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EXPLORING THE MATHEMATICAL PROBLEM-SOLVING ABILITIES OF GRADE XI STUDENTS BASED ON POLYA'S MODEL

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ABSTRACT

Kemampuan pemecahan masalah menjadi bekal dalam menghadapi tantangan dan perkembangan saat ini, penelitian ini bertujuan untuk mendeskripsikan kemampuan siswa dalam memecahkan masalah matematis siswa berbentuk soal cerita matriks. Penelitian ini menggunakan metode deskriptif kualitatif dan melibatkan 93 siswa kelas XI SMA. Instrumen yang digunakan berupa tes tertulis yang terdiri dari 2 butir soal pemecahan masalah. Pemilihan subjek dilakukan berdasarkan hasil tes kemampuan pemecahan masalah. Pengumpulan data menggunakan soal tes kemampuan pemecahan masalah dan wawancara. Analisis data kualitatif melalui reduksi data, penyajian data dan penarikan kesimpulan. Analisis dilakukan menurut model Polya. Hasil penelitian menunjukkan bahwa 7 siswa (8%) siswa memiliki kemampuan pemecahan masalah matematis yang sangat baik, karena mampu melaksanakan keempat tahapan Polya secara lengkap. 19 siswa (20%) lainnya juga dikategorikan memiliki kemampuan yang baik, meskipun hanya melaksanakan tiga tahapan Polya tanpa melakukan tahap pengecekan ulang. Sementara itu, sebanyak 30 siswa (32%) lainnya hanya mampu melaksanakan dua tahapan Polya tanpa memahami masalah secara menyeluruh dan tanpa melakukan pengecekan kembali, sehingga dikategorikan memiliki kemampuan pemecahan masalah cukup baik, dan sebanyak 37 siswa (40%) lainnya hanya mampu melaksanakan satu tahapan Polya tanpa memahami masalah secara menyeluruh, tanpa menyusun rencana, melaksanakan rencana dan tanpa melakukan pengecekan kembali. Sehingga dikategorikan memiliki kemampuan pemecahan masalah yang kurang baik. Hal ini terlihat bahwa masing-masing siswa memiliki kemampuan dalam memahami masalah, menyusun rencana penyelesaian masalah, melaksanakan rencana penyelesaian masalah, dan memeriksa kembali jawaban yang masih termasuk kategori rendah. Jadi dapat disimpulkan bahwa kemampuan pemecahan masalah matematis siswa masih rendah, oleh karenanya diharapkan guru mampu melatih siswa dalam pembelajaran, melakukan pembelajaran yang efektif sehingga dapat meningkatkan kemampuan pemecehan masalah siswa.

Problem-solving skills are essential in facing current challenges and developments. This study aims to describe students' ability to solve mathematical problems in the form of matrix story problems. This study employs a qualitative descriptive method and involves 93 eleventh-grade high school students. The instrument used is a written test consisting of two problem-solving questions. Subject selection was based on the results of a problem-solving ability test. Data collection utilized the problem-solving ability test questions and interviews. Qualitative data analysis was conducted through data reduction, data presentation, and conclusion drawing. The

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analysis was conducted according to Polya's model. The results showed that 7 students (8%) had very good mathematical problem-solving skills, as they were able to complete all four stages of Polya's model. Another 19 students (20%) were categorized as having good skills, although they only completed three stages of Polya's model without performing the final verification stage. Meanwhile, 30 students (32%) were only able to complete two stages of Polya's model without fully understanding the problem and without conducting a recheck, thus categorized as having adequate problem-solving skills. Additionally, 37 students (40%) were only able to complete one stage of Polya's model without fully understanding the problem, without formulating a plan, executing the plan, and without conducting a recheck. Thus, they were categorized as having poor problem-solving skills. This indicates that each student's ability to understand the problem, develop a problem-solving plan, implement the problem-solving plan, and check the answers is still in the low category. Therefore, it can be concluded that students' mathematical problem-solving abilities are still low. It is hoped that teachers can train students in learning, conduct effective learning, and thus improve students' problem-solving abilities.

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INTRODUCTION

Mathematics plays an important role in everyday life because it develops human thinking skills, which is why mathematics is a compulsory subject at every level of education. One of the main objectives of mathematics education is to develop students' problem-solving skills, as problem-solving is considered the core of mathematics curricula worldwide (Toh, et al, 2023; Törner et al, 2007). Through problem-solving, students learn to apply their knowledge and reasoning to non-routine situations (Permata & Sandri, 2020). (Ulva & Fitri, 2022) state that problem-solving is an effort to solve problems using prior understanding and new knowledge to resolve an issue. Based on the objectives of mathematics education, mathematical problem-solving is crucial for students to master to develop and support other mathematical skills. Problem-solving skills are essential for individuals in addressing issues related to daily life or academic subjects. (Hanan, 2019) classifies basic mathematical abilities into five standards of ability, namely: a) mathematical understanding; b) mathematical problem solving; c) mathematical reasoning; d) mathematical connections; and e) mathematical communication. The National Council of Teachers of Mathematics (NCTM) establishes standards for mathematical abilities, including problem-solving, reasoning, and proof for students.

The five competency standards above are possessed by every student to be able to follow mathematics learning as it should be. This is certainly related to the learning model used by educators in teaching mathematics. This is in accordance with the core competencies outlined in the Ministry of Education and Culture Regulation No. 21 of 2016 regarding the content standards for basic and secondary education. According to these core competencies, students should at least be able to apply their knowledge in a specific field of study to solve problems in line with their interests and talents (Permendikbud, 2016). The purpose of the independent curriculum is to give schools the freedom to design and develop curricula or learning that suits local needs and contexts, as well as to improve the quality of education holistically in line with the times, and provide opportunities for students to develop their potential holistically according to their interests, talents,

and abilities. This aims to create relevant and effective learning and improve the overall quality of education (Tuerah & Tuerah, 2023).

In practice, some students experience many difficulties when solving problems related to mathematics. One reason for this, according to Siregar (2017), could be that some students still consider mathematics difficult. Another factor contributing to students' difficulties may be that certain aspects of classroom instruction have not been implemented optimally. The mathematics instruction in question involves the ability to understand problems, design mathematical models, solve the models, and interpret the solutions obtained (Azhari & Irfan, 2019).

Each student's problem-solving ability varies, as can be seen in several studies conducted by other researchers related to problem-solving. Emilia, in her study entitled “Problem-solving strategies in solving story problems in SPLDV material for eighth-grade students at SMP Kristen 2 Salatiga,” concluded that students performed the understanding stage 35.13% of the time, 19.23% in the planning stage, and 45.64% in the solving stage, while the checking stage was not performed. This was due to the students' varying thought processes. No students performed the checking stage because they were confident in their answers, and there was no habit of checking answers instilled by the teacher. Additionally, the results of a study by Sembiring (2023) on 34 tenth-grade students at SMA Arif Rahman Hakim in South Tangerang found that five students (14.71%) had high-level problem-solving skills (very good), 21 students (61.76%) had moderate problem-solving skills (good), while 8 students (23.53%) had low problem-solving skills (poor).

Both studies show that each student's problem-solving abilities vary. This diversity in problem-solving abilities is also experienced by students in the 11th grade at SMAK Bhakti Luhur Malang. A preliminary study at SMAK Bhakti Luhur Malang shows that many 11th-grade students still have difficulty solving mathematical problems, and not all stages of problem solving are carried out effectively. Unlike other studies that focus on junior high schools or general senior high schools, research analyzing students' problem-solving abilities in the context of private Catholic senior high schools, such as SMAK Bhakti Luhur Malang, is still limited.

Students' problem-solving skills are their ability to use their thinking processes to solve problems by gathering facts, analyzing information, developing various alternative solutions, and choosing the most effective solution. Students' problem-solving skills can be measured in various ways, including through tests, interviews, and observations. Problem-solving tests typically assess students' ability to solve non-academic problems, such as social issues or everyday problems. Problem-solving observations are usually conducted to observe how students solve problems in their daily lives.

The reasons why the researcher chose SMAK Bhakti Luhur Malang as the research location are as follows :

1. SMAK Bhakti Luhur Malang is an A-accredited school and is among the best schools in Malang based on UTBK scores, as cited from the LTMPT website, with a national ranking of 751 and a provincial ranking of 136. Therefore, the researcher was interested in conducting research there.
2. SMAK Bhakti Luhur Malang is a school that demonstrates consistency in implementing the curriculum and has a learning system that is relevant to the research topic.
3. In addition to the above reasons, the school is also supported by complete and easily accessible academic data, as well as having representative students to obtain valid data that can be analyzed scientifically.

Students' mathematical problem-solving abilities in schools are still relatively low. Mathematics learning that develops problem-solving abilities provides situations that emphasize problem-solving by regularly giving non-routine problems that require students to think using their

prior knowledge related to the problems they face, so that students can find strategies to solve the problems in the given questions.

It is hoped that this research can serve as a foundation for educators in designing more appropriate learning strategies, enabling teachers to provide effective support to students who struggle with mathematical problem-solving, whether through individual guidance, providing varied learning methods, or strengthening students' problem-solving and metacognitive skills.

METHOD

The method used in this study is descriptive with a qualitative approach. Qualitative research is a type of research that aims to describe and analyze phenomena, events, social activities, attitudes, beliefs, perceptions, and thoughts of individuals or groups (Sukmadinata, 2011). Qualitative research is research that analyzes descriptive data in the form of written words. It is descriptive in nature because it aims to describe students' understanding of solving matrix story problems based on Polya's steps. The subjects in this study were 93 students in the 11th grade at SMAK Bhakti Luhur Malang. The subjects were categorized into three categories: high, medium, and low ability.

The instruments used in this study were tests and interviews. The study began with administering a test of matrix problem-solving skills, using indicators based on Polya's problem-solving steps, namely: (1) understanding the problem, (2) devising a plan, (3) implementing the plan, and (4) checking the results.

The data collection techniques used in this study were measurement and direct communication through interviews. The measurement technique involved administering tests to 11th-grade students at SMAK Bhakti Luhur Malang, which contained material on matrices and continuity with a focus on problem-solving skills. Interviews were used as a technique to obtain supplementary data from the test results.

The mathematical problem-solving test is based on Polya's problem-solving characteristics, namely understanding the problem, devising a solution plan, implementing the solution plan, and reviewing the solution. Through this test, it is hoped that students will develop the ability to understand problems, plan solutions, implement plans, and review problem solutions.

The test questions consist of two items. Both questions will be validated by a validator, then revised according to the validator's assessment and suggestions. Validation is carried out by experts. Validation takes the form of expert consideration and suggestions regarding the mathematical problem-solving test questions for matrix material, which are used as the basis for revision. The two questions used in this study have complementary functions: the first question is designed to assess students' ability to solve mathematical problems, while the second question serves as a control to evaluate the consistency, accuracy, and depth of students' problem-solving abilities, thereby providing a more comprehensive understanding of their capabilities.

The data processing technique used in analyzing these results was to assess students' answers based on questions that indicated problem-solving abilities according to Polya.

The following are indicators of problem-solving ability based on Polya's stages of problem-solving.

Table 1. Problem Solving Ability

Steps	Solution to problem	Problem solving stage indicators
1	Understand the problem	Students read and understand the problem by noting various relevant information, such as what information is known and what is asked. Ignore irrelevant things and do not add or subtract information that can create new problems that are not in accordance with the problem to be solved. Trying to explain the problem in a new form to be solved.
2	Designing problem solving	Students are able to review formulas or equations that are in accordance with the information that has been obtained previously. Afterward, students design the procedure used to solve the problem.
3	Perform the completion procedure	Students can carry out the designed procedure. Ensure that each line of completion is done correctly and thoroughly. If there is a mistake in carrying out this procedure, then there must be another procedure ready to be used.
4	Re-evaluate	In this part, students recheck their answers and make sure they are correct. Ensure that there are no mistakes in the process and provide the right final conclusion.

In addition, to describe the results of students' work when solving matrix story problems, a holistic rubric is used in this study, presented in the following table.

Table 2. Holistic Rubric

Criteria	Description
Very good	Students solve problems correctly by applying Polya's four stages.
Good	Students are able to solve the problem correctly by applying the three stages of Polya (students are not able to carry out the stages of looking back at the process and results).
Good enough	Students can solve problems appropriately by applying two stages of Polya's solution (students are not able to implement the plan and look back at the process and results of their work)
Less Good	Students can solve problems correctly by applying one stage of Polya, namely, only applying the stage of understanding the problem.

The holistic rubric applied in this study was developed based on Polya's four stages of problem solving, namely understanding the problem, planning the solution, implementing the plan, and reviewing the process and results of the solution. To ensure the accuracy and consistency of the rubric, a verification process was carried out through validation by experts. The expert

validation involved mathematics education faculty members who evaluated the alignment of the indicators with Polya's theory and the clarity of differences between the existing criteria. Subsequently, the rubric was pilot-tested on several student responses outside the research area to assess whether the explanations for each category (excellent, good, satisfactory, and poor) could effectively distinguish students' proficiency levels. Based on expert feedback, the rubric was revised to be more structured, objective, and consistently applicable in assessing students' work outcomes. Additionally, the study's validity was strengthened through the application of triangulation techniques, which involved comparing data from written tests and semi-structured interviews. The written test provides an overview of the final results of students' ability to solve problems according to the indicators in the rubric, while the interview aims to explore further information about the thinking process, strategies used, and obstacles faced by students that may not be fully reflected in their written answers. In this way, interviews serve as a complement and explanation to the data from written tests, so that the assessment of students' problem-solving abilities does not only focus on the final results but also includes the accompanying cognitive processes. Through this triangulation, a more comprehensive, in-depth, and valid understanding of students' mathematical problem-solving abilities is obtained.

RESULTS

Based on the results of research conducted in class XI of SMAK Bhakti Luhur Malang on matrix material. The indicators used in this study were problem-solving ability indicators based on Polya's stages, which consist of understanding the problem, planning the solution, implementing the solution plan, and reviewing.

In the study, the researcher selected subjects in consultation with mathematics teachers at SMAK Bhakti Luhur Malang. Based on the results of this consultation, the researcher was instructed to conduct research in the 11th grade, which consisted of 93 students in three classes: class A with 29 students, class B with 31 students, and class C with 33 students. To obtain suitable subjects, the researcher administered a mathematics problem-solving ability test consisting of two narrative questions on matrix material, then reviewed the students' test results. Next, the researcher selected students categorized as high, medium, and low ability. The selection of analysis subjects was based on the scores obtained by the students. Based on the assessment indicators in Table 1, the determination of analysis subjects was ranked according to the results of the students' problem-solving ability tests, from highest to lowest.

Based on the results of the problem-solving ability test, the following diagram of the mathematical problem-solving ability of grade XI students at SMAK Bhakti Luhur Malang was obtained:

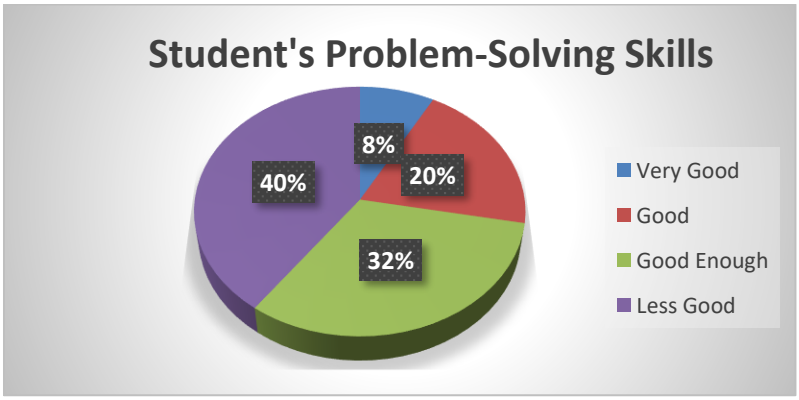

Figure 1. Result of Student's Mathematical Problem-Solving Abilities

Based on the diagram above, it can be seen that 37 students (40%) are categorized as poor because they generally experience difficulties from the problem understanding stage, such as being unable to identify important information and determine what is being asked, resulting in an inappropriate solution plan. They also experience errors in implementing the plan, and the process and results observation stage is rarely carried out. 30 students (32%) are in the adequate category because they can understand the problem and begin to plan a solution strategy, but often choose an inappropriate approach or make procedural errors in implementing the solution plan. Additionally, they are accustomed to reviewing their answers, so errors are not corrected. Furthermore, 19 students (20%) were categorized as good because they had mastered the first three stages, namely understanding the problem, planning the solution, and implementing the plan fairly well and accurately, but were not consistent in reviewing their answers to ensure their accuracy, interpreting the results, or exploring alternative strategies. Meanwhile, only 7 students (8%) were categorized as excellent, demonstrating comprehensive performance across all four stages of Polya's problem-solving process: thoroughly understanding the problem, effectively planning a solution strategy, executing the plan accurately, and conducting a review by validating results, drawing correct and precise conclusions, and providing interpretations.

The results of the study, which show that only 26 students (28%) met the criteria for good or very good problem-solving, indicate that the majority of 11th-grade students are still in the poor category in terms of mathematical problem-solving skills. This means that most students are not yet fully capable of completing Polya's four stages of problem solving. At the stage of understanding the problem, many students are unable to identify important information, determine what is being asked, and separate relevant and irrelevant data. At the stage of planning the solution, students still have difficulty choosing the right strategy or method to use, so the steps taken to solve the problem are not systematic or even contain errors from the outset. Furthermore, in executing the plan stage, errors made in the previous stage continue in the form of inappropriate procedures, inaccurate calculations, and answers that do not match the question's requirements. Finally, in the inspecting the solution stage, students rarely review the process and results obtained, whether in terms of procedural accuracy, the reasonableness of the answers, or interpretation in the context of the problem.

DISCUSSION

From the data presented above, it can be seen that seven students have very good problem-solving skills because they can apply Polya's four stages correctly. Therefore, these students have a high ability to solve problems well. Students who can solve problems are those with high ability, both male and female, who can understand the problem well, have a solution plan, and can complete the problem-solving process according to the plan, as well as perform a review. Students who can find the right solutions will find it easier to solve problems effectively, which ultimately has a positive impact on improving their mathematical learning achievements (Novitasari & Wilujeng, 2018).

Meanwhile, students in the good problem-solving ability category are able to apply Polya's three stages of problem solving, namely understanding the problem, planning the solution, and implementing the solution plan, but they have not fully completed the stage of reviewing the process and results of the solution. This condition shows that students still face obstacles in the metacognitive aspect, especially in evaluating and reflecting on the solutions obtained. This deficiency is also influenced by cognitive factors, such as a lack of precision when working on problems and conceptual misunderstandings, particularly in the topic of matrices. For example, students can apply calculation procedures but have not yet developed the habit of checking whether the steps and results obtained are correct and appropriate to the context of the problem,

in line with the research of (Lester, 2013; Schoenfeld, 1985), which emphasizes that student failure is not only due to cognitive abilities in understanding and executing procedures but also to metacognitive aspects, namely the awareness to monitor, control, and evaluate the thinking process. Several international studies also confirm that the “looking back” stage tends to be overlooked by students, even though this stage plays a crucial role in improving the quality of answers, detecting errors, and reinforcing conceptual understanding. Thus, the findings of this study are consistent with global findings that students' weaknesses in solving mathematical problems are more often due to weak self-regulation and evaluation habits, rather than simply a lack of mastery of the material. Therefore, teachers need to integrate the “looking back” stage as a routine step in learning. Teachers can train students to always check their answers, discuss alternative solution strategies, and get used to reflecting on mistakes that occur. In this way, students will not only be skilled in the solution procedure but also develop critical and evaluative thinking skills. Additionally, learning should be designed to provide space for students to engage in self-checking and peer-review, so that cognitive and metacognitive aspects can develop in balance.

Students in the category of adequate problem-solving ability are basically able to understand the questions given, but are unable to write them down completely because they are not accustomed to solving problems using Polya's steps. In addition, students with low mathematical problem-solving abilities not only have difficulty implementing the solution plan that has been prepared, but are also unable to evaluate the answers they have obtained. This condition indicates the presence of cognitive factors in the form of misunderstanding of the concept of matrices and metacognitive factors in the form of a lack of habit of rechecking the steps taken to solve the problem, in line with the opinion (Haris et al., 2025) which emphasizes that students' lack of skills in interpreting problems and choosing the wrong strategy causes them to make mistakes in solving problems. Additionally, there is a weak metacognitive awareness in monitoring, controlling, and evaluating the thinking process; therefore, teachers need to implement longitudinal studies to track the development of problem-solving abilities over time and across various levels of mathematical complexity.

From the data presented above, it can be seen that seven students have very good problem-solving skills because they can apply Polya's four stages correctly. Therefore, these students have a high ability to solve problems well. Students who can solve problems are those with high ability, both male and female, who can understand the problem well, have a solution plan, and can complete the problem-solving process. Meanwhile, students in the category of poor problem-solving ability are unable to write down a solution plan or implement the plan they have made, resulting in an unclear problem-solving process. Furthermore, students with low mathematical problem-solving abilities are unable to formulate plans, implement solution strategies, or evaluate the process and results of their answers; this condition reflects cognitive barriers in the form of misunderstandings of matrix concepts. This aligns with the findings of a study (Giawa & Harefa, 2022) indicating that low conceptual understanding can prevent students from solving problems. Additionally, metacognitive factors, such as the lack of a habit to review solution steps, lead to simple errors going undetected and tasks being perceived as difficult due to insufficient practice in problem-solving.

CONCLUSION

Based on the description and analysis of the data, it can be concluded that the problem-solving abilities of the students are still low. This can be seen from the fact that the percentage of problem-solving abilities is still the highest, while the percentage of students who can solve problems very well is the lowest, so they are categorized as having low abilities.

The results of this study indicate that students' ability to solve matrix story problems still faces various obstacles, both from cognitive and metacognitive aspects. These obstacles are evident in the form of conceptual misunderstandings, such as in matrix operations, a tendency to use procedures mechanically without understanding the meaning of the problem, and a lack of habit of planning strategies and checking the answers obtained. Additionally, this study has limitations, including a relatively small sample size, which means the results cannot fully represent the conditions of the entire student population, and a narrow focus on matrix material, limiting its generalizability to other mathematical topics. Therefore, further research is recommended to involve a larger sample size, examine different and more diverse mathematical topics, and apply experimental interventions, such as through reflection practices, class discussions, or systematic scaffolding, to test the effectiveness of these strategies in enhancing students' problem-solving abilities more comprehensively. Furthermore, the researchers suggest that teachers administer matrix-based story problems to high school students as an effort to train and improve their ability to solve contextual problems related to daily life, thereby making mathematics learning more meaningful, applicable, and relevant to the real-life situations students face in both social and academic contexts.

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The authors declare that no generative AI or AI-assisted technology was used in any way to complete this manuscript. The authors confirm that they are the sole authors of this article and take full responsibility for the content contained in the article, as outlined in the COPE recommendations.

INFORMED CONSENT

The authors have obtained informed consent from all participants in this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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