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# Exploring the Impact of Deep Learning Activities in the Mathematics Classroom on Students' Academic Performance: A Comprehensive Study

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Keywords: Deep learning; academic performance; mathematics

*Article*

# Exploring the Impact of Deep Learning Activities in the Mathematics Classroom on Students' Academic Performance: A Comprehensive Study

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**Abstract:** The study aimed to investigate the impact of incorporating deep learning strategies in mathematics instruction on students' problem-solving abilities, critical thinking skills, academic achievement, and mathematical skills development. The study population consisted of 280 students, with a sample size of 162 participants. Employing a purely quantitative approach, data collection utilized questionnaires and achievement tests as instruments. Data analysis involved simple linear regression, descriptive analysis, and Pearson correlation. The results of the study revealed that there was no significant enhancement observed in students' problem-solving abilities and critical thinking skills when deep learning strategies were incorporated into mathematics instruction. Additionally, students' attitudes towards deep learning activities in mathematics showed no effect on their academic achievement. Furthermore, students' engagement levels in deep learning activities did not impact their development of mathematical skills. Lastly, the frequency of deep learning activities in the mathematics classroom did not show a significant relationship with students' academic performance. These findings suggest that the implementation of deep learning strategies in mathematics instruction did not yield notable improvements in the specified areas based on the study outcomes.

**Keywords:** deep learning; academic performance; mathematics

## 1. Introduction

Studies show that mathematics is a topic that shapes curricula across the globe and is believed to be related to the corpus of knowledge in science and technology (Fokuo, Lassong, & Kwasi, 2022). As a result, educational institutions are emphasizing greater support for students struggling in the classroom to help them through targeted interventions. The OECD study "Improving Schools in Wales: An OECD Perspective" reveals concerning statistics about the performance of children in Wales in mathematics. In contrast to the 23% OECD average and the 21.8% UK average, Wales had a significantly higher percentage of students who performed poorly in mathematics (29%; OECD, 2014). This source offers a detailed look at the challenges faced by Welsh students due to their weak arithmetic skills, as emphasized by the OECD assessment.

Many nations around the world are very concerned about low math achievement, and Fiji is one of the South Pacific nations where low math achievement among pupils is a problem (Chand, Chaudhary Prasad, & Chand, 2021). Chand, Chaudhary Prasad, and Chand (2021) conducted a study to gather opinions from students, instructors, department heads, and school administrators regarding the reasons behind low math achievement in the senior secondary school grades in the Fijian districts of Ba and Tavua. The authors used both quantitative and qualitative methods in a descriptive design. According to the study, the pupils' attitudes toward mathematics were unfavorable. It was also found that an inadequate curriculum was one of the primary reasons why secondary school students performed below grade level in mathematics. The study also found that a large percentage of elementary school teachers were not prepared to teach mathematics at the elementary school level, which had a negative impact on students' disinterest and, ultimately, poor performance at both the upper and lower secondary levels. On the other hand, it was also found that secondary school teachers were fully certified, very positive, skilled, and efficient in their delivery of the curriculum and in teaching mathematics.

Many math educators and academics have conducted numerous studies in Ghana to identify the root causes of students' subpar academic performance in mathematics, despite ongoing efforts to find a solution. For instance, according to Fokuo, Lassong, and Kwasi (2022), mathematics is taught as a core subject in Ghanaian senior high schools to emphasize students' problem-solving abilities. However, Fokuo, Lassong, and Kwasi (2022) point out that there is scant information available about the reasons behind the poor arithmetic performance of senior high school students in Ghana. In order to improve math competency on the Senior Secondary Certificate Examination, the writers looked at the reasons behind poor performance in mathematics and tried to develop a practical policy direction. The results of the study indicate that a variety of issues, such as a lack of curriculum coverage, a lack of interest in the topic, and the belief that mathematics is beyond their capabilities, contribute to pupils' poor performance in the subject.

In national and international exams, Ghanaian students consistently do poorly in science and mathematics, despite the disciplines' priority in the curriculum (Fletcher, 2018). As a result, the author conducted a study to look at how well Ghanaian children performed in math and science at the elementary and secondary school levels of education, as well as factors that work against students' success in these subjects. According to Fletcher (2018), the effectiveness of implementing the recommended solutions to enhance mathematics instruction and learning in Ghanaian schools would mostly depend on the teachers.

The poor academic performance of students in mathematics concerns a wide range of people, including educators, teachers, students, and others. Consequently, research is being done to investigate teaching methods that could be able to change senior high school students' perceptions and enhance their academic performance in mathematics. This study looked into the fundamentals of deep learning activities in math classes and how they affected students' performance in the subject. Baniata, Kang, Alsharaiah, and Baniata (2024) created a unique deep learning model through their research that is intended to identify children that need academic support. The authors' strategy was designed to assist educational institutions in providing proactive support to underperforming students in order to lower the probability of subpar performance and dropout.

Deep learning algorithms have played a major role in making it possible to predict pupils' academic success. Research on deep learning has shown that students who are proficient in the subject usually achieve well (Phan, 2009; Floyd et al., 2009; Reason et al., 2010). Biggs (1987) highlighted deep motivation and deep strategy as essential elements of deep learning. Deep strategy, as defined by Chotitham, Wongwanich, and Wiratchai (2014), is the ability of a learner to find meaning in order to understand and draw connections between new material and past experiences or knowledge. A student's interest in learning or developing their capacity to learn is referred to as their deep motive.

According to Hall, Ramsay, and Raven (2004), students' deep learning style could be encouraged by altering the learning environment. The authors conducted their study, "Changing the learning environment to promote deep learning approaches in first-year accounting students," in this particular setting. According to the study's findings, students' use of deep learning increased somewhat but statistically significantly. According to Davies et al. (2021), two novel mathematical results—one in representation theory and the other in knot theory—were obtained by using deep learning technology to identify tenable theories. The findings of knot theory showed that deep learning had a minimal role. The representation theory finding showed that deep learning played a far bigger role.

Liquet, Moka, and Nazarathy (2024) focused their investigation of general optimization methods and results on the essential tools for optimization in deep learning model training. Deep learning parameter optimization is the writers' specialty. The writers also examined practical methods that can be used with deep learning. Research on the effects of deep learning activities on students' improvement of mathematical skills was done by Smith and Johnson (2019). The results of

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their study showed the value of deep learning and how it influences students' engagement and mathematical ability development.

The study conducted by Fauskanger and Bjuland (2018) investigated how practicing math teachers conceptualized deep learning in their discourses. Examination of test data revealed that instructors typically conceptualize deep learning in terms of two main areas: the effort of teaching for deep learning and the deep learning that students have accomplished. Emphasis is placed on students' prior knowledge or background information, their interdisciplinary thinking and understanding, and their connections to everyday life. The learning objective for a lesson, the significance of applying information, the variance in mediating instruments, and the variation in teaching methodologies are all related to the process of teaching mathematics for deep learning.

Fauskanger and Bjuland's (2018) analysis of deep learning as it manifests itself in the written discourses of math teachers provides crucial insights into the intricate relationship between pedagogy and the development of mathematical understanding. Fauskanger and Bjuland (2018) highlighted the value of reflective practices in fostering meaningful learning experiences for students by delving into the complex ways that educators define and mold the concept of deep learning, in addition to illuminating the difficulties associated with teaching mathematics.

These previously mentioned sources offer a thorough summary of the difficulties students face when performing poorly in mathematics as well as the function of deep learning in the mathematics classroom. However, the environment in which these experiments were conducted was distinct from the present research site. Additionally, these research studies were conducted on different populations. Through a thorough analysis of the relationship between deep learning activities and academic achievement, this study aimed to offer significant perspectives on effective teaching approaches that can maximize students' learning outcomes in mathematics education. The study's objective was to ascertain how deep learning techniques, such as critical thinking, problem-solving, and collaborative learning, can help students do better academically overall and increase their comprehension of mathematical ideas.

### *1.1. Objective of the Study*

The study aimed to;

1. To assess the correlation between the frequency of deep learning activities in the mathematics classroom and students' academic performance.
2. To investigate the influence of students' engagement levels in deep learning activities on their mathematical skills development.
3. To examine the relationship between students' attitudes towards deep learning activities in mathematics and their academic achievement.
4. To analyze the effect of incorporating deep learning strategies in mathematics instruction on students' problem-solving abilities and critical thinking skills.

### *1.2. Hypotheses*

The following hypotheses were formulated to guide the study:

**$H_0$:** There is no significant relationship between the frequency of deep learning activities in the mathematics classroom and students' academic performance.

**$H_0$:** Students' engagement levels in deep learning activities do not impact their mathematical skills development.

**$H_0$:** Students' attitudes towards deep learning activities in mathematics have no effect on their academic achievement.

**$H_0$:** Incorporating deep learning strategies in mathematics instruction does not enhance students' problem-solving abilities and critical thinking skills.

*1.3. Significance of the Study*

The study on exploring the impact of deep learning activities in the mathematics classroom on students' academic performance holds significant implications for various stakeholders, including: 1) Teachers can benefit from this study by understanding how incorporating deep learning activities can enhance students' academic performance in mathematics. It provides insights into effective teaching strategies that can improve student engagement, understanding, and achievement in the subject. 2) For students, this study is crucial as it highlights the positive impact of deep learning activities on their academic performance in mathematics. It offers them a more engaging and effective learning experience, potentially leading to improved comprehension and performance in the subject. 3) Educational stakeholders, such as school administrators and policymakers, can use the findings of this study to advocate for the integration of deep learning activities in mathematics classrooms. This can lead to more innovative and effective teaching methods that benefit both students and teachers. 4) Parents can appreciate the significance of this study as it demonstrates how deep learning activities can positively influence their children's academic performance in mathematics. Understanding the benefits of such activities can help parents support and encourage their children's learning the subject. 5) Researchers in the field of education can find value in this study as it contributes to the growing body of knowledge on the effectiveness of deep learning strategies in improving students' academic performance in mathematics. It inspires further research and exploration into innovative teaching methods and their impact on student learning outcomes.

*1.4. Delimitation*

In order to provide a more specific investigation of the effects of deep learning activities in mathematics classrooms, this study centered on a senior high school in the Builsa District of the Upper East Region. In order to present an overview of the influence within a specific time frame, the research was restricted to the academic years 2023–2024. In order to have a consistent focus on a particular age group, the study also focused on senior high school students in their last year. To focus the investigation, this study also looked into particular kinds of deep learning activities, like computer-based simulations, cooperative projects, and problem-based learning. The study employed accomplishment test results to measure academic performance, guaranteeing a transparent and impartial evaluation of students' advancement. The research was conducted in traditional classroom settings rather than online or hybrid learning environments to maintain consistency in the study's context.

*1.6. Limitations of the Study*

The following were some of the limitations that the study considered that could have an influence on the outcome of the study: The following are some of these limitations: 1) Control variables: the study felt that it would be more difficult to determine the precise impact of deep learning activities if it did not take into consideration all pertinent variables that could affect academic performance, such as prior knowledge, socioeconomic status, or teacher effectiveness. 2) Measurement methods: The ability of the study to accurately determine the genuine impact may be limited if the assessment methods utilized to measure academic performance fail to completely represent the complex nature of learning mathematics. 3) Implementation Fidelity: The study also postulated that variations in the fidelity with which deep learning exercises are carried out across classes may have an impact on the dependability and consistency of the outcomes. 4) Student Engagement: Differences in how engaged students are with deep learning activities may have an impact on their efficacy and cause students to perform differently.

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## 2. Literature Review

*Deep Learning and Academic Performance in Mathematics*

In order to better understand the connections between student involvement, deep learning techniques, surface learning strategies, and perceived course value, Floyd, Harrington, and Santiago (2009) conducted a study. The study's measurements of course value, engagement, surface learning strategy, and deep learning strategy were based on constructs from earlier research. Relationships between deep learning strategy, student engagement, and perceived course value were found to be statistically significant. The use of surface learning tactics happens when students don't think the course is worth it. According to these results, students who are actively participating in the learning process and who strongly believe that the course material is valuable will employ deep learning tactics. The results of this study demonstrated that course value, as opposed to engagement, had a stronger favorable impact on surface learning and deep learning strategies.

In a four-year study involving undergraduate students, Maciejewski and Merchant (2016) found a correlation between higher marks and deep learning. According to the authors, students approach learning differently depending on the type of learning environment they are in. They said that the deep approach to knowledge acquisition is focused on conceptual change and long-term retention. The study's authors examined students' learning strategies from courses taken during all four years of undergraduate mathematics, looking at a cross-sectional view and analyzing the relationship between these strategies and the students' grades.

Liu (2022) examined the backdrop of classroom instruction in mathematics and talent training requirements. The characteristics of mathematical deep learning are as follows: mastery of knowledge and promotion ability; independent learning and cooperative learning; unity of multiple understandings and overall construction; unity of shallow processing and deep processing; and unity of active learning and lifelong learning. These are the differences between shallow learning and deep learning that the author compared. As a result, it presents the logical understanding needed to encourage deep learning in mathematics, including handling dialectical relations, putting teachers' guiding principles front and center, and rationally understanding deep learning.

Brown and Lee (2020) investigated the connection between improving mathematical skills and students' participation in deep learning. Through their research, they have illuminated the significance of active student participation in deep learning techniques for the development of mathematical abilities. Their results highlight how important it is to create a learning environment that encourages participation and in-depth comprehension, as this will eventually improve students' mathematical proficiency. This study makes a significant contribution to the field of education by highlighting how important participation is in supporting the development of skills and academic performance.

In order to investigate the impact of deep learning activities on students' development of mathematical skills, Garcia and Martinez (2018) conducted a longitudinal study. The research's longitudinal design made it possible to gain a thorough grasp of how these activities affect students' mathematical abilities. According to the findings, deep learning activities help students become more proficient mathematicians, which emphasize the value of using cutting-edge teaching strategies to raise student achievement. The present study makes a noteworthy contribution to the field of education by highlighting the advantages of implementing deep learning methodologies to promote the development of mathematical skills in students.

The meta-analysis carried out by Patel and Nguyen (2021) offers significant insights into the correlation between these factors regarding the effect of student participation in deep learning activities on mathematical competency. The study examined how important it is for students to be actively involved in deep learning activities that improve their mathematical skills. The meta-analysis clarifies the benefits of active student participation in deep learning on mathematical skills by combining the body of studies. By highlighting the significance of interactive and immersive learning experiences in enhancing students' mathematical proficiency, this thorough

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investigation advances our understanding of how engagement affects mathematical learning outcomes.

The paper "Deep Learning Strategies for Online Math Classes" by Iehl (2021) offers insightful advice on how to improve online math instruction. Iehl underlined how crucial it is to choose the appropriate resources, uphold clear standards, streamline lesson plans, foster student engagement, and encourage deeper learning in the context of a virtual classroom. Teachers may construct successful and engaging online math learning environments that support student success by giving priority to these tactics. The need for creativity and adaptability in education is highlighted by Iehl's insightful observations and helpful guidance on adjusting to online teaching, particularly in trying times like the epidemic. Her focus on using technology, establishing clear expectations, and encouraging a sense of community among students brings to light the essential components required for effective online math instruction.

In their study, Chotitham, Wongwanich, and Wiratchai (2014) emphasized that deep learning improves attention, particularly among university students who must study in depth because higher education emphasizes information synthesis. The purpose of the study conducted by the authors was to examine the extent of students' deep learning as well as the impact of deep learning on academic performance. A total of eleven students were chosen to partake in the research. The pupils demonstrated a significant degree of deep learning, according to the results. Through route analysis, their study also discovered that deep learning improved students' academic performance.

In order to find out how well deep learning and machine learning models work for early student performance prediction in higher education institutions, Balcioğlu and Artar (2023) conducted research. The authors predicted student performance in three categories: pass/fail, close to fail, and close to pass using the Open University Learning Analytics dataset and a variety of models, including decision trees, support vector machines, neural networks, and ensemble models. Based on the study's findings, the authors emphasized how data-driven approaches can support targeted interventions, enable personalized learning plans that are suited to each student's needs, and inform the decision-making processes of educational stakeholders.

In their study, Everaert, P., Opdecam, E., & Maussen, S. (2017) noted that the body of literature demands more research on the history and effects of learning methodologies like surface and deep learning. Thus, in order to investigate the connections among motivation, learning strategies, academic achievement, and time invested, the authors conducted their study. The study's findings demonstrated that deep learning improves academic achievement, with accounting students scoring marginally higher on deep learning tests than on surface tests. In their conclusion, the authors noted that a deep learning method entails much more than just putting in a lot of study time.

These reviews imply a positive correlation between student engagement and academic achievement in mathematics education and the deep learning strategy. Improved academic achievement in mathematics can result from deep learning activities that promote comprehension, critical thinking, problem-solving, and relational understanding of mathematical topics.

## 3. Methods and Design

### *3.1. Study Design*

The impact of deep learning activities on pupils' mathematics performance at a particular school in the Builsa South District was examined using a correlational research method. This strategy was selected in order to investigate the correlation between these variables and comprehend the potential impact of deep learning on students' mathematical academic performance.

### *3.2. Target Population*

Shukla (2020) defined a research population as a collection of all units that have a common variable characteristic that is being studied, enabling wide generalization of study conclusions. Outlining the traits of the available group under study is crucial in the section on the study

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population. There were 280 final-year students in the study's available population, of which 52% were male and 48% were female. This composition ensures a diverse and inclusive study group by reflecting a balanced representation of both genders within the sample. Through the inclusion of final-year students from a range of backgrounds and demographics, the study sought to obtain a comprehensive understanding of the viewpoints and experiences of the target audience. This gender-balanced approach enhances the validity and generalizability of the study findings by encompassing a broad spectrum of viewpoints and insights from male and female students alike.

### 3.3. Sample Size and Sampling

A sample size of 162 final-year students has been selected for the study based on the Krejcie and Morgan (1970) sample size determination table. A sufficient degree of statistical power to identify significant effects or relationships within the data is made possible by the utilization of a sample size of 162 students. A straightforward random selection procedure was used to choose the sample participants, guaranteeing that the study will be representative of the community. Selecting a subset of people from a broader population so that each person has an equal probability of being chosen is known as simple random sampling. The study sought to collect data that accurately reflected the features and trends within the final-year student population by using this method and following the suggested sample size. This strategy improved the validity and reliability of the research findings by ensuring that the conclusions drawn from the sample can be safely extrapolated to the larger population of final-year students.

### 3.4. Sampling Procedure

To lay the groundwork for the sampling procedure, the study's population size was established. Every person in the population was given a distinct sequential number between 1 and 280. You have determined that 162 sample members are required for your investigation. To choose the sample, a random number generator was employed. There were 162 distinct numbers between 1 and 280 that were produced by the random number generator. These match the people who make up the population. The sample members were chosen at random from among the 162 distinct numbers between 1 and 280. This process was used to guarantee that every member of the population had an equal opportunity of being chosen, resulting in an impartial and representative sample.

### 3.5. Data Collection Instrument

The data collection tool for the study was a questionnaire with statements on it that were scored on a 4-point scale. With a scale that went from 1 for "strongly disagree" to 4 for "strongly agree," participants may indicate different levels of agreement or disagreement. Past WASSCE mathematics questions were also included in the study; these were given as an Achievement Test (AT) to participants in order to gauge their mathematical knowledge and ability. Using an Achievement Test based on accepted academic standards in conjunction with a structured questionnaire allowed researchers to fully capture participants' viewpoints and academic performance within the study's parameters.

### 3.6. Data Collection Procedure

Prior to commencing data collection, the research study secured consent from the academic board head of the participants' school. Following the acquisition of permission, students underwent an orientation detailing the research's aim and objectives. In line with the recommendations of scholars like Denzin and Lincoln (2005) stressing the importance of adhering to professional standards and ethical guidelines governing participant interactions, the study deemed it essential to obtain consent and permission from both the participants and the school administration. Subsequently, students completed an achievement test before proceeding to respond to the questionnaire items.

### 3.7. Data Analysis

This study used a variety of data analysis techniques, each with a distinct function, including descriptive analysis, Pearson correlation, and simple linear regression analysis. For the purpose of summarizing and analyzing individual items within a dataset and offering insights into the features of the data, descriptive item analysis was essential. As a measure of association, Pearson correlation was used, on the other hand, to quantify the direction and strength of the linear relationship between the research variables. This statistical technique was useful in figuring out how variables change in tandem. Finally, a straight line was fitted to the data points using simple linear regression analysis to represent the link between each independent variable of the study objectives and the academic achievement of the students as the dependent variable. It allowed for predicting the value of one variable based on the other, providing a clear understanding of the relationship between the variables. Therefore, in the context of data analysis, these tools are essential for exploring, understanding, and drawing meaningful conclusions from the dataset by examining individual item characteristics, assessing relationships between variables, and modeling predictive associations.

## 4. Results and Discussion

### 4.1. Introduction

The findings of the study, "Exploring the impact of deep learning activities in the mathematics classroom on students' academic performance," are presented in this section. The findings presented here offer a thorough examination of the outcomes of incorporating deep learning strategies into math teaching. The outcome of the analysis are represented in statistical tables and followed up with interpretations and discussions in relation to literature.

### 4.2. Null Hypothesis 1: There is No Significant Relationship between the Frequency of Deep Learning Activities in the Mathematics Classroom and Students' Academic Performance

The null hypothesis sets the foundation for statistical analysis to determine whether there is indeed a significant relationship between the depth of learning experiences provided in math classes and the academic outcomes of students. It forms the basis for research to either accept or reject the idea that deep learning practices influence students' academic performance in mathematics. The output for this hypothesis is shown in Table 1.

**Table 1.** Showing a Pearson Correlations of statements relating to objective one of the study.

| | | S1 | S2 | S3 | S4 | S5 | Test scores |
|---|---|---|---|---|---|---|---|
| S1 | Pearson Correlation | 1 | .483** | .517** | .474** | .355** | .094 |
| | Sig. (2-tailed) | | .000 | .000 | .000 | .000 | .234 |
| S2 | Pearson Correlation | .483** | 1 | .568** | .545** | .469** | .079 |
| | Sig. (2-tailed) | .000 | | .000 | .000 | .000 | .319 |
| S3 | Pearson Correlation | .517** | .568** | 1 | .624** | .488** | .029 |
| | Sig. (2-tailed) | .000 | .000 | | .000 | .000 | .710 |
| S4 | Pearson Correlation | .474** | .545** | .624** | 1 | .544** | .026 |
| | Sig. (2-tailed) | .000 | .000 | .000 | | .000 | .744 |
| S5 | Pearson Correlation | .355** | .469** | .488** | .544** | 1 | .039 |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 | | .625 |

**. Correlation is significant at the 0.01 level (2-tailed). Source: Field data, 2024.

As can be seen in Table 1, the Pearson correlation coefficient revealed a weak positive relationship between statement 1 and the test scores (r = 0.234, p = 0.094, two-tailed). A Pearson correlation coefficient of 0.234 indicates a relatively weak positive correlation between two variables and the relationship is not statistically significant at the 0.05 significance level with a p-value of 0.094. For statement 2, the Pearson correlation coefficient calculated also revealed a weak positive relationship between the variables (r = .079, p = .319, two-tailed). This indicates that there is a weak positive correlation between the variables with a Pearson correlation coefficient of 0.079, and the relationship is not statistically significant at the 0.05 significance level with a p-value of 0.319. The Pearson correlation value for statement 3 was r = .029, indicating a very weak positive correlation. The two-tailed significance value was p = .710, suggested that this correlation is not statistically significant. A Pearson correlation analysis for statement 4 revealed a very weak positive correlation between the variables (r = .026, p = .744, two-tailed). This statement indicates that there is a minimal positive relationship between the variables, with the correlation being close to zero and the p-value being non-significant at .05 levels. Lastly, a Pearson correlation analysis for statement 5 revealed a very weak positive correlation between the variables, r= .039, p = .625. The Pearson correlation value of .039 indicates a very weak positive correlation. The two-tailed significance value of .625 suggests that the correlation is not statistically significant at the conventional alpha level of .05. The results in Table 1 showed that all the statements relating to objective 1 are not significantly correlated with the student's academic performance, S1(p =.094), S2(p = .319), S3(p=.710), S4(p = .744) and S5(p=.625). Therefore, the study failed to reject the null hypothesis that "there is no significant relationship between the frequency of deep learning activities in the mathematics classroom and students' academic performance. This implies that there is no correlation between the extent of deep learning activities conducted in mathematics classes and the academic performance of students. The finding in respect to objective 1 of the study contradicts with that of Garcia and Martinez (2018). The authors conducted a longitudinal study to gain a thorough grasp of how deep learning activities affect students' mathematical abilities. According to their findings, deep learning activities help students become more proficient mathematicians, which emphasize the value of using cutting-edge teaching strategies to raise student achievement.

The finding of the current study also diverges from that of Brown and Lee (2020). Brown and Lee (2020) investigated the connection between improving mathematical skills and students' participation in deep learning. Through their research, they have illuminated the significance of active student participation in deep learning techniques for the development of mathematical abilities. Their results highlight how important it is to create a learning environment that encourages participation and in-depth comprehension, as this will eventually improve students' mathematical proficiency.

### *4.3. Null Hypothesis 2: Students' Engagement Levels in Deep Learning Activities Do Not Impact Their Mathematical Skills Development*

This null hypothesis served as the baseline assumption to be tested against any observed effects or correlations between the measures variables. By this null hypothesis, the study aimed to investigate whether the level of engagement in deep learning activities has a direct impact on enhancing students' mathematical abilities. The output for this hypothesis is shown in Table 2.

**Table 2.** Showing a simple linear regression test results for objective one of the study.

| R Square | Std. Error | R Square Change | F Change | df1 | df2 | Sig. F Change |
|---|---|---|---|---|---|---|
| 0.013 | 1.936 | 0.013 | 0.407 | 5 | 156 | 0.843 |
| a. Predictors: (Constant), S5, S1, S2, S4, S3 | | | | | | |

Sources: field data, 2024.

A simple linear regression analysis was conducted to examine the relationship between students' engagement levels in deep learning activities (independent variable) and the academic performance (dependent variable). The results in Table 3 showed that there was no statistically

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significant relationship between the two variables, (F(5, 156) = 0.233, p = 0.947). The model accounted for a small amount of variance in the dependent variable (r^2=.007). The standard error of the estimate was 1.941, showing the average amount that the observed values deviated from the predicted values. The change in r^2was minimal (R Square Change = 0.007). The df1 (5) represents the degrees of freedom for the numerator in the F statistic whiles df2 (156) is the degrees of freedom for the denominator in the F statistic. Since there is no statistically significant relationship between the two variables, the study failed to reject the null hypothesis that "Students' engagement levels in deep learning activities do not impact their mathematical skills development". This implies that there is no relationship between students' engagement in deep learning and the development of their mathematical skills. This hypothesis assumes that regardless of how engaged students are in deep learning activities, it does not affect their mathematical skills progression. This study's conclusion, however, runs counter to the ideas of Sornson, B. (2014), who examined fundamental math skills and paid special attention to over 250 activities that foster deep learning. The author highlighted that there was a connection between deep learning activities and basic math skills.

**Table 3.** Showing a simple linear regression test results for objective two of the study.

| $r^2$ | Std. Error | R Square Change | F Change | df1 | df2 | Sig. F Change |
|---|---|---|---|---|---|---|
| 0.007 | 1.941 | 0.007 | 0.233 | 5 | 156 | 0.947 |
| a. Predictors: (Constant), S5, S1, S2, S3, S4 | | | | | | |

Sources: field data, 2024.

This finding of the study also contradicts the finding of Garcia and Martinez, (2018). The authors conducted a longitudinal study to explore deep learning activities and their effect on mathematical skill acquisition among students. They indicated that students' engagement in deep learning activities influences their mathematical skills. This finding of the study also contradicts the findings of Smith and Johnson, (2019) and Brown and Lee, (2020). These authors also studied students' engagement in deep learning activities and the impact on mathematical skill development. The authors highlighted a positive relationship between students' engagement in deep learning and mathematical skills enhancement.

### *4.4. Null Hypothesis 3: Students' Attitudes towards Deep Learning Activities in Mathematics Have No Effect on Their Academic Achievement*

For statistical tests to investigate the relationship between the dependent and independent variables for objective three and to make meaningful inferences based on the data acquired during the research, the null hypothesis, which states that students' attitudes toward deep learning activities in mathematics have no effect on their academic achievement, was formulated. Table 3 displays the result.

**Table 4.** Showing a simple linear regression test results for objective three of the study.

| R Square | Std. Error | R Square Change | F Change | df1 | df2 | Sig. F Change |
|---|---|---|---|---|---|---|
| .062 | 1.886 | 0.062 | .079 | 5 | 156 | 0.071 |
| a. Predictors: (Constant), S5, S2, S4, S1, S3 | | | | | | |

Sources: field data, 2024.

A simple linear regression analysis was conducted to assess the relationship between students' attitudes towards deep learning activities in mathematics and their academic achievement. The results indicated that the model was not statistically significant, with an $r^2$ of .062, F(5, 156) = 5.079, p = .071. These findings suggest that students' attitudes towards deep learning activities (independent variable) accounted for 6.2% of the variance in the academic achievement (dependent variable) of the students.

### *4.5. Null Hypothesis 4: Incorporating Deep Learning Strategies in Mathematics Instruction Does Not Enhance Students' Problem-Solving Abilities and Critical Thinking Skills*

This null hypothesis was intended to determine the relationship between incorporating deep learning strategies in mathematics instruction and students' problem-solving abilities and critical thinking skills. See Table 5 for the output.

**Table 5.** Showing descriptive frequency analysis results of students' views relating to objective four of the study.

| **Objective 4 Statements** | **SD** | **D** | **A** | **SA** |
|---|---|---|---|---|
| **To analyze the effect of incorporating deep learning strategies in mathematics instruction on students' problem-solving abilities and critical thinking skills** | | | | |
| I strongly believe that incorporating deep learning strategies in mathematics instruction has improved my problem-solving abilities | 20 | 14 | 49 | 79 |
| I feel that deep learning strategies in mathematics instruction have enhanced my critical thinking skills? | 16 | 18 | 61 | 67 |
| Deep learning strategies in mathematics instruction increased my confidence in tackling complex mathematical problems | 20 | 23 | 53 | 66 |
| The use of deep learning techniques in mathematics instruction improved my overall academic performance | 13 | 31 | 51 | 67 |
| To what extent do you think that deep learning strategies have helped you develop a deeper understanding of mathematical problem-solving processes | 14 | 21 | 68 | 59 |

Sources: field data, 2024.

Table 5 captures a descriptive analysis showing students' views relating to the objective of incorporating deep learning strategies in mathematics instruction. The data was analyzed based on the following categories: Strongly Disagree (SD), Disagree (D), Agree (A), and Strongly Agree (SA). From Table 5, a cumulative of 34 students disagreed that incorporating deep learning strategies in mathematics instruction led to improvement in their problem-solving abilities whiles 128 them agreed. Also, 34 again disagreed that deep learning strategies in mathematics instruction have enhanced their critical thinking skills. 128 students however, agreed that deep learning strategies in mathematics instruction have enhanced their critical thinking skills. The results in Table 5 also showed 119 students agreeing that deep learning strategies in mathematics instruction increased their confidence in tackling complex mathematical problems. On the aspect of deep learning impact on academic performance, 118 students agreed that the use of deep learning techniques in mathematics instruction improved their overall academic performance. Lastly, 78.4% of the students expressed the view that deep learning strategies have helped them develop a deeper understanding of mathematical problem-solving processes. These findings from Table 5 provide a comprehensive view of students' perceptions regarding the impact of incorporating deep learning strategies in mathematics instruction on various aspects of their learning experience and skills development.

**Table 6.** Showing a simple linear regression test results for objective four of the study.

| **R Square** | **Std. Error** | **R Square Change** | **F Change** | **df1** | **df2** | **Sig. value** |
|---|---|---|---|---|---|---|
| 0.072 | 1.907 | 0.072 | 1.179 | 10 | 151 | 0.309 |

### *4.6. Conclusions of the Study*

The study concludes that the implementation of deep learning strategies in mathematics instruction did not yield measurable improvements in students' problem-solving abilities, critical thinking skills, academic achievement, or mathematical skills development. Despite the growing interest in integrating deep learning approaches into education, the findings suggest that these specific strategies did not lead to the desired outcomes in the context of mathematics learning.

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## 5. Recommendation

The following recommendations were made based on the findings of the study:

**Further Research:** Given the non-significant results of this study, further research is recommended to explore alternative or supplementary teaching methods that may better enhance students' mathematical skills and academic performance.

**Professional Development:** Educators should receive training and professional development opportunities to effectively integrate innovative teaching strategies, including deep learning, into their mathematics instruction.

**Curriculum Design:** Curriculum developers should consider revising mathematics curricula to incorporate a balanced mix of traditional and modern teaching approaches to cater to diverse learning needs and styles.

**Monitoring and Evaluation:** Schools should implement robust monitoring and evaluation mechanisms to continuously assess the effectiveness of teaching strategies, including deep learning, in improving students' mathematical competencies. By critically analyzing the study's results and implementing the above recommendations, educational stakeholders can work towards enhancing mathematics instruction and student learning outcomes effectively.

**Ethical Clearance:** The study was given ethical clearance by the FumSec School Ethical Review Academic Headmaster/Board Chair.

**Competing Interest:** I, the main author of this paper declare that there is known competing financial interest or personal relationships that could have appeared to influence the outcome of this study. The author declares that there is known competing financial interest or personal relationships that could have appeared to influence the outcome of this study.

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