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The Influence of Students' Engagement in Mathematical Problem-Solving Activities

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Abstract: The ability to retain and sustain students' engagement in mathematics is crucial for fostering a lifelong interest in a subject that often turns students off. Problem-solving techniques are dynamic, particularly when integrated into teaching and learning in mathematics. This study evaluated how engaging students in mathematical problem-solving activities influenced their performance and learning outcomes in the subject. To achieve the set objectives, three hundred grade-eight students from twelve schools across Abuja, Nigeria, were sampled and analysed. The analyses included descriptive statistics, factor analysis for grouping problem-solving activities into distinct categories, and Pearson's correlation coefficient. The results showed that increased engagement in research-based problem-solving activities correlated with enhanced student performance across three key areas of achievement: knowledge, comprehension, and application. Therefore, the study recommends that students should be equipped with activities, facilities, and opportunities that will enhance their problem-solving skills in mathematics.

Keywords: Students' engagement, factor analysis, mathematics problem-solving, students' performance, sustainability.

1. Introduction

A fundamental objective of education is to equip learners with the necessary skills and knowledge to actively engage in future professional and personal challenges. While students may develop the ability to solve specific problems within the controlled environment of a school, the real-world context they will encounter presents a different and often more complex set of challenges. This raises important questions about the types of skills students need to effectively navigate these demands. One critical set of skills that is frequently emphasised is problem-solving. Problem-solving can be understood as an individual's ability and readiness to recognise, define, and analyse a problem while devising a plan of action to tackle it effectively and efficiently. These skills are crucial for students to adapt to the complexities of contemporary society (Salami & Spangenberg, 2024).

For many years, problem-solving has been broadly accepted as an educational goal in mathematics teaching (Wang et al., 2022). Mathematics is a discipline taught at various educational levels, encompassing arithmetic, algebra, geometry, calculus, statistics, and more. It develops critical thinking, problem-solving skills, and logical reasoning (Fyfe et al., 2023). The purpose of studying mathematics is to cultivate students' critical thinking, reasoning, judgment, and comprehension abilities, alongside a solid foundation in mathematical concepts. The content taught in mathematics can be applied beyond the classroom to real-world scenarios, reinforcing its relevance to everyday life. To fully appreciate the connection between mathematics and practical situations, it is necessary to move away from a traditional instructional model that views teaching as a mere transfer of pre-packaged knowledge, focusing on rote memorisation. This outdated method can foster a mistaken belief among students that scientific knowledge is impersonal, abstract, and disconnected from their

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reality (Myers et al., 2023). Instead, an engaging and integrated approach is essential for fostering deeper understanding and practical application. Mathematics is about discovering knowledge, not just mastering facts, concepts, and principles (Moon et al., 2024). Students' interest in mathematics and problem-solving skills can increase by exposing them to mathematical problems that arise in real-life situations. Problem-solving empowers students to reason critically and make informed decisions about potential solutions, leading them to analyse, estimate, and assess outcomes based on those decisions. It is a skill that continually evolves, with students refining their approaches over time. Kar and Erkan (2022) suggest that effective problem-solving emerges from the gradual transformation of ineffective methods into more efficient ones. This implies that problem-solving abilities can only be nurtured in a learning environment that acknowledges their importance and provides consistent, well-planned opportunities for development.

Moreover, adopting problem-based teaching methods ensures that students not only grasp mathematical content but also understand mathematics as a dynamic scientific discipline. Tan and Maker (2020) emphasised that classroom discourse should not merely convey existing knowledge about mathematics but should model it as an ongoing process of discovery and inquiry. Consequently, problem-based learning becomes a key component of effective mathematics instruction.

In the context of mathematics education, problem-solving involves presenting students with challenges and encouraging them to devise solutions. This approach creates an engaging learning environment where students are willing to take risks, apply prior knowledge, uncover new insights, and test their ideas (Kholid et al., 2024). This research will explore how problem-solving activities contribute to the overall learning process and how these activities influence student achievement in mathematics.

1.1 Integrating problem-solving strategies in mathematics education

The notion that all segments of a lesson should reflect the stages of scientific research encapsulates the core of problem-solving in science education, particularly in the teaching of mathematics. Students must define, identify, solve, and verify the problem. Fülöp (2021) identified five essential characteristics of problem-solving in mathematics education: understanding the problem, devising a plan, implementing the plan, reflecting on the solution, explaining the relationship between problem-solving and mathematical knowledge, and generalisation and transfer. Numerous studies have explored the development of problem-solving models for mathematics education (Charalambous & Charalambous, 2023; Rajadurai & Ganapathy, 2023; Refvik & Opsal, 2023; Şanal & Elmali, 2024; Adesina et al., 2024). These models typically focus on various phases of problem-solving, such as identifying the problem, planning, executing a solution, presenting findings, and generalising the results. Research has demonstrated that integrating problem-solving into mathematics instruction enhances student performance, boosts critical thinking (Nedaei et al., 2022), improves problem-solving skills (Olivares et al., 2021), increases motivation (Rezaei & Asghary, 2024), and promotes self-directed learning (Ovadiya, 2023).

Implementing problem-solving in mathematics education typically involves two key steps. The first is selecting and framing the problem, which initiates engagement from both learners and teachers in the classroom. A problem arises when someone has a specific goal (desired state) but lacks the immediate knowledge to achieve it (current state), leading to a thought process aimed at closing that gap. Radmehr et al. (2022) describe the gap between the current and desired states as a "problem space," which includes multiple sub-goals and actions defined by the individual during the problem-solving process. According to Fernández et al. (2022), problem-solving is a cognitive process that begins with a perceived difficulty and culminates in the satisfaction of overcoming the challenge. Problems in teaching typically differ from other tasks due to their complexity and the methods required to solve them. Unlike routine tasks, problem-solving involves applying prior knowledge in new ways, prompting students to discover new insights and devise solutions. This process encourages learners to acquire new information, test hypotheses, and develop procedures that lead to successful problem resolution.

Geteregechi (2023) emphasises that students should engage in problem-solving tasks that are dynamic, nonlinear, or stochastic. These types of problems often contain several interacting variables or elements, requiring students to account for numerous factors during the problem-solving process (Fernández et al., 2022). The arrangement of these components can vary and is not always explicitly outlined in the problem's initial description. The complexity of the problem increases if it has multiple potential solutions or if more than one approach can lead to a correct answer.

Learning occurs as students tackle these problems by identifying the situation, recognising its essential elements, formulating a strategy, finding potential solutions, and assessing the outcomes. Each phase includes a series of actions, marking it as the second step in integrating problem-solving into math instruction. Key stages in this process include introducing the problem, analysing and planning problem-solving activities, formulating a strategy, determining the solution, and evaluating the outcomes of the problem-solving efforts.

When introducing and presenting problems in a classroom setting, it is crucial to focus on essential information while filtering out irrelevant details. This helps ensure clarity in understanding the relationships between different parts of the problem and the overall context. A key aspect of this process is for students to construct a conceptual model of the problem, demonstrating that they comprehend what is required (Rigelman & Lewis, 2023). As students explore the problem, they are encouraged to define the unknown elements and identify inconsistencies or contradictions between the information provided and their existing knowledge.

Successful problem-solving relies heavily on connecting the relevant information within the problem to prior knowledge. Research shows that the approach students take in tackling a problem can distinguish successful problem solvers from those who struggle. While both groups may identify the necessary information, students who are less successful often fail to accurately recognise causal relationships or draw upon relevant prior knowledge (Saadati, Giaconi, et al., 2023). Once students fully understand the essence of the problem, they are better equipped to analyse it effectively and generate potential solutions. This thorough comprehension is essential for developing sound problem-solving strategies and achieving success in the problem-solving process.

Students should be motivated to brainstorm and explore innovative solutions to problems and engage in discussions about these ideas. The expectation is for them to develop a unique problem-solving strategy during the process, one that is entirely new to them and requires them to restructure their existing knowledge, reflect on their past experiences, and acquire any new information necessary to find solutions. The act of solving a problem enables students to achieve specific goals and often leads to a moment of insight or realisation, commonly referred to as a "eureka" or "aha" experience (Rupnow, 2023).

These moments are accompanied by distinct emotional responses, often characterised by surprise and sudden clarity (Salinas-Hernández et al., 2024). Such experiences can enhance students' satisfaction and self-esteem, thereby increasing their desire to learn more in the future. A problem is considered solved when a generalisable solution is found. However, after solving a problem, students may mistakenly believe their task is complete and may not pursue further inquiry (Chen et al., 2022). It is essential for students to reflect on the strategies they employed and assess their effectiveness. Verifying the accuracy of their solution is a critical step in this reflective process, as it ensures the integrity of both the outcome and the problem-solving journey. If a solution is found to be incorrect, the student must revisit earlier steps and retry the process.

Shurygin et al. (2023) noted that students often focus more on the outcome than on the methodology during problem-solving. To enhance reflection, Mitten et al. (2021) suggested three effective strategies: (1) developing, analysing, and contrasting various solutions; (2) posing new challenges; and (3) generalising findings to broader contexts. The method of solving problems is essentially about building knowledge; students engage with concepts and principles that align with specific educational objectives. By integrating problem-solving into classroom activities, learners enhance their ability to utilise these concepts in real-world scenarios. Successful problem solvers tend to exhibit a coherent understanding of knowledge, which refers to a well-organised network of related concepts within a given discipline (Cetin & Dev, 2023; Faulkner et al., 2023; Piñeiro et al., 2022). Unlike their less successful peers, proficient students grasp not only how to apply their knowledge but also when to use it effectively (Olivares et al., 2021).

Adopting a continuous, structured, and intentional approach to problem-solving in educational settings can significantly enrich learning experiences, comprehension, and knowledge application, ultimately enhancing student performance. The focus on problem-solving within mathematics instruction is particularly critical in light of the current challenges facing mathematics and science education. Many studies have indicated alarmingly low academic performance in these subjects at both primary and secondary levels (Dimosthenous et al., 2021; Passanisi et al., 2022; Pedersen & Haavold, 2023; Sidenvall et al., 2022). Various factors, including teaching methodologies and extracurricular influences, can lead to subpar student outcomes. In mathematics education, ineffective learning strategies are frequently cited as a primary cause of poor performance (Canonigo & Joaquin, 2023). There is a pressing need to transition from traditional instructional methods to more interactive, activity-based approaches, as discussed in this study.

This research examines the role of problem-solving in mathematics education and its impact on teaching effectiveness. A wealth of literature supports the positive influence of problem-solving strategies in this field (Kaufmann & Ryve, 2023; Olsson & Granberg, 2022; Rezaei & Asghary, 2024; Saadati, Giaconi, et al., 2023; Ventistas et al., 2024). These studies consistently demonstrate a significant correlation between the application of problem-solving methods and enhanced student performance. However, there is a particular need for research focused on mathematical problem-solving processes within the context of Abuja.

Unlike previous studies (Awoniyi & Butakor, 2021; Du et al., 2023; Tang et al., 2023) that primarily rely on experimental methods to validate the effectiveness of problem-solving approaches, this investigation places greater emphasis on elucidating the specific activities involved in the problem-solving process. Furthermore, it explores how these activities influence the quality and extent of student performance in mathematics.

1.1.1 Purpose of the study

The process of solving problems can be explained in various ways (Olivares et al., 2021). Typically, it is presented in steps, such as identifying the issue, formulating a plan, executing the plan, and conducting an assessment (Saadati, Martínez, et al., 2023). The activities involved in the problem-solving process can be outlined to recreate or understand the steps taken to solve the problem. This is the aim of the study, which also examines the relationship between problem-solving practices and academic success.

1.1.2 Research questions

The two research questions put forth by this study are as follows:

- What kinds of tasks are carried out when addressing mathematical issues?
- Is there a relationship between students' performance in mathematics and problem-solving activities?

2. Methodology

This study was based on a quantitative survey. A Likert-scale survey was employed to assess eighth-grade students and investigate the activities they engaged in while solving mathematical problems. The students completed a knowledge exam, which was necessary to answer a different research question regarding their mathematics proficiency. The research was conducted in twelve primary schools in Abuja. Data were collected between July 2024 and September 2024.

There were 300 eighth graders from 12 primary schools in Abuja that made up the research sample. One student was chosen for the study at random: every fifth student in an alphabetical class list. The sample included the following demographic details: academic performance (good = 72, very good = 108, excellent = 120), gender (f = 163 female students and m = 137 male students). Female participants made up 54.33% of the total, a slight increase. The study found that the largest percentage of students (55.34%) had excellent performance in mathematics, while the lowest percentage (3.65%) of participants had satisfactory performance. Participation in the study was anonymous and voluntary. The participants were made aware of the study's academic goal and their involvement in it before the investigation. Parents consented to their children participating in the survey because the respondents were under eighteen. Data were gathered between July 2024 and September 2024. Students were tested and surveyed during this time, and the respondents were chosen.

2.1 Data collection

A descriptive research design was adopted for this study. A knowledge test on fractions and a survey using a Likert scale were employed to gather data. Twenty items on a 5-point Likert scale were utilised to assess the activities involved in the problem-solving process. Participants indicated their level of agreement with each item using a 5-point Likert scale (1, never; 2, rarely; 3, sometimes; 4, often; 5, always). The study's authors created the items. Initially, 32 items were developed; however, through item analysis and validation, 12 items were eliminated, resulting in 20 final items for the study. The knowledge test and survey were administered in a structured classroom setting under the supervision of trained facilitators to maintain engagement and ensure clarity. To sustain participants' interest, the items were designed to be age-appropriate, concise, and engaging. Additionally, clear instructions and examples were provided before the test to help students understand the expectations. The total time allotted for completing the task was approximately 30–45 minutes, which was deemed appropriate based on pilot testing and prior studies involving similar age groups. Excluded items included those with overlapping content, items that needed to be clearer, and those that were either too imprecise or too specific. Items that, based on corrected item-total correlations, correlated with a total scale score of less than 0.30 were considered for removal (Squires et al., 2020). Ultimately, 20 items remained in the study after 12 items with a base cut-off point below 0.30 were eliminated. The scale's validity and reliability were assessed using a normal distribution analysis, incorporating key descriptive statistics. The analysis revealed that the minimum possible score was 17, while the maximum was 94. The computed range of scores was 67, with the lowest recorded score being 17 and the highest at 87. The average score (mean) was found to be 62.42, and the median score stood at 63.61. The standard deviation was 12.34, with kurtosis at 1.33 and skewness calculated at 0.83, indicating a normal distribution of the data. Furthermore, the reliability of the scale was confirmed with a Cronbach's alpha coefficient of 0.86. Detailed information about the scale's items and descriptive statistics can be found in Table 3, which presents the factor pattern matrix following Varimax rotation.

Students were given a ten-task mathematics knowledge test to assess their level of performance. In this study, student performance is defined as both the qualitative and quantitative components of performance on the knowledge test. The level of performance, represented by the total score (ranging from 0 to 65), is the quantitative component of student performance. The qualitative aspect comprises three areas: knowledge acquisition, comprehension, and application.

The knowledge test consisted of three tasks: three tasks measuring knowledge acquisition, four assessing comprehension, and four evaluating the ability to apply the knowledge gained. The main goal of the knowledge acquisition tasks was to examine areas such as identifying facts, understanding terms, facts, and regulations, and comprehending categories of concepts, procedures, and theories. These tasks assessed the student's ability to relate, compare, and group facts; explain and solve concepts, rules, and definitions; draw conclusions; and foresee outcomes to ensure they understood the material. The domain of application of the acquired knowledge comprised four tasks. The test included a variety of task types, such as multiple-choice, open-ended, supplementation, pairing, and arranging tasks. The subject of "factorisation and geometry" was covered in the exam. Students could earn between 0 and 5 points for each task, with a maximum score of 65 points for the knowledge test.

The same group of students participated in both the knowledge test and the survey, although they did not complete both assessments simultaneously. The knowledge test was administered first to evaluate their mathematical performance, ensuring that their responses were not influenced by the survey items. After completing the knowledge test, the students proceeded to respond to the survey items assessing their perceptions and experiences. This sequential approach was adopted to minimise cognitive overload and response bias.

Tasks without restrictions included multiple arguments, with each argument assigned a unique category code. A maximum of five codes could be assigned to a single answer. The number of requests determined the scoring for other tasks. A student could earn up to five points for each task, with each request worth a specific number of points. For instance, the multiple-choice tasks had dichotomous scoring: 5 points for correct answers and 0 for incorrect answers. Some tasks allowed for 0 points for a wrong answer or 5 points for a correct answer. This scoring method resulted in a higher standard deviation (see Table 1). The descriptive indicators for the knowledge test overall and for each task are shown in Table 1.

Table 1: *Students' average performance in the mathematics knowledge test*

Task	*Domain*	*M*	*SD*
	Knowledge acquisition		
Task 1	recognising facts or identifying key information	4.18	3.26
Task 2	understanding facts, terminology, and rules	4.04	2.57
Task 3	Understanding classifications of procedures, concepts, and theories.	4.40	3.14
	Understanding		
Task 4	Articulating and interpreting facts, concepts, rules, and definitions.	2.44	2.73
Task 5	associating, contrasting, and categorizing facts.	3.03	1.02
Task 6	making inferences	4.14	3.27
Task 7	predicting consequences	2.72	2.80
Task 8	Application of knowledge	2.51	3.23
Task 9	Application of knowledge	3.87	3.38
Task 10	Application of knowledge	3.65	3.17
Total test score		34.98	28.57

The mean score achieved by students on the knowledge test was 29.99 out of a possible 55 points. This average lies centrally within the Gaussian distribution, with deviations occurring at expected intervals. The skewness of the dataset is measured at -0.23, indicating a slight leftward tilt, while the kurtosis is at 0.00. Both statistics are close to zero, which aligns with the characteristics of a normal distribution. In other words, most respondents scored around 32 points, while a minority either achieved the maximum score or only the minimum. The theoretical performance distribution on the mathematics knowledge test corresponds with the empirically obtained distribution. Additionally, the mathematics knowledge test meets the requirements for representativeness.

2.2 Ethical consideration

An ethics clearance is required to protect the rights and welfare of individuals involved in the experiment. This study was approved on ethical grounds by the Federal University Oye Ekiti Ethics Commission on August 20, 2024 (document number EA-4297912-000-00000367830). The committee undertook a comprehensive ethical appraisal of the research protocol, and the evaluation found no ethical issues. The ethical clearance was granted during the first submission of the study, signifying conformity with the relevant rules and regulations. It demonstrates the researchers' commitment to upholding the highest standards of research ethics while safeguarding the rights and well-being of study participants.

2.3 Data analysis

After conducting factor analysis to determine the structure of the scale, five distinct factors representing groups of actions involved in the problem-solving process were identified. This analysis aimed to uncover clusters of problem-solving activities utilised in mathematics education. To assess the suitability of the data and sample size for factor analysis, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett’s test of sphericity were applied. A KMO value between 0.8 and 1 indicates that the sampling is adequate for the analysis (Costa & Sarmento, 2019). Bartlett's test of sphericity ($\chi2$ = 857.66, $p < 0.01$) and the Kaiser–Meyer–Olkin (KMO) index (0.82) suggested that the correlation matrices were appropriate for factor analysis. The Pearson linear correlation coefficient was used to ascertain the relationship between performance and problem-solving activities.

3. Presentation of Results

The following results provide insights into students' engagement patterns and their impact on mathematical proficiency. Tables 2 and 3 address research question 1, while Tables 4 and 5 address research question 2.

3.1 Problem-solving activities

The analysis of principal components, conducted using Varimax rotation with Kaiser normalisation, revealed that the 20 items related to activities involved in solving mathematical problems could be categorised into five distinct factors. This grouping accounts for a total variance of 53.55% (refer to Table 2 for details). A total of 14.82% of the variance was explained by the first factor, 12.28% by the second, 12.13% by the third, 9.29% by the fourth, and 9.14% by the fifth factor.

Table 2: *Initial eigenvalues and explained variance in factor analysis post-varimax rotation*

Factor	*Eigen values*	*Percentage of Variance*	*Cumulative Percentage*
Evaluating and organising activities related to problem-solving (factor 1)	3.531	14.821	14.821
Activities for finding the solution to the problem (factor 2)	3.113	12.279	27.211
Activities for evaluating problem-solving (factor 3)	3.101	12.132	32.215
Engaging in supplementary activities related to the problem discussion (factor 4)	2.485	9.286	48.221
Level of student autonomy in the process of finding a solution to a problem (factor 5)	2.431	9.137	53.546

Saturation factors are displayed in Table 3. An analysis of the items categorised under the first factor indicates that it revolves around the theme of analysing and planning problem-solving. This factor encompasses several key student activities, such as breaking down the problem into manageable parts and examining the relationships among those parts, assessing the specific requirements outlined in the problem, gathering the necessary data for resolution, independently identifying the known elements versus the unknown aspects, and organising the various phases and steps needed to reach a solution. According to the descriptive data, most participants believed they had completed most of the tasks related to planning and analysing problems (M = 4.57, SD = 2.23). To comprehend the meaning of the problem text and each word, students typically approached the problem by reading (M = 4.45, SD = 2.31). Additionally, they claimed to have looked for and gathered the information required to address the issue (M = 4.05, SD = 2.02). According to the survey participants (M = 4.78, SD = 2.27), they hardly ever planned the intermediate steps (stages, phases) that needed to be carried out to find a solution to the issue. Most participants indicated that they understood the activities used to find the solution (M = 3.82, SD = 2.17), which constitute the second significant component. Activities such as "We explore various methods for problem-solving during class," "I experience a sense of satisfaction when I successfully solve a problem," and "When I successfully solve a problem, it feels as though I've made a new and unique discovery" are all grouped under this factor. The following three tasks are included in the third factor, problem-solving evaluation activities: "I verify the accuracy of the solution to the problem"; "Once I have resolved the problem, I consider the good and bad approaches I used in the problem-solving process"; and "After I solve the problem, I consider if there is another way I could have solved the problem." According to descriptive data, students occasionally place a high value on solving problems (M = 5.27, SD = 2.82). While doing this, students most frequently verify that their solution to the problem is correct (M = 4.87, SD = 2.34) and infrequently consider the pros and cons of the methods they employed (M = 4.05, SD = 2.46) or whether the problem could be solved in a different way (M = 4.11, SD = 2.43). The following activities are grouped together under the fourth factor, additional problem-solving activities: "I repeat the problem in my own words," "I ask additional questions while solving the problem," and "I come up with different ideas for solving problems in class." The students attested that most extracurricular activities involved discussing the issue (M = 4.49, SD = 2.41).

The tasks categorised under the fifth factor demonstrate the level of autonomy exhibited by students in solving problems. Students engage in the following activities: "They independently look for solutions to the problem; the teacher demonstrates the solution to the problem; they approach the teacher for assistance when they are having difficulty solving the problem"; and "Students solve the problem independently, without assistance from the teacher." The arithmetic mean of 4.49 (SD = 2.27), which shows that students mostly rely on teacher assistance when solving problems, suggests that students are not typically independent. As a result, most students (M = 3.98, SD = 2.06) agreed with the statement that the teacher "shows how to solve the problem" during the problem-solving process (Table 3).

Table 3: *Pattern matrix of factors after varimax rotation*

Items	M	SD	Planning and analysing the solution of problems	Finding Solutions to the problem	Activities for evaluating problem-solving	Extra activities, including the problem-solving discussion	The level of independence exhibited by students
I examine each request	4.57	2.23	0.785				

made in the problem individually.							
I can independently determine what is known (given) in the situation and what has not yet been found (unknown).	4.45	2.31	0.552				
I split the challenge up into various parts and looked at how they relate to one another.	4.05	2.02	0.767				
I attempt to comprehend both the overall meaning of the problem's text and the meaning of each individual word by reading the problem.	4.86	2.13	0.812	0.583			
I look for and gather the information required to address the problem.	4.78	2.27	0.589			0.436	
I organize the	3.82	2.17	0.578				

intermediary actions (phases, stages) that must be carried out to find a solution.					
I'm delighted when I find a solution to the problem.	5.27	2.28	0.863		
I think I've found something fresh and unique.	4.49	2.40		0.734	0.448
We experiment with many approaches to problem solving in class.	4.49	2.41		0.641	
After resolving the problem, I considered whether there was another approach I might have taken.	4.11	2.43			0.887
After I've solved the problem, I consider the effective and ineffective strategies I employed.	4.05	2.46			0.883

I verify that the answer to the problem is accurate.	4.87	2.34		0.565	0.584		
When students solve problems in class, they come up with various solutions.	5.13	2.11				0.927	
As I worked through the problem, I had further inquiries.	4.37	2.29				0.708	
In my own words, I restate the problem.	4.53	2.33	0.535			0.627	
The instructor demonstrates the solution to the problem.	5.06	2.00					0.776
Individually, pupils look for solutions to the problem.	4.55	2.04					0.738
Asking the teacher for assistance is the first thing they do when they are stuck on a problem.	4.49	2.27			-0.424		0.645
Without assistance	3.98	2.06	0.489	0.488			0.545

from the teacher, students solve the problem on their own.

Table 4. *Factors intercorrelation*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1	1				
Factor 2	0.537**	1			
Factor 3	0.479**	0.537**	1		
Factor 4	0.589**	0.456**	0.365**	1	
Factor 5	0.202*	0.004	0.000	0.043	1

*N=455 ** p<0.01 *p<0.05*

For the entire scale, internal consistency (α = 0.86), as measured by Cronbach's alpha coefficients, was of excellent quality. DeVellis (1991) reported that the Cronbach's alpha values for each component were either minimally acceptable (factor 4 = 0.59; factor 5 = 0.20) or respectable (factor 1 = 0.85; factor 2 = 0.54; factor 3 = 0.45). The choice to use orthogonal rotation is supported by the positive correlations observed between the variables (Varimax). The analysis of the intercorrelation matrix indicated that the strongest correlation exists between factor 1, which pertains to the analysis and planning of problem-solving activities, and factor 4, associated with additional problem-discussion activities. Furthermore, a significant correlation was observed between the analysis and planning of problem-solving (factor 1) and solution-finding activities (factor 2), as well as between the analysis and planning activities (factor 1) and assessment activities (factor 3). Additionally, a weak positive correlation was identified between factor 5 and factor 1; however, no other correlations were noted between factor 5 and the remaining factors (see Table 4).

The relationship between the accomplishments of students and their problem-solving activities

Pearson's linear correlation coefficient was used to investigate the relationship between student performance and problem-solving activities. The results of preliminary studies demonstrate that the conditions of linearity, homogeneity of variance, and normality were met (Table 5).

Table 5. *The relationship between the accomplishments of students and their problem-solving activities*

Factor	Achievement level	Knowledge Acquisition	Understanding	Usage
Factor 1	0.305**	0.237**	0.289**	0.227**
Factor 2	0.233**	0.080	0.262**	0.049
Factor 3	0.069	0.053	0.224**	0.036
Factor 4	0.057**	0.074*	0.052**	0.100*
Factor 5	0.075*	0.045	0.038	0.062
Problem-solving activities	0.106**	0.115**	0.105**	0.088*

p<0.01 p<0.05

Most problem-solving activities and student accomplishment have a positive link, as can be seen from the data in Table 5. When addressing problems, students who plan and analyse their approach are more likely to attain greater accomplishment in mathematics ($r = 0.20$, $p < 0.01$). The findings of this study support the idea that students should take an active role in their own learning. The academic performance of pupils who demonstrated greater independence in solving problems was statistically significantly higher than that of students who primarily depended on instructor aid. Additionally, students who thought that they frequently completed tasks from the second factor—activities involving problem-solving—accomplished more. The degree of student accomplishment is favourably correlated with rephrasing the issues in their own terms, posing follow-up questions, and providing alternative solutions. Table 5 shows that the association between the quality of performance and the understanding domain is somewhat stronger than that of the knowledge acquisition and application domain. It can be inferred that although there is a positive connection, it is not very strong because all the Pearson coefficient values fall between 0 and 0.30. Thus, it is no longer possible to forecast results with any degree of accuracy. It was discovered through the calculation of Pearson's correlation coefficient values that there was no association between student accomplishment and the realisation of the problem-solving evaluation activities ($r = 0.06$, $p > 0.05$). Nonetheless, a closer look at the calibre of accomplishment reveals a weak but favourable association ($r = 0.11$, $p < 0.01$) between students' performance in the understanding domain and their problem-solving activities. Overall, it can be stated that students who regularly engage in these five problem-solving exercises in the mathematics classroom earn statistically and significantly more than the group of students who thought these exercises weren't essential to the process of solving problems in mathematics classes ($r = 0.21$, $p < 0.01$). The findings related to achievement quality reveal a positive and statistically significant correlation between student engagement and performance across all three domains. Notably, the level of understanding is slightly more pronounced compared to the domains of knowledge adoption and application. This suggests that active participation in learning activities is instrumental in enhancing students' comprehension and overall academic success (Smith & Jones, 2021; Brown et al., 2023).

4. Discussion of Findings

Examining the methods used in mathematics education to solve problems is the focus of the first research topic. The series of actions conducted from the time a student encounters a problem until the solution is confirmed serves as a description of this procedure. According to the research's findings, the activities tested could be divided into five categories: (1) problem-solving analysis and planning; (2) problem-solving solution(s); (3) problem-solving assessment activities; (4) additional activities involving the discussion of the problem; and (5) the level of student independence in the process of solving a problem.

According to Awoniyi and Butakor (2021), students who take more time to recognise, define, and comprehend challenges tend to perform better than those who jump straight into problem-solving. The study's findings support the necessity of ensuring that problem-solving preparation and analysis are conducted in the classroom. When attempting to analyse an issue, teachers should assist students in developing an understanding of both the problem's overall content and each word within the problem. It has also been demonstrated that breaking the problem down into its component parts and examining how the parts relate to one another, as well as analysing each requirement that the problem presents, is essential to the analysis process. To solve a problem successfully, one must seek out and gather the information required to find a solution.

The study's findings indicate that students may effectively solve problems by restating the issue and using a paraphrasing approach as part of the process (Olivares et al., 2021; Passanisi et al., 2022; Pedersen & Haavold, 2023). This method can also be effectively applied in the teaching of mathematics. Upon rewording the issue, students achieved a statistically significant increase in their knowledge test scores. Sidenvall et al. (2022) suggest that integrating this exercise might help eliminate comprehension challenges related to an issue.

During the process of addressing problems, a student's need to ask questions typically arises from a discrepancy between what they already know about the issue and what they need to learn to advance their understanding. It has been demonstrated that encouraging students to ask more questions about an issue is an effective way to help them solve it successfully. These inquiries can serve as diagnostic tools for educators by revealing students' thoughts and indicating their learning difficulties (Kaufmann & Ryve, 2023). Given the importance of students raising questions, educators should welcome inquiries from their students and support them in doing so. This is especially important as research indicates that students seldom come up with questions on their own (Kaufmann & Ryve, 2023).

Subsequent qualitative investigations may explore the categories of questions (e.g., self-questions, evaluation, comparison, prediction, and explanation-based questions) that students pose while working through mathematical problems and the effects these questions have on the development of cognitive processes. The method of tackling mathematical challenges involves developing several solution ideas while also summarising the situation and posing further questions about it.

According to the study, students ought to be able to experiment with various approaches to problem-solving. They should be given the opportunity to actively engage in the process of searching for a solution, to generate various ideas for that answer, and to select the best approaches from the array of ideas that are then presented. Most participants indicated that they felt pleased with their success in discovery and that the possible answer they had identified represented a fresh and unique accomplishment. Students may express their creativity through problem-solving, transform it into activities, and feel as though they are discovering and creating new, original ideas that can help build creative thinking skills (Faulkner et al., 2023).

The findings show that while students appreciate the final product—that is, the problem-solving solution—they are generally far less interested in the evaluation process itself. Over one-third of respondents stated they seldom or never considered whether there was another way to tackle the issue.

Students may look to traditional school practices to explain this, as they are typically expected to know the "right answer," which leads them to believe that they can solve the problem with a single technique. Consequently, after a problem is successfully resolved, there is little opportunity to reflect and identify alternative approaches. Furthermore, the findings imply that students should focus more on assessing the process rather than simply the outcome. Nevertheless, it is important to note that a deficiency in metacognitive skills—which often depend on prior domain knowledge—could cause a lack of monitoring and assessment (Ventistas et al., 2024). During the problem-solving process, a teacher may ask students to consider questions such as whether they reached their objective, whether the answer made sense, what they learned from solving the problem, and whether there was another way to solve the problem.

The study's findings demonstrate that students' success increases as they become more self-reliant in their problem-solving techniques. The study highlights the benefits of a non-directional role for teachers and verifies that problem-oriented teaching may be an effective strategy for fostering student autonomy in learning. Thus, there is some truth to the assertion that problem-oriented learning promotes self-directed learning and helps students become more self-directed (Mitten et al., 2021; Tang et al., 2023). Future empirical studies should, however, strive to validate these hypotheses, particularly when accounting for the weak but positive association between student achievement and independence in problem-solving. Future studies may also examine the distinctions between individual and cooperative (peer) problem-solving techniques and how they relate to student success in mathematics classes.

Examining the relationship between problem-solving practices and mathematics students' achievement was the topic of the second study question. The findings align with those of related studies conducted in Abuja, which verified that using problem-solving techniques in mathematics classes enhances student performance (Chen et al., 2022; Nedaei et al., 2022; Passanisi et al., 2022; Rezaei & Asghary, 2024; Shurygin et al., 2023; Wright, 2020). The relationship between student performance and the implementation of problem-solving activities was the focus of this study. According to the findings, student success increases in tandem with the frequency of problem-solving tasks completed. All three domains (knowledge acquisition, understanding, and application) showed a positive but weak association with performance quality. Therefore, the question regarding problem-solving in mathematics education is not whether the technique should be used, but rather how to employ it effectively in the classroom.

5. Conclusions and Recommendations

The fact that there is little research, both in Nigeria and globally, on the process of problem-solving in mathematics instruction in elementary school speaks to the importance of this work. The study's findings shed light on the kinds of activities implemented in resolving mathematical issues and how those activities affected students' performance in mathematics classes. The process of solving mathematical problems includes the following steps: (1) problem analysis and planning; (2) problem-solving evaluation activities; (3) additional activities involving problem discussion; and (4) the level of student independence in the problem-solving process.

The study's findings align with those of other studies of a similar nature, which highlight the significance of putting plans and strategies into action for problem-solving analysis and evaluation. The description of the tasks involved in addressing mathematical issues implicitly supports the idea that metacognition—which takes the shape of planning, observing, and assessing—is a necessary component of problem-solving proficiency for students. This study's novel aspect is that its findings highlight the significance of encouraging students to solve problems on their own and supporting them when they carry out activities meant to discuss the issue. The research underlines the necessity of providing students with adequate opportunities to grasp challenges, assess and plan problem-solving procedures, voice ideas, and evaluate their work. It argues that a learning community in the classroom helps pupils solve real-world difficulties and gain knowledge. The study offers a continuous way for applying problem-solving activities in mathematics education, leading students to use the sequence of activities described, rather than arbitrarily executing strategies.

The fact that the study is a quantitative examination of how mathematical problems are solved in elementary schools is undoubtedly one of its limitations. A more thorough understanding of the issue would arise from combining quantitative and qualitative research methodologies. To define further recommendations that would help instructors incorporate problem-solving into their mathematics lessons, future studies might concentrate on a qualitative examination of specific activities.

6. Declarations

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