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Rethinking Matrix Instruction: A Mixed-Methods Analysis of Students' Problem-Solving Skills and Pedagogical Challenges

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Abstract

This study aims to analyze students' problem-solving skills in the matrix topic and to identify instructional constraints that influence the learning process. A mixed-methods approach was employed: the quantitative phase involved an eight-session expository intervention (90 minutes per session) and an assessment consisting of 30 multiple-choice and 5 essay questions (scored 0–100), while the qualitative phase included open-ended interviews with the teacher responsible for matrix instruction. Quantitative findings revealed that most students remained at the basic mastery level, with an average score of 26.82 and a distribution dominated by the "Low" category. Only 3.88% of students reached the "Good" level, and a binomial test confirmed that this proportion was significantly lower than the reference threshold ($p < 0.001$), reinforcing the conclusion that student performance fell short of expected standards. These findings highlight the urgent need for early diagnosis of foundational algebra skills—such as row-column operations and linear equation manipulation—before introducing more complex matrix concepts. The qualitative analysis revealed that although the teacher still employed expository methods—lectures, question and answer, and open discussions—these strategies were insufficient for fostering deep problem-solving skills. Students often relied on mechanical procedures without conceptual understanding, struggled to connect algebraic notation to real-world contexts, and lost motivation when facing multi-step problems. The combined results suggest that instructional design should shift toward more contextual and concept-exploratory approaches. Strategic steps are recommended, including the adoption of structured problem-solving methods to improve learning outcomes in mathematics. Furthermore, curriculum development should allocate sufficient time and resources to matrix topics, provide professional development for teachers in designing innovative instruction, and ensure access to digital infrastructure that supports mathematical visualization.

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INTRODUCTION

Problem-solving skills play a central role in mathematics education—not only as a means of applying procedural knowledge but also as a vehicle for developing students' critical and creative thinking abilities. In the learning context, these skills go beyond mechanical competence; students are encouraged to engage with complex problems that reflect real-world situations and to devise effective solution strategies. This approach is widely supported by international educational bodies, including the Organization for Economic Co-operation and Development (OECD), which emphasizes that traditional methods focused solely on theoretical problem-solving are insufficient to prepare students for real-life challenges (Kabael & Baran, 2023). Furthermore, the use of STEM pedagogy has been proven to enrich the problem-solving process by integrating creative processes with mathematical reasoning (Ballon et al., 2024; Demirci & Şahin, 2024).

Curriculum reforms in various countries reflect a growing need to prioritize problem-solving skills and critical thinking in mathematics learning. Policy analyses in developed countries such as Norway indicate that findings from the Programme for International Student Assessment (PISA) have driven reforms emphasizing these competencies as key to success in modern society (Nortvedt, 2018). Likewise, many national curricula now adopt constructivist and hands-on approaches that value active student engagement in solving problems (Ling & Mahmud, 2023). Other studies show that integrating technology into teaching methods has created dynamic learning environments conducive to the development of creativity and critical thinking skills (Said et al., 2023; Khalid et al., 2020).

Despite the increasing recognition of problem-solving's importance, research indicates that many students still struggle to apply appropriate strategies to solve mathematical problems—particularly in the topic of matrices. These difficulties often stem from a tendency to memorize procedures without grasping underlying concepts, which prevents students from flexibly transferring knowledge to contextual problems (Ramirez et al., 2016). Moreover, conceptual misconceptions hinder their ability to map real-life problems into proper mathematical representations (Van Dooren et al., 2019).

As common solutions, Problem-Based Learning (PBL) and Realistic Mathematics Education (RME) have been proposed to enhance student engagement and understanding. The RME approach encourages students to work within real-world contexts, enabling them to develop problem formulation and systematic problem-solving steps (Ulandari et al., 2019; Umar & Zakaria, 2022). This strategy has successfully improved mathematical problem-solving by emphasizing visual representations and group discussions to strengthen conceptual understanding.

Previous studies have shown that integrating contextual problem-solving tasks into matrix learning can significantly enhance student performance (Setiawan et al., 2023). These methods guide students in identifying solution steps through the exploration of matrix concepts, linear algebra, and applications in simple simulation models—later discussed in small groups to reinforce shared understanding. Other studies highlight the importance of student-centered learning that emphasizes open-ended questions and metacognitive reflection (Agustiningsih & Syamsudin, 2019). Allowing students to independently formulate matrix problems and evaluate peer-reviewed solutions has been shown to improve higher-order thinking skills and learning autonomy, contributing to long-term retention of mathematical concepts. Moreover, STEM approaches integrated with interactive technology—such as computer algebra systems—have been found effective by Ballon et al. (2024) and Demirci & Şahin (2024) in enhancing student creativity and analytical skills. In their studies, project-based tasks combined numerical experiments with graphical visualizations of matrices, allowing students to explore patterns of spatial transformations and test hypotheses through simulation.

Numerous efforts have emphasized strategies to strengthen problem-solving skills, yet certain external and psychological factors—such as math anxiety and classroom dynamics—remain underexplored. Ramirez et al. (2016) highlighted how math anxiety drives students to adopt rigid strategies, reducing flexibility in solving problems. Meanwhile, Jiang et al. (2022) noted that teachers' beliefs and instructional practices significantly influence students' motivation and engagement in problem-solving tasks. Few studies have investigated how these factors interact with mathematical problem-solving approaches in the context of matrices.

In addition, although evidence suggests that game-based learning (e.g., Ke et al., 2023; Ke et al., 2024) and personalized learning (Bernacki & Walkington, 2018) enhance problem-solving performance, their structured implementation in matrix topics remains limited. Most existing studies focus on basic algebra or geometry, meaning the application of such methods in matrix topics—which require abstract understanding and representational skills—has not been comprehensively examined. This gap points to the need for further research on the effectiveness of specific methods in fostering problem-solving strategies in matrix-related learning.

This study aims to analyze the problem-solving skills of high school students in learning mathematics, particularly in the matrix topic. The scope of the research includes both quantitative and qualitative analysis involving high school students, using a problem-solving test focused on matrices and structured interviews with mathematics teachers. Accordingly, this study is expected to provide practical insights for educators and policymakers in designing more effective and contextual matrix learning strategies to better support students' problem-solving skills.

In line with the research objectives, the specific research questions are as follows:

1. How are high school students' problem-solving skills in learning mathematics on the topic of matrix?
2. What are the conceptual barriers and challenges students face in developing problem-solving skills in matrix learning under the current instructional strategies?

METHOD

This study was designed using a mixed-methods approach, integrating both quantitative and qualitative components to obtain a holistic understanding of students' problem-solving skills in the matrix topic and to explore instructional challenges faced by teachers during the learning process. On the quantitative side, the instructional intervention employed an expository method—combining lectures, question-and-answer sessions, and open discussions—across eight sessions, each lasting 90 minutes. After these sessions, students completed a mathematics problem-solving test consisting of 30 multiple-choice and 5 essay questions, with final scores calculated on a 0–100 scale. The test results were analyzed descriptively and categorized into five levels of problem-solving skills (see Table 1) to facilitate the identification of performance patterns and areas requiring improvement. Additionally, a binomial test was conducted to determine whether the proportion of students achieving a "Good" level (score range 61–80) significantly differed from a reference proportion of 0.5. This test served to statistically evaluate whether the number of students reaching the expected competency threshold met the ideal benchmark for instructional success.

The qualitative component focused on open-ended interviews with the mathematics teacher responsible for teaching the matrix topic. The interview explored conceptual difficulties and teaching strategies applied in the classroom, particularly challenges encountered in implementing expository methods. Each interview session was recorded and transcribed, followed by thematic analysis. The integration of quantitative and qualitative data enabled robust triangulation, enriching insights into the effectiveness of instructional approaches and the factors influencing students' problem-solving skills.

A total of 103 Grade XII students aged 17–18, with a relatively balanced gender composition, participated in the study through total sampling. Prior to the intervention, students were briefed on the study's objectives, procedures, and ethics, and completed a demographic questionnaire capturing age, gender, and academic background. This step ensured transparency and adherence to ethical research standards within the school context.

Following the eight-session expository intervention, students took a mathematics problem-solving test composed of 30 multiple-choice items (worth 2 points each) and 5 essay items (worth up to 8 points each), totaling a maximum score of 100. The test was administered in a 90-minute session held in the same classroom as the intervention, under strict supervision to ensure uniform testing conditions and minimize external disruptions.

Quantitative data from the test scores were analyzed descriptively using measures of central tendency (mean, median, mode) and dispersion (standard deviation, score range). This analysis aimed to describe the overall distribution of students' problem-solving skills and identify emerging performance patterns. The scores were classified into five levels of mathematical problem-solving skills, ranging from "Very Poor" to "Very Good" (see Table 1), to provide teachers with practical insight into categorizing students' abilities. A binomial test was then applied, comparing the proportion of students scoring within the "Good" category (61–80) against a reference proportion of 0.5. The test offered inferential support to descriptive findings by assessing whether students' collective performance had met the expected competency level for problem-solving-oriented instruction.

Table 1. Score ranges and problem-solving skill categories

Category	Score Range	Skill Description
Very Poor	0 – 20	Students lack understanding of basic concepts
Poor	21 – 40	Minimal understanding, difficulty in application
Fair	41 – 60	Basic understanding, limited application
Good	61 – 80	Adequate understanding and application
Very Good	81 – 100	Deep understanding, proficient in problem-solving

The qualitative study proceeded with an in-depth interview with the mathematics teacher handling the matrix material. The open-ended interview focused on two core aspects: students' conceptual difficulties and problem-solving strategies during instruction, and the teacher's perception of the effectiveness of expository methods. Each interview was recorded and transcribed verbatim for further analysis. Thematic analysis was employed, with themes selected based on frequency and relevance to the research objectives. Finally, triangulation was conducted by comparing qualitative findings with quantitative results to enhance the study's internal validity.

Through the addition of the binomial analysis, this study not only described the distribution of student scores but also statistically assessed the effectiveness of instruction based on the proportion of students meeting the "Good" category—the minimum competency threshold.

With this comprehensive methodological design, the study aims not only to measure students' mastery of problem-solving strategies in matrix material but also to uncover psychosocial and instructional factors influencing the learning process. The combined quantitative and qualitative results are expected to offer a well-rounded perspective and serve as a foundation for practical recommendations to improve mathematics instruction in the matrix topic.

RESULTS AND DISCUSSION

This study investigated students' problem-solving skills in mathematics, particularly in the matrix topic. The descriptive quantitative analysis of students' problem-solving performance is presented in Table 2, followed by a descriptive plot in Figure 1.

Table 2. Descriptive statistical analysis

Variabel	Value
Valid	103
Mean	26.823 ("Poor")
Std. Error of Mean	1.405
Std. Deviation	14.258
Coefficient of variation	0.532
Minimum	6.250
Maximum	71.880
Lower Whisker	6.250
Upper Whisker	40.630

Table 2 summarizes the descriptive statistics for students' problem-solving scores on matrix-related tasks (N = 103). The mean score was 26.82 (classified as "Poor"), with a standard error of 1.41 and a standard deviation of 14.26, indicating a relatively wide distribution. The coefficient of variation of 0.532 reflects high inter-individual variability. Scores ranged from 6.25 to 71.88, suggesting considerable differences in student abilities.

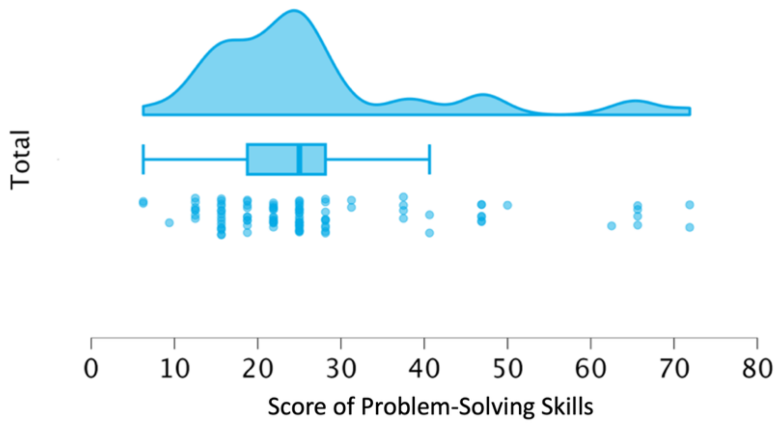

Figure 1. Descriptive plot of students' problem-solving scores

The descriptive plot in Figure 1 shows the score distribution using a combination of boxplots, individual data points, and a violin plot. The whiskers span scores from 6.25 to 40.63, indicating that 50% of the data lie below 40.63. A few extreme values nearing 72 suggest the presence of positive outliers. The right-skewed shape of the violin plot confirms that most students scored within the "Very Poor" to "Fair" range. This visualization highlights that the majority have not achieved adequate proficiency in matrix problem-solving, emphasizing the need for more targeted interventions for lower-performing groups.

Quantitative analysis revealed that overall student problem-solving skills in matrix topics were low, with most scores clustered at the lower end and only a small fraction demonstrating high performance. The wide score distribution indicates substantial variation among students, while the visual distribution confirms the predominance of low scores with a few positive outliers. These findings underscore the need for more specific instructional support, especially for those with the weakest skills, to enhance conceptual understanding and problem-solving strategies.

In addition to descriptive analysis, a binomial test was conducted to assess whether the proportion of students achieving the “Good” category (scores between 61–80) met the minimum threshold for success ($p = 0.5$). Among the 103 students, only 4 (3.88%) reached this level. The binomial test produced a p-value of < 0.001, indicating that the proportion of students achieving “Good” performance was significantly lower than the benchmark. Table 3 presents the full results of the binomial test by individual score, and Figure 2 visualizes these results.

Table 3. Binomial test results based on individual scores

Level	Counts	Total	Proportion	p-value
6.25	2	103	0.019	< .001
9.38	1	103	0.010	< .001
12.5	7	103	0.068	< .001
15.63	15	103	0.146	< .001
18.75	10	103	0.097	< .001
21.88	14	103	0.136	< .001
25.00	22	103	0.214	< .001
28.13	10	103	0.097	< .001
31.25	2	103	0.019	< .001
37.5	4	103	0.039	< .001
40.63	2	103	0.019	< .001
46.88	6	103	0.058	< .001
50.00	1	103	0.010	< .001
62.50	1	103	0.010	< .001
65.63	4	103	0.039	< .001
71.88	2	103	0.019	< .001

Note. Proportions tested against value: 0.5

The binomial test results in Table 3 indicate that all observed scores in the student distribution have proportions significantly lower than the reference value of 0.5. This reinforces the conclusion that student performance is heavily concentrated in the lower score ranges, with only a few students reaching scores close to the "Good" category.

To visualize the distribution of proportions from the binomial test across individual scores, Figure 2 presents a descriptive plot with confidence intervals. The black dots represent the actual proportion of students at each score level, while the dashed horizontal line marks the reference proportion of 0.5. Nearly all data points lie well below this reference line, emphasizing that none of the scores approached the ideal proportion.

Figure 2 visualizes the binomial test results, showing confidence intervals for each score’s proportion. The black dots represent actual proportions, while the dashed horizontal line indicates the 0.5 benchmark. Nearly all data points fall well below this line, confirming that none of the score categories approached the ideal proportion.

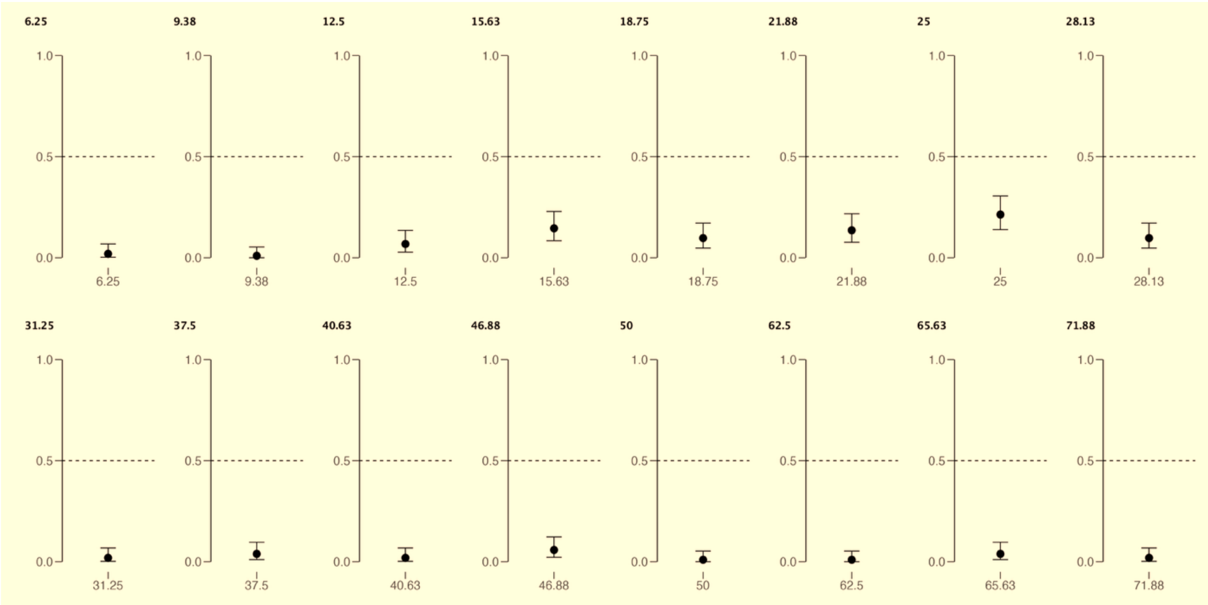

Figure 2. Binomial test proportion plot of students' problem-solving scores

The visualization in Figure 2 supports the statistical interpretation that the distribution of students' problem-solving skills is skewed heavily toward the lower end, with most proportions for individual scores falling well below the 0.5 threshold. These consistently low proportions indicate that the majority of students did not reach an adequate mastery level, even for mid-range scores. The absence of points near the central benchmark further reveals that student performance is not only low but also unevenly distributed—heavily concentrated in the "Very Poor" and "Poor" categories. This underscores a wide gap between actual outcomes and learning expectations, suggesting that current instructional strategies are ineffective in reaching and developing most students' problem-solving competencies.

To complement the quantitative findings, a qualitative study was conducted through an interview with the mathematics teacher responsible for matrix instruction. The results are summarized in Table 4.

Table 4. Summary of themes, key findings, and teacher statements

No.	Theme	Key Findings	Teacher Statement
1	Initial Concept Understanding	Students recognize rows and columns but memorize matrix formats without understanding each element's function.	*"They often just memorize the format '[a b; c d]' without really grasping what each element means."*
2	Basic Operations Challenges	Students confuse row-column order in addition/subtraction and struggle with multiplication and inverses.	*"Many students get confused about when to multiply rows by columns, and inverses totally confuse them with determinants."*
3	Real-World Application	Students struggle to model rotation or transformation due to lack of algebra-context linkage.	*"When asked to make a rotation matrix, they don't know how to relate the numbers to image movement."*

No.	Theme	Key Findings	Teacher Statement
4	Teaching Strategy	Use of software and peer teaching varies in effectiveness depending on group readiness.	*"I show geometric transformation with software first, then switch to algebra—but if the group isn't ready, discussions stall."*
5	Response to Complex Problems	Students lose motivation after a single misstep and abandon multi-step problems.	*"Once they make one mistake, students tend to give up and don't continue solving layered questions."*
6	Open-Ended Task Limitations	Time constraints make designing rich open-ended tasks difficult within 45-minute lessons.	*"It's hard to make open-ended questions that challenge everyone in just 45 minutes without confusing others."*
7	Error Type Progression	Procedural errors dominate early on; later conceptual/strategic errors appear.	*"At first, they made a lot of calculation mistakes; later, they calculated better but still chose wrong strategies."*
8	Algebra Prerequisite	Basic linear equation skills are essential for matrix operations.	*"If their basic algebra isn't solid, they get confused when operating matrices."*
9	Supporting & Inhibiting Factors	Visual aids help, but access and practice time at home are limited.	*"Visualization helps a lot, but not everyone has the tools or time to practice at home."*
10	Desired Improvements	Workshops and formative quizzes are proposed to enhance relevance and early problem detection.	*"I want matrix cryptography workshops and regular quizzes so they stay motivated and issues are identified early."*

The interview findings summarized in Table 4 reveal that although most students were already familiar with the concept of rows and columns in matrices, their conceptual understanding remained shallow (Theme 1). The teacher noted a tendency among students to memorize the format "[a b; c d]" without grasping the operational function of each element. As a result, when faced with addition, subtraction, or multiplication—tasks requiring careful attention to row–column order—students frequently made fundamental mistakes (Theme 2). This confusion was even more apparent in inverse operations, where students struggled with applying rules involving determinants and cofactors, indicating that procedural mastery was not supported by a solid understanding of the underlying algebraic principles. Furthermore, when students were asked to apply matrix concepts to real-world problems, such as modeling rotations or geometric transformations, most were unable to connect algebraic notation to the required visual or physical context (Theme 3), revealing a significant gap between theoretical knowledge and practical application.

From a pedagogical perspective, the teacher relied heavily on dynamic visualizations—for example, demonstrating geometric transformations using simple software—before transitioning to algebraic notation, and facilitated peer teaching in small groups (Theme 4). While this strategy was intended to support collaborative formulation of problem-solving steps, its effectiveness varied depending on group readiness and dynamics. Additionally, the teacher reported that complex problem-solving tasks—especially those requiring multiple steps like calculating a determinant followed by an inverse—often caused students to lose motivation after an initial mistake (Theme 5). This pattern suggests that students' metacognitive readiness and resilience in the face of errors need to be strengthened.

When designing open-ended and challenging questions, the teacher encountered time constraints during the one-hour lessons: questions that were too simple failed to stimulate critical thinking, while overly complex tasks could only be solved by a small number of students (Theme 6). This dynamic was also reflected in the progression of student errors throughout the unit (Theme 7): at the beginning, procedural errors were most common—such as incorrectly adding matrix elements—whereas by the end, despite improved mechanical skills, students often made conceptual errors or chose inappropriate strategies. This transition indicates progress in procedural execution but highlights the ongoing need to strengthen conceptual understanding and strategic problem-solving.

Basic algebra skills—particularly in manipulating linear equations—were described as a crucial prerequisite for mastering matrix operations (Theme 8). The teacher emphasized that without a strong foundation in algebra, students quickly became confused when faced with more complex matrix procedures. On the other hand, external factors such as access to interactive visual media were seen as helpful in supporting understanding, yet access to devices and quality time for independent practice at home remained limited (Theme 9). This points to the need for equitable provision of learning resources and a structured schedule for practice outside the classroom.

In response to these findings, the teacher proposed several instructional changes (Theme 10). Short workshops based on real-world case studies—such as applying matrices in computer graphics or basic cryptography—were considered effective in enhancing the relevance of the material and boosting student motivation. Additionally, the introduction of regular formative quizzes in class was expected to help map out students' difficulties at an earlier stage, enabling timely intervention. These recommendations underscore the need to integrate real-world contexts, reinforce algebraic foundations, and implement continuous formative feedback into matrix instruction in order to comprehensively improve students' problem-solving skills.

The quantitative findings of this study reveal that the majority of students still operate at a low competency level in mathematical problem-solving within the topic of matrices. The mean score, which reflects only basic mastery, combined with a wide score distribution, highlights a substantial gap in students' mathematical understanding and preparedness. In this regard, foundational algebraic skills—such as row-column operations and linear equation manipulation—serve as crucial prerequisites that remain inconsistently mastered. These findings are consistent with Nahdi et al. (2023), who emphasized the strong relationship between reading comprehension and students' mathematical problem-solving skills, noting that a weak understanding of mathematical language impairs how students interpret problems. Similarly, research in Narvacan North District shows that mastery of key mathematical vocabulary significantly affects the accuracy of students' problem-solving strategies (Cabotage, 2024). Therefore, early diagnosis of students' algebraic and mathematical language proficiency must be prioritized before introducing more complex matrix content, enabling instructional interventions to be aligned with individual competency levels and closing conceptual gaps as early as possible. Furthermore, the binomial test results in this study reinforce the descriptive findings, revealing that only 3.88% of students reached the "Good" category (scores 61–80), with a p-value < 0.001. Statistically, this indicates that students' achievements fall far below the reasonable minimum expectations for problem-solving-based instruction, highlighting an urgent pedagogical need for targeted interventions.

The qualitative component enriches the understanding of concrete challenges students face in matrix learning. Thematic analysis of the teacher interview shows that many students perceive matrices merely as a set of numbers enclosed in brackets, without comprehending their operational significance as tools for transformation or modeling. This misconception lies at the root of frequent procedural errors in basic operations—such as confusion in row–column addition and subtraction, mistakes in multiplication, and difficulties with inverse calculations that involve determinants and cofactors. These findings are aligned with Wangmo (2021), who asserted that deep conceptual understanding plays a vital role in students' ability to solve word problems; without a strong foundation in algebraic terminology and processes, instructional effectiveness is significantly hindered. The binomial results, showing statistically low proportions of high scores, further support the conclusion that the procedural errors and misconceptions reported by the teacher are not incidental but have a systemic impact on student success.

Conceptual difficulties become even more pronounced when students are asked to apply matrices in real-world contexts, such as designing rotation or geometric transformation matrices. The teacher noted that students often fail to connect algebraic notation to the intended spatial changes, resulting in inaccurate transformation patterns. This illustrates a gap between theory and real-world application, where students are unable to project abstract concepts into visual or physical representations. Simamora et al. (2018) emphasized that guided discovery learning can improve students' problem-solving abilities and confidence, as it enables them to achieve dual meaning: cognitively through concept manipulation and affectively through engagement with relevant contexts. Applying similar principles in matrix instruction may help bridge the gap between concept and context while fostering students' intrinsic motivation.

To address the need for individual identification and improvement, implementing regular formative assessments becomes essential. Uji et al. (2022) demonstrated that contextual learning interventions supported by routine formative quizzes significantly enhanced students' mathematical communication and conceptual clarity. By administering short quizzes—such as tasks asking students to construct a 90° rotation matrix or verify a matrix's invertibility using its determinant—teachers can quickly identify specific error patterns, whether procedural or conceptual. These quiz data can then be used for differentiated instruction: students struggling with basic steps can receive immediate reinforcement, while those who have mastered procedures can be challenged with more advanced tasks. In this way, formative assessment functions as a continuous feedback system, guiding timely interventions and maximizing individual student progress.

The use of interactive visual tools also emerged as an effective strategy for facilitating understanding of matrix operations. With dynamic software—such as digital geometry applications or matrix transformation visualizations—students can manipulate rows and columns in real time, observe matrix changes instantly, and experience how determinant values affect invertibility. This approach reduces the cognitive load often associated with repetitive manual calculations and shifts students' focus toward problem-solving strategies and conceptual understanding. However, the teacher interview highlighted limited access to devices and restricted time for independent practice at home. Therefore, schools must ensure the availability of computer labs or tablets for regular use and incorporate structured visualization sessions during class time.

Furthermore, the development of open-ended tasks in matrix learning can play a key role in fostering students' critical thinking and strategic flexibility. Such tasks might involve designing a series of matrices to model rotation, reflection, and scaling, or exploring the commutative and non-commutative properties of matrices through collaborative activities. By allowing room for multiple solution approaches, students are encouraged to articulate and compare strategies, practice mathematical argumentation, and build cognitive resilience when facing complex challenges. While personalized learning experiences are promoted by Capuano et al. (2014) as a way to increase engagement, applying this approach to matrix tasks requires teacher support in the form of scaffolding: offering sample solutions, guiding reflection through critical questions (e.g., "Why does row–column multiplication order matter?"), and gradually withdrawing assistance to help students develop autonomy.

Overall, the findings of this study affirm that improving students' mathematical problem-solving skills in the topic of matrices demands a holistic effort: strengthening foundational algebra and mathematical language, implementing meaningful contextual learning, providing continuous formative feedback, utilizing interactive visualization tools, and designing open-ended, challenging tasks. Coupled with inferential results from the binomial test, which indicate collective student failure to reach the minimum expected score, the case for instructional reform centered on exploration, modeling, and reasoning becomes more compelling. By orchestrating these elements within a coherent instructional framework, educators can empower students not only to compute matrices accurately but also to apply matrix reasoning flexibly across diverse mathematical and real-world scenarios—fulfilling the goal of problem-solving as the core of mathematics education.

CONCLUSION

This study aimed to analyze students' problem-solving skills in learning mathematics on the topic of matrices by integrating both quantitative and qualitative approaches. The quantitative findings revealed that the majority of students remained at a basic level of mastery, with average scores falling in the low category. These results emphasize the need for early diagnosis of foundational algebra skills—such as row-column operations and linear equation manipulation—as an essential step before introducing more complex matrix concepts. Inferential findings also reinforced the conclusion that most students had not yet achieved the expected level of competence, suggesting that learning outcomes remain far from the basic standards ideally attained through meaningful mathematics instruction. The qualitative analysis revealed that although teachers continued to apply expository methods—lectures, question and answer, and open discussions—such strategies were found to be less effective in fostering deep problem-solving skills. Students frequently relied on mechanical procedures without conceptual understanding, struggled to relate algebraic notation to real-world contexts, and became demotivated when confronted with multi-step problems. Taking into account both descriptive and inferential findings, it is concluded that matrix instruction requires a more contextual, visual, and targeted approach to more effectively develop students' problem-solving skills. Strategic steps are recommended, including the implementation of structured problem-solving approaches, reinforcement of formative assessments, and the design of activities that bridge abstract concepts with real-life applications to optimize mathematical learning outcomes.

LIMITATION

This study was conducted in a single senior high school in Central Lombok, involving 103 twelfth-grade students and one mathematics teacher, thus the findings may not fully represent the diversity of matrix instruction contexts in other schools. Additionally, the quantitative test primarily focused on procedural aspects and did not adequately capture students' metacognitive strategies, while the qualitative data were limited to a single teacher interview, lacking broader insights into diverse teaching practices.

RECOMMENDATION

To enhance problem-solving outcomes in matrix learning, it is recommended that future research be extended across various school levels and regions. Instruments should be developed to observe and interview students to better understand their thinking strategies. Professional development programs for teachers should be conducted to support the design of contextual learning and formative assessment, and communities of practice among mathematics teachers should be established to share and refine effective instructional practices.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Declaration of Interest

The author declare no conflict of interest.

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