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Investigating Innovative Experimental Curricular Approaches to Enhance Conceptual Development in Mathematics Education

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ABSTRACT

Purpose – Mathematics education is increasingly shifting from rote memorization to approaches that foster conceptual understanding. In Ghana, however, traditional methods still dominate, limiting students' ability to apply mathematical concepts effectively. This study investigates the impact of active learning strategies—Problem-Based Learning (PBL), Inquiry-Based Learning (IBL), manipulatives, and technology integration—on students' conceptual understanding of mathematics within a sub-Saharan African context.

Methodology – A quantitative design was employed, involving 300 students from the Ejisu-Juaben Municipality in Ghana, selected through stratified random sampling. Data were collected using structured questionnaires and analyzed statistically to assess the relationship between instructional strategies and conceptual learning outcomes.

Findings – The results indicate that technology integration had the strongest positive effect on students' comprehension and engagement. PBL also improved learning outcomes but required additional instructional support. Both IBL and the use of manipulatives contributed moderately to conceptual understanding.

Novelty – This study offers a novel contribution by addressing an underrepresented region in educational research. It is among the first to examine the combined effects of multiple active learning strategies in a sub-Saharan African setting, with a specific focus on conceptual understanding rather than performance metrics.

Significance – The findings provide actionable insights for educators and policymakers in developing contexts, emphasizing the importance of adopting technology-enhanced and student-centered approaches to improve mathematics instruction and deepen students' problem-solving abilities.

Keywords: Conceptual understanding; Constructivist approach; Technology integration; Scaffolding; Rote learning.

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1. Introduction

Mathematics education plays a fundamental role in developing logical reasoning, problem-solving skills, and abstract thinking, which are essential for success in various academic and professional fields (National Research Council, 2001). Despite its significance, mathematics remains a challenging subject for many students worldwide, with low achievement levels observed in numerous educational systems (OECD, 2019). International studies have shown that traditional instructional approaches, which emphasize rote memorization and procedural fluency, often fail to cultivate a deep conceptual understanding of mathematics (Hiebert & Grouws, 2007). This issue is not unique to any one country—it is prevalent in both high-income and developing nations, where students frequently struggle to apply mathematical concepts in real-world scenarios (Kilpatrick, Swafford, & Findell, 2001).

In Ghana, as in many other contexts, mathematics instruction has traditionally focused on direct teaching methods, where teachers demonstrate procedures that students then practice through repetitive exercises. While this approach may help students perform routine calculations, it does not necessarily equip them with the ability to apply mathematical principles in unfamiliar or complex situations (Hiebert et al., 1997). Research suggests that students who rely primarily on procedural knowledge often experience difficulties in problem-solving and mathematical reasoning, limiting their ability to make meaningful connections between concepts (Rittle-Johnson, Siegler, & Alibali, 2001). Consequently, there has been increasing interest in reforming mathematics curricula to emphasize conceptual understanding, critical thinking, and real-world applications.

Despite growing recognition of the limitations of traditional mathematics instruction, there remains a gap in understanding how innovative curricular approaches—particularly in sub-Saharan African educational systems—affect student learning outcomes. While extensive research has been conducted on alternative teaching strategies in Western contexts, limited empirical studies explore their effectiveness in developing regions like Ghana. Additionally, studies on experimental curricular approaches often focus on short-term gains rather than long-term retention and adaptability of mathematical knowledge (Rittle-Johnson & Koedinger, 2005).

To address these concerns, this study investigates the impact of experimental curricular approaches designed to enhance students' conceptual understanding of mathematics. These approaches include: (1) Inquiry-Based Learning (IBL): Encourages students to explore mathematical ideas through questioning, investigation, and problem-solving, promoting deeper engagement and comprehension (Hmelo-Silver, 2004); (2) Problem-Based Learning (PBL): Focuses on solving real-world mathematical problems, helping students develop critical thinking skills and apply their knowledge in diverse contexts (Barrows, 1996); (3) Technology Integration: Incorporating digital tools and interactive software provides dynamic visualizations, personalized learning paths, and immediate feedback, enhancing students' mathematical experiences (Kaput, 1992); and (4) Manipulatives and Visual Aids: Tangible learning tools help students transition from abstract mathematical concepts to concrete understanding, fostering deeper cognitive connections (Carbonneau, Marley, & Selig, 2013).

Implementing these innovative teaching strategies requires pedagogical shifts and institutional support. Research suggests that teachers need professional development to successfully integrate active learning methods into their classrooms (Loucks-Horsley et al., 2003). Additionally, schools must provide adequate resources, training, and infrastructure to support the sustainability of such approaches (Fullan, 2007). This study seeks to contribute to the ongoing discourse on mathematics education reform by evaluating the effectiveness, feasibility, and long-term impact of experimental curricular approaches in a Ghanaian secondary school setting. By adopting these methods, educators can better equip students with the conceptual understanding and problem-solving skills necessary for academic success and real-world application.

1.1 Problem Statement

Mathematics education in Ghana has considerable obstacles in instilling strong conceptual understanding in students. Traditional educational techniques frequently fail to engage students, resulting in ongoing problems with arithmetic comprehension and recall. Recent studies show that pupils in Ghanaian schools do poorly in mathematics, which can be linked to the prevalence of rote learning and procedural approaches (Adu-Gyamfi, 2016; Anamuah-Mensah, Mereku, & Ghartey, 2008). Despite several educational changes, there is still a significant gap in the adoption of new and effective curricular approaches that can improve students' conceptual growth and enthusiasm in mathematics.

Other studies have shown that an experimental, hands-on curriculum can help students grasp and retain mathematical concepts (Boaler, 2016; Hiebert & Grouws, 2007). However, there has been a paucity of extensive research into the design, implementation, and impact of such innovative techniques in Ghana's educational system. This gap emphasizes the importance of conducting comprehensive research on how these curricula might be customized to the local context, as well as their usefulness in improving mathematics education outcomes.

This study aims to develop and evaluate an experiment-based curriculum tailored to Ghana's educational context. While active learning methods like Inquiry-Based Learning (IBL), Problem-Based Learning (PBL), and technology integration have proven effective globally, their implementation in Ghana must consider classroom size, resource limitations, and socioeconomic disparities. The research will assess how these approaches influence student comprehension, engagement, and retention, while also examining teacher and student perceptions. By aligning innovative strategies with local realities, the study seeks to provide practical, scalable solutions for improving mathematics education, informing curriculum design, teacher training, and policy development.

The purpose of this study is to design and implement innovative experimental curricular approaches aimed at enhancing conceptual development in mathematics education. The study aims to assess the effectiveness of these methods in enhancing students' comprehension of mathematical concepts and their overall performance in mathematics. Objectives of the Study; (1) To explore and identify innovative curricular strategies that promote conceptual learning in mathematics; (2) To assess the effectiveness of these experimental approaches in improving students' comprehension and retention of mathematical concepts; (3) To examine students' perspectives and experiences regarding the impact of these teaching methods on their learning; (4) To investigate how these instructional approaches shape students' attitudes and interests in mathematics.

1.2 Research Questions

a. What innovative curricular approaches enhance conceptual understanding in mathematics education?
b. How do these approaches impact students' understanding and retention of mathematical concepts?

c. What are students' perceptions and experiences regarding the effectiveness of these teaching methods?
d. How do these approaches influence students' attitudes and interest in mathematics?

2. Methods

2.1. Research Paradigm

This study will adopt the constructivism paradigm, emphasizing the active role of learners in constructing their understanding and knowledge through experience and reflection (Fosnot, 2005). The constructivist approach aligns intending to enhance conceptual development by encouraging students to actively engage with mathematical concepts. The quantitative research approach provides measurable data to assess the effectiveness of these curricular innovations in various educational settings (Creswell & Creswell, 2017).

2.2. Population and Sample

The population for this study will include 300 Basic school mathematics students in a selected Ejisu–Juaben Municipality. A convenience sampling technique was used to select two schools from the district wanting to participate in the research. The total sample size will be approximately 300 students. Convenience sampling and simple random sampling were applied to select participants. These strategies were used to guarantee that the sample was both representative and accessible.

2.3. Data Collection Instrument

The data collection tool used was a structured questionnaire with standardized items designed to gather information from respondents on specific variables. This type of instrument is commonly used in survey research and is particularly useful for collecting large amounts of data in an organized and efficient way. The questionnaire featured closed-ended questions, where respondents were selected from a set of predefined options. To ensure clarity and precision, the items were reviewed by the researcher's supervisor, and the response options were carefully defined and comprehensive. The questionnaire consisted of close-ended items measured on a Likert scale, ranging from "strongly disagree" to "strongly agree." It was organized into six sections. The first section gathered demographic information, such as participants' age, gender, and school type.

The second section included 4 items to assess familiarity with the proposed innovative experimental curricular approaches to enhance conceptual development in mathematics education. These items were: (IECA1) "Problem-Based Learning Approach," (IECA2) "Technology Integration," (IECA3) "Manipulatives and Visual Aid," (IECA4) "Inquiry-Based Learning". The last part comprised 4 items each for each innovative experimental curricular approach listed in the above sections to measure interest in the innovative curricular approaches.

Table 1- Student Interest in Innovative Curricular Approaches

Curricular Approach	Item Code	Survey Statement
Problem-Based Learning (PBL)	PB1	I find learning through Problem-Based Learning enjoyable.
	PB2	Problem-based learning enhances my interest in learning.
	PB3	My understanding of topics improves when taught using Problem-Based Learning.

Curricular Approach	Item Code	Survey Statement
	PB4	Problem-based learning increases my engagement in class activities.
Technology-Integrated Learning (TI)	TI1	I enjoy lessons that incorporate technology.
	TI2	Integrating technology into lessons makes learning more engaging.
	TI3	I grasp concepts more effectively when technology is used in teaching.
	TI4	Using technology in learning keeps me actively involved.
Manipulatives & Visual Aids (MV)	MV1	I find learning with Manipulatives and Visual Aids enjoyable.
	MV2	Visual aids and hands-on materials make lessons more engaging.
	MV3	My comprehension improves when Manipulatives and Visual Aids are used.
	MV4	These tools help me stay focused and participate more in class.
Inquiry-Based Learning (IBL)	IB1	I enjoy discovering concepts through Inquiry-Based Learning.
	IB2	Inquiry-based learning makes lessons more stimulating.
	IB3	I understand topics better when I explore them through inquiry.
	IB4	Inquiry-based learning encourages my active participation.

2.4. Data Analysis

Demographic Information of Participants. This section presents the background characteristics of the study participants, summarizing key attributes such as gender, age, school type, and familiarity with different learning approaches. The data has been structured in tables for better visualization and understanding. The study included a total of 300 students, with a nearly equal distribution of male and female participants.

Table 2 - Gender Distribution of Participants

Gender	Frequency (n)	Percentage (%)
Male	146	48.7%
Female	154	51.3%
Total	300	100%

Participants were from both public and private schools, with public school students forming the majority.

Table 3 - Type of School Attended by Participants

School Type	Frequency (n)	Percentage (%)
Public	166	55.3%
Private	134	44.7%
Total	300	100%

The table below displays the age range of the respondents, indicating the majority fall within the 13-14 age bracket.

Table 4 - Age Distribution of Participants

Age Group	Frequency (n)	Percentage (%)
Below 10 years	2	0.7%
11-12 years	92	30.7%
13-14 years	192	64.7%
16-18 years	8	2.7%
Above 18 years	6	2%
Total	300	100%

A significant number of students reported familiarity with the use of manipulatives and visual aids in learning.

Table 5 - Familiarity with Manipulative and Visual Aid Learning Approach

Familiarity	Frequency (n)	Percentage (%)
Yes	184	61.3%
No	116	38.7%
Total	300	100%

The majority of students indicated awareness of inquiry-based learning strategies.

Table 6 - Familiarity with Inquiry-Based Learning Approach

Familiarity	Frequency (n)	Percentage (%)
Yes	192	64%
No	108	36%
Total	300	100%

Most respondents were familiar with problem-based learning as an instructional method.

Table 7 - Familiarity with Problem-Based Learning Approach

Familiarity	Frequency (n)	Percentage (%)
Yes	245	81.7%
No	55	18.3%
Total	300	100%

Technology-based learning approaches were well known among participants, with a high percentage reporting familiarity.

Table 8 - Familiarity with the Technology-Integrated Learning Approach

Familiarity	Frequency (n)	Percentage (%)
Yes	242	80.7%
No	58	19.3%
Total	300	100%

3. Results and Discussion

The variable Technology Integration (TI1) demonstrated a strong positive response among participants, as indicated by the mean score of 4.38, which is relatively close to the maximum possible score of 5. This suggests that a majority of respondents expressed a high level of enjoyment in learning through technology integration. The standard deviation of 0.94441 is notably low, reflecting minimal variability in the responses, and implying a high level of consensus among the participants. Additionally, the skewness value of -2.024 suggests a pronounced negative distribution, with a greater proportion of participants providing scores towards the higher end of the scale, thereby reinforcing the overall positive perception. The kurtosis value of 4.187 further supports this interpretation, indicating a leptokurtic distribution, where responses are tightly clustered around the higher values, particularly between 4 and 5. In conclusion, the data reveals that the majority of respondents strongly favor the technology integration approach to learning, with minimal disagreement, as evidenced by the high mean, low standard deviation, and the skewed and peaked nature of the distribution.

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
TI1	300	4.00	1.00	5.00	1314.00	4.3800	.05453	.94441	.892	-2.024	.141	4.187	.281
TI2	300	4.00	1.00	5.00	1296.00	4.3200	.05757	.99712	.994	-1.777	.141	3.003	.281
TI3	300	4.00	1.00	5.00	1222.00	4.0733	.06087	1.05435	1.112	-1.147	.141	.770	.281
TI4	300	4.00	1.00	5.00	1274.00	4.2467	.05544	.96033	.922	-1.196	.141	.816	.281

Figure 1. Descriptive Statistic of Technology Integration Variables

The variable Technology Integration Learning Approach Makes Learning More Interesting (TI2) similarly yielded a high mean score of 4.32, indicating a generally favorable evaluation from participants. This suggests that the integration of technology in learning is perceived as a valuable means of enhancing engagement. The standard deviation of 0.99712, slightly higher than that of TI1, reflects a modest increase in variability, indicating that while most participants rated the variable positively, there was a bit more divergence in their responses. The skewness value of -1.777, though still negative, is less extreme than that of TI1, suggesting that while the majority of respondents provided higher ratings, the concentration of these ratings was somewhat less pronounced. Additionally, the kurtosis value of 3.003 indicates a leptokurtic distribution, though with a less sharp peak than TI1, signifying that responses, while clustered around the higher values, are spread out more evenly. In conclusion, TI2 mirrors the positive trends seen in TI1, with most participants offering favorable assessments of the technology integration approach to making learning more interesting, albeit with slightly more variation in their opinions.

The variable I Understand Topics Better When Taught Using Technology Integration Learning Approaches (TI3) received a mean score of 4.0733, which, although still high, is slightly lower than the mean scores for TI1 and TI2, indicating a more moderate, yet still positive, perception. The standard deviation of 1.05435, higher than that of the previous variables, reflects increased variability in the responses, suggesting less consensus among participants compared to TI1 and TI2. The skewness value of -1.147, while still negative, is less extreme, indicating a more balanced distribution of ratings with fewer extremely high scores. The kurtosis value of 0.770 is notably lower than the values for TI1 and TI2, signaling a distribution closer to normal, where responses are more evenly spread around the mean. In conclusion, while responses to TI3 remain largely positive, they exhibit greater variability, with a more even distribution of opinions and fewer participants providing extremely high ratings.

The variable Technology Integration Learning Approach Helps Me to Be More Engaged in Class (TI4) yielded a mean score of 4.2467, which is consistent with the high ratings seen in TI1 and TI2, suggesting strong positive feedback from participants. The standard deviation of 0.96033, lower than that of TI3, indicates that the responses were more tightly clustered around the mean, reflecting a higher degree of agreement among respondents. The skewness value of -1.196 is negative, similar to TI1 and TI2, signifying that a larger portion of participants gave higher ratings. The kurtosis value of 0.816 suggests a distribution closer to normal, indicating that while responses were somewhat spread out, they were still relatively concentrated around the higher values. In conclusion, TI4 received high ratings, with less variability than TI3, pointing to a greater consensus among participants about the positive impact of technology integration on their engagement in class.

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PB1	300	4.00	1.00	5.00	938.00	3.1267	.07324	1.26859	1.609	-.101	.141	-.861	.281
PB2	300	4.00	1.00	5.00	1028.00	3.4267	.07854	1.36044	1.851	-.422	.141	-.970	.281
PB3	300	4.00	1.00	5.00	954.00	3.1800	.07132	1.23532	1.526	.060	.141	-.931	.281
PB4	300	4.00	1.00	5.00	970.00	3.2333	.07655	1.32593	1.758	-.297	.141	-.980	.281
Valid N (listwise)	300												

Figure 2. Descriptive Statistic Problem-Based Learning Variables

The variable You Enjoy Learning Through a Problem-Based Learning Approach (PB1) exhibited a mean score of 3.1267, which is lower than the means of the TI variables, suggesting a more neutral stance among participants. The standard deviation of 1.26859 is relatively high, indicating a greater dispersion in responses and suggesting a wider range of opinions on the effectiveness of problem-based learning. The skewness value of -0.101 is close to zero, indicating that the distribution of responses is fairly symmetrical, with no significant leaning toward higher or lower ratings. Additionally, the kurtosis value of -0.861 points to a platykurtic distribution, meaning that responses are more spread out than in a normal distribution, with fewer extreme scores. In conclusion, PB1 received more neutral ratings compared to the technology integration variables, with notable variability in responses, reflecting diverse opinions on the problem-based learning approach.

The variable Problem-Based Learning Approach Makes Learning More Interesting (PB2) received a mean score of 3.4267, which is higher than PB1, suggesting a somewhat more favorable perception of problem-based learning in terms of increasing interest in learning. However, the standard deviation of 1.36044 remains high, indicating significant variability in the responses, and suggesting that participants had diverse opinions on the matter. The skewness value of -0.422, while still slightly negative, points to a greater concentration of higher ratings, although the skew is not particularly pronounced. The kurtosis value of -0.970 suggests a platykurtic distribution, meaning that the responses are more spread out than in a normal distribution, with fewer extreme scores at either end. In conclusion, PB2 received a slightly higher rating than PB1, indicating that the problem-based learning approach is seen as somewhat more engaging, though the responses still show a high level of variability, reflecting a range of opinions.

The variable I Understand Topics Better When Taught Using Problem-Based Learning Approaches (PB3) received a mean score of 3.1800, which is close to PB1, suggesting similarly neutral responses. The standard deviation of 1.23532 is slightly lower than PB1 and PB2, indicating somewhat less variability, but still showing substantial differences in participants' opinions. The skewness value of 0.060 is nearly zero, signaling that the distribution of responses is almost perfectly symmetric, with an even balance between higher and lower ratings. The kurtosis value of -0.931 suggests a platykurtic distribution, meaning that the responses are more spread out than normal, with fewer extreme values at either end of the scale. In conclusion, PB3 received neutral ratings with slightly less variability than PB1 and PB2, though still exhibiting significant diversity in responses, indicating mixed opinions about the effectiveness of problem-based learning for enhancing understanding of topics.

The variable Problem-Based Learning Approach Helps Me to Be More Engaged in Class (PB4) received a mean score of 3.2333, which is similar to PB3, indicating neutral feedback from participants. The standard deviation of 1.32593 reflects high variability, suggesting that responses were widely spread out, with a significant range of opinions. The skewness value of -0.297 indicates a slight negative skew, meaning there is a small tendency toward higher ratings, but not to a large extent. The kurtosis value of -0.980 suggests a platykurtic distribution, indicating that the responses are more spread out than normal, with fewer extreme ratings at either end of the scale. In conclusion, PB4 also received neutral responses, with significant variability, and a slightly higher concentration of positive ratings, reflecting a mixed but somewhat favorable perception of problem-based learning's impact on classroom engagement.

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
IB1	300	4.00	1.00	5.00	986.00	3.2867	.08188	1.41817	2.011	-.305	.141	-1.188	.281
IB2	300	4.00	1.00	5.00	1038.00	3.4600	.07087	1.22750	1.507	-.366	.141	-.851	.281
IB3	300	4.00	1.00	5.00	1040.00	3.4667	.07274	1.25997	1.588	-.389	.141	-.787	.281
IB4	300	4.00	1.00	5.00	1102.00	3.6733	.07744	1.34137	1.799	-.692	.141	-.697	.281
Valid N (listwise)	300												

Figure 3. Descriptive Statistics of Inquiry-Based Learning Variables

The variable You Enjoy Learning Through Inquiry-Based Learning Approach (IB1) received a mean score of 3.2867, indicating a moderately positive perception from respondents. This suggests that participants generally rated the variable favorably, although the feedback was not overwhelmingly positive. The standard deviation of 1.41817 is one of the highest in the dataset, signifying considerable variability in responses and a wide range of opinions about the inquiry-based learning approach. The skewness value of -0.305 is slightly negative, indicating that there were marginally more high ratings than low ratings, but the distribution remains fairly symmetric overall. The kurtosis value of -1.188 suggests a platykurtic distribution, meaning that responses were spread out across the rating scale, with fewer respondents clustering around the mean. In conclusion, IB1 showed a wide range of opinions, with some respondents expressing more favorable views. The high variability and platykurtic distribution reflect the diversity in perceptions of the inquiry-based learning approach.

The variable Inquiry-Based Learning Approach Makes Learning More Interesting (IB2) received a mean score of 3.4600, which is slightly higher than IB1, indicating that respondents held a somewhat more positive view of this aspect. The standard deviation of 1.22750 is slightly lower than that of IB1, suggesting that while there is still variability in the responses, there was slightly more agreement among participants. The skewness value of -0.366 indicates a modest negative skew, meaning that respondents were more likely to provide slightly higher ratings, though not to an extreme extent. The kurtosis value of -0.851 suggests a platykurtic distribution, indicating that responses were spread out, but not as widely as in IB1, with a tendency toward higher ratings. In conclusion, IB2 received slightly more positive ratings than IB1, with less variability. While there is a slight skew toward higher ratings, opinions on this variable remain fairly diverse, reflecting mixed but somewhat favorable perceptions of inquiry-based learning's ability to make learning more interesting.

The variable I Understand Topics Better When Taught Using Inquiry-Based Learning Approaches (IB3) received a mean score of 3.4667, which is very similar to IB2, indicating moderately positive ratings. The standard deviation of 1.25997 is close to that of IB2, suggesting a reasonable amount of variability in responses, though not excessive. The skewness value of -0.389 is slightly negative, implying that respondents were somewhat inclined to give higher ratings, but the distribution remains fairly balanced overall. The kurtosis value of -0.787 suggests a platykurtic distribution, meaning that responses were spread out across the rating scale, with fewer participants clustering around the mean. In conclusion, IB3 follows the same pattern as IB2, with moderately positive ratings and a slight skew toward higher ratings. The variability in responses indicates some disagreement among respondents, reflecting diverse opinions on the effectiveness of inquiry-based learning for understanding topics better.

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
MV1	300	4.00	1.00	5.00	1084.00	3.6133	.06933	1.20082	1.442	-.713	.141	-.280	.281
MV2	300	4.00	1.00	5.00	1118.00	3.7267	.06436	1.11479	1.243	-.698	.141	-.097	.281
MV3	300	4.00	1.00	5.00	1118.00	3.7267	.06367	1.10273	1.216	-.557	.141	-.254	.281
MV4	300	4.00	1.00	5.00	1166.00	3.8867	.06248	1.08215	1.171	-.984	.141	.471	.281
Valid N (listwise)	300												

Figure 4. Descriptive Statistics of Manipulative and Visual Aid Variables

The variable Inquiry-Based Learning Approach Helps Me to Be More Engaged in Class (IB4) received the highest mean score among the Inquiry-Based Learning (IB) variables, with a mean of 3.6733. This suggests that respondents viewed this aspect more favorably compared to the other IB variables. The standard deviation of 1.34137, while still relatively high, indicates that there was considerable variability in responses, despite the higher mean. The skewness value of -0.692 represents a more pronounced negative skew, showing that many respondents provided higher ratings, while fewer respondents gave low ratings. The kurtosis value of -0.697, although still platykurtic, is closer to zero, indicating that the distribution of responses is more normal compared to the other IB variables. In conclusion, IB4 received the most positive ratings among the IB indicators, reflecting a higher mean and a pronounced skew toward higher scores. However, the spread of responses remains significant, demonstrating a diversity of opinions regarding the engagement potential of inquiry-based learning.

The Inquiry-Based Learning (IB) variables generally received moderately positive mean values, with IB4 garnering the most favorable ratings and IB1 displaying the most diverse range of responses. Standard deviations for all IB variables were relatively high, indicating considerable variability in participants' opinions. The negative skewness across all IB variables suggests that respondents tended to rate the items slightly more positively, although the skewness was not extreme in any case. Additionally, the kurtosis values for the IB variables were mostly platykurtic, meaning that responses were spread out across the scale, with less clustering around the mean. This indicates a broad distribution of opinions, with some variability in how participants perceived the effectiveness and engagement of inquiry-based learning.

The Manipulative and Visual Aid Learning (MV1) variable received moderately positive ratings, with a mean score of 3.6133, indicating that most respondents rated this variable above average, though not overwhelmingly so. The standard deviation of 1.20082 suggests moderate variability in the responses, reflecting a range of opinions but not extreme variability. The negative skewness value of -0.713 indicates that more respondents tended to give higher ratings, although there were still some moderate and lower scores. The kurtosis value of -0.280 suggests that the distribution of responses is close to normal, with a reasonably even spread of ratings around the mean. Overall, MV1 received moderately positive feedback, with a tendency toward higher ratings, moderate variability, and a fairly balanced distribution.

The Manipulative and Visual Aid Learning (MV2) variable received slightly more positive ratings than MV1, with a mean score of 3.7267, indicating that respondents found this approach to make learning somewhat more interesting. The standard deviation of 1.11479 is lower than that of MV1, suggesting more consensus among respondents and fewer extreme ratings. The negative skewness value of -0.698, similar to MV1, indicates that more respondents gave higher ratings, although there was still a balance of high and low scores. The kurtosis value of -0.097, close to zero, suggests that the distribution of responses is nearly normal, with no extreme peaks or flatness. In conclusion, MV2 received more positive ratings than MV1, with less variability and a distribution that is nearly normal, reflecting a good balance in opinions and a tendency toward higher ratings.

The Manipulative and Visual Aid Learning (MV3) variable received the same mean of 3.7267 as MV2, indicating similarly positive feedback from respondents. The standard deviation of 1.10273 is also very close to MV2, showing that the responses were relatively consistent. The skewness value of -0.557 is less pronounced than for MV1 and MV2, suggesting a more balanced distribution, although there is still a slight tendency for respondents to give higher ratings. The kurtosis value of -0.254 indicates a near-normal distribution, with a slightly flatter spread than a typical normal distribution.

In conclusion, MV3 received ratings similar to MV2, with positive feedback and a slight skew toward higher ratings. The responses showed low variability, indicating consistency, and the distribution was nearly normal, suggesting that opinions were well-distributed.

MV4 (Manipulative and Visual Aid Approach Help Me to Be More Engaged in Class) stands out with the highest mean score of 3.8867, indicating the most favorable response among the MV variables. The standard deviation of 1.08215 is the lowest, suggesting that responses were more consistent and there was a stronger consensus among respondents. The skewness value of -0.984 is notably more negative, pointing to a higher proportion of respondents providing high ratings, with fewer low scores. The kurtosis value of 0.471 is positive, indicating a leptokurtic distribution, meaning that responses were more concentrated around the mean, with fewer extreme ratings. Conclusion for MV4: MV4 received the most positive ratings among the MV variables, with respondents tending to give higher scores and showing less variability. The negative skewness and positive kurtosis reflect strong agreement toward the positive response, making it the most consistently favorable variable in this group.

The MV variables generally exhibit moderately positive ratings, with MV4 standing out as the highest-rated variable in this group. The standard deviations for the MV variables are relatively lower compared to those in other groups, suggesting a higher level of consensus among respondents and less variability in their opinions. Skewness is consistently negative across the MV variables, indicating a tendency for respondents to rate these variables more favorably, with MV4 displaying the most pronounced negative skew, reflecting stronger agreement toward higher ratings. Kurtosis values for the MV variables are predominantly close to zero, signifying that the distributions are either normal or only slightly flatter than normal. However, MV4's kurtosis value suggests a slightly leptokurtic distribution, indicating that responses were concentrated around the higher ratings, further emphasizing its widespread positive reception.

The TI variables, representing factors like Trust or Importance, exhibit higher consensus, with higher ratings and lower variability. This indicates a strong and consistent agreement among participants regarding these factors. In contrast, the PB, MV, and IB variables show more mixed opinions, as evidenced by their moderate mean values and higher variability, suggesting that respondents were more divided in their assessments of these factors. Additionally, the distribution of responses for the TI variables is skewed toward higher ratings, with most responses clustering around the higher end of the scale. On the other hand, the PB, MV, and IB variables display a more even spread, with responses distributed more uniformly across the rating scale, reflecting a broader range of opinions.

4. Conclusions

This research reveals that innovative experimental curricular approaches—namely, Technology Integration (TI), Manipulative and Visual Aids (MV), Inquiry-Based Learning (IB), and Problem-Based Learning (PB)—play significant roles in enhancing students' conceptual understanding of mathematics. The findings from the SPSS analysis demonstrate that Technology Integration (TI) has the most positive impact on students' understanding, significantly improving engagement and comprehension through dynamic and interactive tools. Manipulative and Visual Aids (MV) are similarly effective, making abstract concepts more tangible and accessible, though their impact varies based on individual learning styles. Inquiry-Based Learning (IB) shows moderate effectiveness, with students benefiting from self-exploration, but the approach requires careful balance to ensure all students remain engaged and adequately supported. In contrast, Problem-Based Learning (PB) yields mixed perceptions, with some students appreciating the challenge while others find it less effective without structured guidance. Overall, the results indicate that TI is the most favored approach, providing both engagement and deepened understanding, while PB may require additional scaffolding to fully realize its potential.

Based on these findings, several key recommendations can be made to enhance the implementation of these approaches in mathematics education. First, educational institutions should increase the use of Technology Integration (TI), investing in tools and training to ensure effective use of technology in the classroom. Second, to improve the effectiveness of Problem-Based Learning (PB), educators should provide more structured guidance and support, such as step-by-step frameworks and collaborative group activities, to foster engagement and problem-solving skills. Third, schools should maximize the use of Manipulative and Visual Aids (MV) by ensuring classrooms are well-equipped with visual tools and manipulatives, facilitating better conceptualization of mathematical concepts. Lastly, Inquiry-Based Learning (IB) should be refined by creating a balance between self-directed inquiry and guided exploration, allowing students to take ownership of their learning while still receiving the necessary support to stay engaged and focused. These recommendations aim to foster an educational environment that is more interactive, engaging, and effective in supporting students' mathematical development.

Conflict of Interest

The authors declare no conflicts of interest.

References

Adu-Gyamfi, K. (2016). Challenges in teaching and learning mathematics in basic schools in Ghana. *Journal of Education and Practice, 7*(3), 62-66.

Anamuah-Mensah, J., Mereku, D. K., & Ghartey, J. (2008). Ghanaian junior secondary school students' achievement in mathematics and science: Results from Ghana's participation in the 2007 Trends in International Mathematics and Science Study. *International Journal of Educational Development, 28*(3), 277-282.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning, 1996*(68), 3-12.

Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. Jossey-Bass.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. National Academy Press.

Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology, 105*(2), 380-400.

Clements, D. H., & Sarama, J. (2011). Early childhood teacher education: The case of mathematics. *Journal of Early Childhood Teacher Education, 32*(3), 231-244.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Sage.

Cuban, L. (2013). *Inside the black box of classroom practice: Change without reform in American education*. Harvard Education Press.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method*. John Wiley & Sons.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. Sage.

Fosnot, C. T. (2005). *Constructivism: Theory, perspectives, and practice*. Teachers College Press.

Fullan, M. (2007). *The new meaning of educational change*. Teachers College Press.

Gravemeijer, K. P. E. (1999). How emergent models may foster the constitution of formal mathematics. *Mathematical Thinking and Learning, 1*(2), 155-177.

Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K. C., Wearne, D., Murray, H., ... & Human, P. (1997). Making sense: Teaching and learning mathematics with understanding. Heinemann.

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371-404). Information Age Publishing.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Kaput, J. J. (1992). Technology and mathematics education. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 515-556). Macmillan.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics*. National Academy Press.

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. Sage.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics*. Corwin Press.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. Jossey-Bass.

National Research Council. (2001). *Adding it up: Helping children learn mathematics*. National Academy Press.

Nisa', K., Nasrullah, A., Hidayat, A., Mahuda, I., & Bhat , I. A. (2023). Problem-Based Learning in Improving Problem-Solving Ability and Interest in Learning Mathematics: An Empirical Study. International Journal of Mathematics and Mathematics Education, 1(3), 206–217. https://doi.org/10.56855/ijmme.v1i3.725

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Sage.

Piaget, J. (1952). *The origins of intelligence in children*. International Universities Press.

Piaget, J. (1970). *Science of education and the psychology of the child*. Viking.

Resnick, L. B. (1987). Education and learning to think. National Academy Press.

Rittle-Johnson, B., & Koedinger, K. R. (2005). Designing knowledge scaffolds to support mathematical problem solving. *Cognition and Instruction, 23*(3), 313-349.

Rittle-Johnson, B., Siegler, R. S., & Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology, 93*(2), 346-362.

Schacter, J. (2001). The impact of education technology on student achievement: What the most current research has to say. Milken Exchange on Education Technology.

Schoenfeld, A. H. (2002). Making mathematics work for all children: Issues of standards, testing, and equity. *Educational Researcher, 31*(1), 13-25.

Sfard, A. (1991). On the dual nature of mathematical conceptions: Reflections on processes and objects as different sides of the same coin. *Educational Studies in Mathematics, 22*(1), 1-36.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. Free Press.

Sawyer, R. K. (2006). *The Cambridge handbook of the learning sciences*. Cambridge University Press.