 53 (27 AFUSTA, 26 FUBK) students were purposively selected as the sample. The instrument used for data collection was a partial differential equation performance test. The instrument was validated by three experts in Science Education and had a reliability coefficient of 0.84 using Cronbach's alpha. Data was analyzed using mean and standard deviation to answer research question while Ancova was used to test hypotheses at $p< 0.05$ using SPSS. The findings showed that students taught using Inquiry oriented instructional approach (IOIA) performed better than those taught using conventional approach. The study concludes that inquiry -oriented instructional approach enhances undergraduate students' academic performance in Partial differential equations.

ARTICLE HISTORY
Received 28 Aug. 2026
Accepted 4th Sept. 2026

KEYWORDS:
Inquiry Oriented Instructional Approach, Partial Differential Equations, Academic Performance, Undergraduate Students

1. Introduction

Mathematics is a field of science that is concerned with studying numbers and how to use them to carry out calculations, computations, and problem solving, among other things (Santos-Trigo, 2024). Globally, mastery of mathematics is recognized as a basic component for academic excellence and a gateway to professional Careers in science, engineering and technology related fields which are indispensable in today's innovative driven world. It occupies a very important position in Nigerian educational context, this recognition is reflected

in the national requirement that candidates must achieve a secondary school mathematics credit pass at the graduating level to gain admission into tertiary institutions (Falebita et al., 2026). At the undergraduate level, mathematics is expected to assist students in cultivating conceptual understanding, critical thinking, and problem solving skills that will enable them to apply the mathematical knowledge in diverse context.

Among the numerous aspects of mathematics in the undergraduate studies in tertiary institutions, Partial Differential Equations (PDE) occupies a central position because it has real-life application in many fields. The concept of differential equations is mostly used in solving applied problems in various disciplines ranging from Physics through Medicine and Economics. Differential equations have remarkable ability to predict the world around us. The concept of DEs is used to model and understand real life problems (Habre, 2020).

Numerous Studies have shown that students at the undergraduate level persistently experiences difficulties in learning partial differential equation and finds it difficult to interpret mathematical models, relate symbolic representations to physical phenomena and solutions especially when faced with unfamiliar problems. These challenges in most cases are attributed to the teaching approach used by the teachers (Rezvanifard et al., 2023). In most of the cases, mathematics teachers' instructional approach is traditional focusing on the use of rules and algorithms in finding solutions to problems which lead to lack of conceptual understanding. Students have also associated difficulties in differential equations with the use of series of algorithms and procedures to find their solutions and to solve corresponding problems rather than establishing conceptual understanding (Habre, 2020).

Traditional instruction in differential equations has been used by instructors using a lecture format to present analytic methods for equation. In mathematics classrooms that uses a traditional approach, effective participation means that students listen to and watch the teacher demonstrate procedures, and then practice what was demonstrated by completing textbook exercises. This instructional approach presents challenges to students developing deep conceptual understanding of course topics and leaves students at a disadvantage when needing to apply course content in subsequent courses (Lozada et al., 2021a). This prevalent phenomenon of traditional approach to instruction is linked with some general existing 'myths and practices in the teaching of the mathematics at the undergraduate level. In the last two decades, there has been a growth in educational research on undergraduate mathematics education. Research began by investigating student's learning and understanding of specific mathematical concepts. The results obtained offered convincing evidence of the limitations of traditional teaching practices evident from the gap between what a teacher tells students and what is learned was noted by several researchers.

The inquiry- oriented instructional approach has emerged as an active learning strategy capable of addressing the limitations of the traditional teaching approach. The inquiry oriented instructional approach is an instructional model which allows students to explain, predict, experiment, and make decisions with opportunities to investigate their own questions about science-based topics and problems. This approach allows students to engage with data, analyse and interpret the data in other to construct models or develop scientific explanations through a set of integrated activities that include experiments, integrating scientific knowledge and

reasoning (Johnson et al, 2020). Inquiry oriented instructional approach facilitates a deep understanding rather than rote learning or cramming by positioning students as active participants in the learning process and thus promotes a deeper understanding of complex mathematical concepts such as partial differential equations. Previous research has reported beneficial effects of inquiry oriented instructional approach in mathematics and partial differential equations. Habre (2020) for example described inquiry oriented instructional approach as a step by step process in which learners develop understanding through effective engagement with mathematical ideas. Similarly,(Khasawneh et al., 2023) Khasanweh et al (2023) reported an improvement in mathematics achievement of undergraduate students taught partial differential equation using inquiry oriented instructional approach compared with those taught using traditional approach.

Although many researchers have investigated inquiry-oriented instructional approaches in mathematics education, majority of them focuses on secondary schools and other aspects of mathematics like algebra, geometry etc. with limited attention given to Partial Differential Equations at the undergraduate level. There appears to be little empirical evidence on the effectiveness of inquiry oriented instructional approach in improving the academic performance in partial differential equations among undergraduate students in Kebbi State universities. Exploring this topic is important because institutional evidence from the universities involved (FUBK and AFUSTA) shows that students still experience difficulty in understanding the course resulting in high failure and poor grades in examinations. Accordingly, this study investigated the effect of inquiry oriented instructional approach on academic performance of undergraduate students in partial differential equations in Kebbi state Nigeria. Specifically, the current study aimed at achieving the following objective.

Research Objective

To investigate the effect of inquiry oriented instructional approach on the academic performance in Partial Differential Equation among undergraduate students in Kebbi State.

Research Question

Is there any significant difference in the academic performance of undergraduate students in Kebbi State taught Partial Differential Equation using inquiry oriented instructional approach and those taught using traditional approach?

Null Hypothesis

There is no significant differences in the performance of students taught partial differential equation using inquiry oriented instructional approach of teaching and those taught using traditional approach.

1. Literature Review

Inquiry Oriented Instructional Approach and Partial Differential Equations

According to Johnson et al. (2020) , inquiry oriented instruction is a sequence of activities that are connected with one another and entail experiments by merging scientific knowledge and reasoning. It plays a significant role in improving students' understanding of scientific procedure by assisting them to inquire, investigate, explore, ask, and participate in learning. All of these contribute to the development of science and mathematics.

Beswick 2021 examined how two groups of undergraduate mathematics instructors engaged in pedagogical reasoning as part of a workshop on inquiry-oriented instruction. Each group engaged with a mathematics task in either abstract algebra or linear algebra firstly in the role of doers of mathematics and then as mathematics instructors. He found that the more deeply the mathematicians engaged with the mathematics inherent in the task, the greater was their engagement with the evidence of student mathematical reasoning. The group that engaged more deeply with the mathematics and student reasoning were more likely to focus on supporting students in their mathematical work and maintaining the students' ownership of the ways in which they represented the mathematics.

This was in contrast to the group that engaged less deeply with the mathematics and hence with the evidence of student thinking, that focussed more on describing the representational choices that the students made and on evaluating the students' contributions. This frames the need for change to dominant approaches to mathematics teaching in terms of the negative impacts, both cognitive and affective, of such teaching for many students, but goes beyond this to draw attention to the socio-political implications of traditional mathematics teaching practices in which attainment correlates with students' socioeconomic status, and students deemed less capable experience impoverished curricula and pedagogies. Spencer et al., 2024 argued that the traditional instructional approach presents challenges to students developing deep conceptual understanding of course topics and leaves students at a disadvantage when needing to apply course content in subsequent courses.

In contrast Inquiry-oriented instructional approach differential equations applies theory developed from years of research specific to students' understanding of partial differential equations. For example, the literature shows that most often, students who have completed a course in differential equations do not demonstrate a consistent understanding of a solution being a function. Therefore, activities in the inquiry-oriented method consistently ask students to interpret their solutions. Data from the past two decades has shown that inquiry-oriented instruction leads to gains in conceptual knowledge without sacrificing procedural knowledge (Lozada et al., 2021b).

Additionally, some studies have shown that this type of instruction narrows the gap for underperforming students. For example, Laursen (2014) and colleagues showed that while college mathematics courses normally result in students' decreased mathematical confidence, and to a greater degree for women, this effect was diminished in an inquiry-oriented classrooms and the confidence level for women actually increased. Moreover, proponents of IODE instruction argue that because of increased focus of conceptual understanding, retention of both

conceptual and procedural knowledge increases for Inquiry oriented instructional approach students leading.

Inquiry Oriented Instructional Approach and Academic Performance

Academic performance refers to the degree to which the student has achieved the learning outcome that was intended for them to achieve within the framework of an educational program. Exams, continuous assessment, examinations, assignments, class average, cumulative grade points, and other activities of a similar nature are some examples of the types of learning activities that are often used to evaluate this level of performance(Ogunsola et al., 2021).

In their study,Antonio and Prudente (2026) discovered that inquiry-based strategies had a significant and favorable impact on higher-order thinking as well as conceptual comprehension. This discovery is quite similar to the one that was discussed before. For the purpose of achieving success in advanced mathematics classes, they emphasized the need of developing abilities in analytical reasoning and reasoning via inquiry procedures (Valderama & Jubert, 2021). Having these abilities is necessary in order to be successful in advanced mathematics. The empirical investigation that was carried out over the course of differential equations classes offers further evidence for the arguments that have been provided in this article.

According to (Spencer et al., 2024), a university differential equations course that was revamped using an inquiry-oriented framework was shown to have significant gains in students' test scores and confidence when compared to students who were taught using the lecture technique. This was shown by the fact that the students' confidence levels and test scores increased significantly. This was shown by the fact that the academic performance of the students who participated in the course improved significantly in both domains. The findings of the research, which also indicated that students' perceptions of mathematics evolved, demonstrated that students' conceptions of mathematics as a process of thinking rather than a matter of rote calculation increased in a positive way (Zwanch et al., 2021).

2. Research Methodology

This study adopts a quasi-experimental design involving a pre-test and a post-test. The researcher used intact classes of 300l students in the two schools. The participants were grouped into two groups; experimental group and control group. Both groups were pretested to determine their current performance before the intervention. The researcher then adopted inquiry oriented instructional approach to teach the experimental group while traditional method was used for the control group. After the intervention a post test was administered to the both groups. The population of the study consisted of 216 students. Purposive Sampling technique was used to select all 300l students of mathematics and education mathematics in the two Universities which gives a total of 53 students as the sample .Twenty seven (27) students constituted the experimental group while twenty six (26) constituted the control group. The instrument used for data collection was a Partial Differential Equation Performance Test. The test was adapted from the work of (Mohammed, 2019).

The instrument was subjected to face and content validation by three experts, two in Science Education and one in Measurement and Evaluation from the Department of Science Education, Federal University Birnin Kebbi. Their suggestions and corrections were incorporated to produce the final version of the instrument. The reliability of the instrument was established through a pilot test conducted on 30 respondents who were not part of the main study, and the data collected were analyzed using Cronbach's alpha, which yielded a reliability coefficient of 0.84

Data Collection and Analysis

Prior to the commencement of the intervention, a pretest was given to the two groups to measure their prior knowledge in Partial differential Equation. After the intervention, a post test was given to the students. Data was analyzed using statistical package for social science (SPSS). Mean and standard deviation was used to describe students' academic performance while ANCOVA was used to determine whether there is a statistically significant difference in the academic performance of students in the experimental and control group.

3. Results

Research Question

Is there any significant difference in the performance of students taught partial differential equation using inquiry oriented instructional approach and those taught using conventional approach?

Table 1: Mean Performance and Standard Deviation Scores of Students in Inquiry Oriented Instructional Approach and Conventional Approach Groups.

Group	N	Pre-test		Post-test		Mean Difference
		X	SD	X	SD	
Inquiry Oriented Instruction	27	22.15	6.73	38.52	7.35	16.37
Conventional approach	26	20.27	6.28	32.08	6.86	11.56

The descriptive statistics results show the pre-test and post-test mean performance scores and standard deviation of students in both inquiry oriented instructional approach and conventional approach. The mean Pre-test scores of the inquiry oriented instructional approach and conventional approach are 22.15 and 20.27 respectively, with a standard deviation of 6.73 and 6.28 respectively. While the mean Post-test scores of the inquiry oriented instructional and conventional approach are 38.52 and 32.08 respectively, with a standard deviation of 7.35 and

6.86 respectively. The result reveals the mean difference of pre-test and post-test scores of the inquiry oriented instructional and conventional approach are 16.37 and 11.56 respectively. This suggests that students in inquiry oriented instructional approach performed better.

Test of Hypothesis

There is no significant differences in the performance of students taught partial differential equation using inquiry oriented instructional approach of teaching and those taught using conventional approach.

Table 2: Analysis of Covariance of Students' Scores in the Experimental and Control Group Due to Teaching Approaches.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1930.694[a]	2	965.347	41.493	.000
Intercept	1388.233	1	1388.233	59.670	.000
PRETEST	1392.582	1	1392.582	59.857	.000
GROUP	334.780	1	334.780	14.390	.000
Error	1139.998	49	23.265		
Total	68320.000	52			
Corrected Total	**3070.692**	**51**			

Table 2 shows that the value of the significance of $F(1, 49) = 14.390$, $p < .001$ at 0.05 alpha level already set. Since the probability value associated with F is lower than the set alpha of 0.05. The null hypothesis of no significant difference in the mean performance scores of students taught partial differential equation using inquiry oriented instructional approach is therefore rejected. Therefore, there is a significant difference in the mean performance scores of undergraduate students taught partial differential equation using inquiry oriented instructional approach and those taught using conventional approach.

4. Discussion of Findings

The findings of this study revealed that undergraduate students taught Partial Differential Equations using the inquiry-oriented instructional approach achieved significantly higher academic performance than those taught using the conventional lecture method. Although the two groups had comparable pre-test scores, students in the experimental group demonstrated greater improvement after the instructional intervention. Furthermore, the ANCOVA results showed that the difference in post-test performance remained statistically significant after controlling for pre-test scores, indicating that the observed improvement was attributable to the instructional approach rather than pre-existing differences among the participants.

The superior performance of students exposed to inquiry-oriented instruction may be attributed to the learner-centred nature of the approach. Unlike the conventional lecture method, inquiry-oriented instruction actively engages students in exploring mathematical problems,

formulating conjectures, discussing alternative solution strategies, and constructing mathematical understanding through guided investigation. Such active participation promotes conceptual understanding, mathematical reasoning, and meaningful learning, which are particularly important for complex topics such as Partial Differential Equations. These findings support constructivist perspectives on learning, which argue that students develop deeper understanding when they actively construct knowledge rather than passively receive information from the teacher.

The findings are consistent with previous empirical studies that have reported positive effects of inquiry-based instructional approaches on students' mathematics achievement. For example, Spencer et al. (2024) reported that undergraduate students taught partial differential equation through inquiry-based learning significantly outperformed those taught using traditional lecture methods Similarly, Antonio and Prudente (2026) in their research discovered that inquiry-based strategies had a significant and favourable impact on higher-order thinking as well as conceptual comprehension. Valderama and Oligo, (2021) also concludes that for the purpose of achieving success in advanced mathematics classes, inquiry oriented instructional approach is needed in developing abilities in students analytical reasoning.

The findings also align with broader mathematics education research, which suggests that instructional strategies emphasizing active learning, collaborative problem-solving, and student inquiry contribute positively to academic achievement. Research in mathematics education demonstrated that students engaged in inquiry-based learning activities developed better problem-solving skills and retained mathematical concepts more effectively compared to traditional instruction(Beswick, 2021) .

Lozada et al. (2021) also finds that Students who participate actively in constructing mathematical ideas tend to develop stronger conceptual understanding and greater confidence in solving unfamiliar problems than students whose learning is limited to memorizing procedures demonstrated by the instructor. Consequently, inquiry-oriented instructional approaches provide a more effective learning environment for promoting higher-order thinking and improving academic performance in advanced undergraduate mathematics courses. Overall, the findings demonstrate that adopting an inquiry-oriented instructional approach can substantially improve undergraduate students' performance in Partial Differential Equations.

5. Conclusion

This study investigated the effect of inquiry oriented instructional approach on the academic performance of undergraduate students in partial differential equation in kebbi State, Nigeria. The findings of this study demonstrated that inquiry oriented instructional significantly affect the academic performance of undergraduate students because student in the inquiry group achieved higher academic performance than their counterparts in the conventional lecture group. The study therefore added to the body of empirical evidence that inquiry oriented instructional approach is an effective pedagogical approach for teaching partial differential equations.

6. Recommendations

i. Inquiry Oriented Instructional approach (IOIA) should be adopted by university lecturers in teaching partial differential equation and similar advanced mathematics courses.
ii. Institutions should provide adequate teaching and learning resources to support inquiry-oriented teaching approach.
iii. Workshop should be organized to train lecturers on how to effectively teach or implement inquiry-oriented approach in their partial differential equation classroom.

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