Alifmatika: Jurnal Pendidikan dan Pembelajaran Matematika
Volume 7, Issue 2, 233-259, December 2025
e-ISSN: 2715-6109 | p-ISSN: 2715-6095
https://journal.ibrahimy.ac.id/index.php/Alifmatika

Mathematical modelling problem solving with respect to students' mathematical resilience in GeoGebra-assisted mea learning

Lina Lutfiyana[1*], Emi Pujiastuti[2], Iqbal Kharisudin[3]
[1*,2,3]Program Studi Magister Pendidikan Matematika, Universitas Negeri Semarang, Jawa Tengah 50229, Indonesia
[1*]linalutfiyana611@gmail.com, [2]emi.mat@mail.unnes.ac.id, [3]iqbalkharisudin@mail.unnes.ac.id

Received: April 28, 2025 | Revised: August 10, 2025 | Accepted: October 23, 2025 | Published: December 15, 2025
*Corresponding author

***Abstract*:**
Problem-solving is a crucial 21st-century skill that plays a vital role in mathematics education. One practical approach to developing this skill is through mathematical modelling, particularly by employing GeoGebra-assisted MEA learning. This study aims to: (1) evaluate the quality of GeoGebra-assisted MEA learning; (2) examine the influence of mathematical resilience on Mathematical Modelling Problem-Solving Ability (MMPSA); and (3) describe students' MMPSA based on their levels of mathematical resilience. A mixed-methods approach was employed using a Sequential Explanatory design, with instruments including questionnaires, tests, observations, and interviews. The sample consisted of Class VII A as the experimental group and Class VII B as the control group, each comprising 30 students. Eight students were selected as qualitative subjects based on their mathematical resilience levels. The results indicate that GeoGebra-assisted MEA learning demonstrates high instructional quality and significantly enhances students' MMPSA. Quantitative findings show that mathematical resilience has a significant effect, accounting for 30% of the variance in students' problem-solving performance. These results are further supported by qualitative data obtained through observations and interviews. Students with high resilience tended to be confident, persistent, and effective in solving problems. Those with moderate resilience showed adequate capability but lacked precision, while students with low resilience were easily discouraged and exhibited low self-confidence. In conclusion, integrating quantitative and qualitative findings underscores the importance of fostering mathematical resilience to enhance students' problem-solving abilities, particularly in the context of GeoGebra-assisted MEA in mathematical modelling.

Keywords: Mathematical Modelling; Mathematical Resilience; MEA; Problem-Solving; GeoGebra.

***How to Cite*:** Lutfiyana, L., Pujiastuti, E., & Kharisudin, I. (2025). Mathematical modelling problem solving with respect to students' mathematical resilience in GeoGebra-assisted mea learning. *Alifmatika: Jurnal Pendidikan dan Pembelajaran Matematika*, 7(1), 233-259. https://doi.org/10.35316/alifmatika.2025.v7i2.233-259

Introduction

Problem-solving ability is a 21st-century skill that helps students face everyday challenges (Szabo et al., 2020; Ling & Mahmud, 2023; Ulya et al., 2024), enhances mathematical understanding, and connects mathematical concepts to real-life situations (Klang et al., 2021). Problem-solving ability also supports cognitive development (Xu & Qi, 2022). This skill enables students to adapt quickly to change and solve mathematical problems effectively (Davita & Pujiastuti, 2020).

Mastery of mathematical problem-solving is crucial for improving learning outcomes at the junior high school level (Fitriani et al., 2022). The 2023 academic report from SMP Manbaul Hikmah indicated that the numeracy score for geometry was only 57.86, highlighting the need to improve problem-solving ability and enhance the quality of learning. Therefore, a practical learning approach is needed to enhance students' problem-solving skills, and one promising method is mathematical modelling.

Mathematical modelling is a practical approach to developing problem-solving skills, as it helps students solve contextual problems (Bliss & Libertini, 2016; Kharisudin & Cahyati, 2020). Mathematical modelling also helps students solve contextual issues in daily life (Temur, 2012), stimulates their creativity, and increases participation in learning (Wang et al., 2023). Mathematical modelling not only enhances students' problem-solving abilities but also provides opportunities to face complex challenges. The problem-solving process encourages students to think critically, experiment with various strategies, and maintain perseverance despite difficulties. This experience indirectly develops important affective qualities such as persistence and the ability to manage confusion and obstacles. Therefore, mathematical modelling is effective in fostering positive attitudes toward mathematics, particularly mathematical resilience.

Mathematical resilience is also essential, as it encourages students not to give up easily when facing challenges (Lutfiyana et al., 2023). Mathematical resilience helps students learn with confidence, perseverance, and a willingness to discuss and explore (Lee & Ward-Penny, 2022), as well as manage emotions and stress during learning (Xenofontos & Mouroutsou, 2023; Akkan & Horzum, 2024). Given the critical role of mathematical resilience in promoting perseverance and practical knowledge, it is essential to implement a learning model that not only enhances students' problem-solving abilities but also fosters their confidence and active engagement in the learning process.

One such model is the Means-Ends Analysis (MEA) model, which helps build knowledge and break down mathematical problems (Elmujahidah et al., 2019). This model requires active student participation, with the teacher acting as a facilitator and motivator (Karolina et al., 2021). GeoGebra supports interactive learning by enabling students to visualize abstract concepts (Simbolon, 2020).

Previous studies have demonstrated that mathematical modelling plays a significant role in improving students' problem-solving abilities, especially when linked to real-world contexts (Hamid & Rosyidi, 2025). The MEA learning model has been shown to influence students' mathematical problem-solving skills positively (Nadia et al., 2025). However, most of these studies tend to focus predominantly on cognitive aspects, with limited attention given to how such learning strategies can support affective factors like mathematical resilience. This affective dimension is crucial, particularly for fostering perseverance when students face challenges in solving mathematical problems.

Mathematical resilience itself has a significant impact on students' problem-solving capabilities, as students with higher levels of resilience tend to exhibit better problem-solving performance (Rohantizani et al., 2025). Despite this, research that explicitly explores the relationship between mathematical resilience and specific instructional approaches, such as MEA or the integration of interactive media, remains scarce. Furthermore, the use of GeoGebra as a learning tool has been proven to improve mathematics learning outcomes significantly (Sekali & Boentolo, 2025). GeoGebra also helps boost students' confidence in solving problems and provides a more interactive and enjoyable learning experience (Denada et al., 2025). Despite this, the application of GeoGebra-assisted MEA learning to reinforce mathematical resilience during mathematical modelling problem solving is still underexplored.

Based on the literature review, there remains a research gap in studies that simultaneously integrate problem solving, mathematical modelling, mathematical resilience, and the use of GeoGebra-assisted MEA learning. This study addresses that gap by offering a novel approach that combines these four components to enhance students' cognitive abilities in solving mathematical problems and to strengthen their resilience when facing learning challenges. The uniqueness of this research lies in its focus on GeoGebra-assisted MEA learning as a means to examine the impact on students' MMPSA through the lens of mathematical resilience. Specifically, this study aims to (1) analyze the quality of the implemented learning model, (2) assess the influence of mathematical resilience on MMPSA, and (3) describe the characteristics of MMPSA based on different levels of students' mathematical resilience. The findings are expected to provide both theoretical insights and practical implications for the development of innovative, effective, and resilience-supportive mathematics learning strategies.

Research Methods

This study employed a mixed methods design with a Sequential Explanatory approach. This study employs a mixed-methods design with a Sequential Explanatory approach, where quantitative data collection and analysis are conducted first to assess the quality of learning and examine the influence of mathematical resilience on students' abilities in mathematical modelling problem-solving. Subsequently, qualitative data are gathered to deepen and explain the quantitative findings, particularly in describing how levels of mathematical resilience relate to problem-solving abilities more contextually. This approach was chosen because it allows the study to capture general patterns and relationships between variables through quantitative data, while also gaining an in-depth understanding of students' learning processes and experiences through qualitative insights. Therefore, the results of this research are expected to provide a comprehensive and valid knowledge of instructional quality, the influence of resilience, and the characteristics of problem-solving ability across different resilience levels, thereby supporting the development of effective and adaptive mathematics learning models.

The quantitative method was in the form of a quasi-experimental design using a Pretest-Posttest Nonequivalent Control Group Design. The research was conducted at SMP Manbaul Hikmah, Kendal Regency, during the second semester of the 2023/2024 academic year, involving seventh-grade students across four classes as the population. The sample was selected through simple random sampling, resulting in class VII A as the experimental group and class VII B as the control group, each consisting of 30 students.

Subjects were chosen based on their levels of mathematical resilience (*high, moderate, low*), and the material taught was "*Lines and Angles*." Data collection techniques included observation, questionnaires, tests, and interviews. The instruments used consisted of validation sheets, a mathematical resilience questionnaire, an MMPSA test, a student response questionnaire, a lesson implementation observation sheet, and a student activity observation sheet. These instruments were tested in class VIII B to assess their validity, reliability, discriminating power, and item difficulty index.

The analysis of learning quality covered three aspects: (1) Planning stage, assessed through the validity of learning tools with a minimum category of "*good*"; (2) Implementation stage, evaluated based on the observation of lesson implementation and student activity, with a minimum category of "*good*"; (3) Assessment stage, with effectiveness criteria as follows: (a) the average MMPSA reaches the Minimum Completeness Criteria (MCC); (b) the proportion of MMPSA completeness reaches 75%; (c) the average MMPSA of students taught using GeoGebra-assisted MEA learning is higher than that of students taught using PBL; (d) the proportion of MMPSA completeness of students taught using GeoGebra-assisted MEA learning is higher than that of students taught using PBL; and (e) there is an improvement in MMPSA and students' mathematical resilience. The effectiveness of learning was analyzed using average completeness tests, proportion tests, mean difference tests, proportion difference tests, and improvement tests. The influence of mathematical resilience on MMPSA was analyzed using simple linear regression tests. Qualitative analysis was carried out through technique triangulation.

Results and Discussions

Quality of GeoGebra-Assisted MEA Learning

The quality of learning in this study was reflected in the planning, implementation, and evaluation stages, all of which were carried out effectively. In the planning stage, the learning tools and research instruments were developed concurrently and validated by four expert validators, yielding a validity score of 89% (categorized as very good). Although minor revisions were made, the results indicate that both the learning tools and instruments met validity criteria and were feasible for classroom use. This finding aligns with previous research, which highlights that the feasibility of instructional tools, measured by their validity level, is a key indicator of successful classroom implementation (Verawati et al., 2022). Valid and reliable instructional tools are essential for achieving specific learning objectives (Prahani et al., 2021). Furthermore, well-validated learning devices can significantly contribute to improving student learning outcomes (Dwikoranto et al., 2020).

During the implementation stage, the teacher began the learning activities with greetings, prayer, and motivational statements aimed at fostering students' mathematical resilience. Students were grouped heterogeneously and encouraged to discuss problems using worksheets supported by GeoGebra collaboratively. These activities engaged students in analyzing and visualizing problems, asking questions, and selecting appropriate problem-solving strategies. Observations revealed that the implementation level of GeoGebra-assisted MEA learning reached 92.97% (*excellent category*), while student activity levels reached 72.85% (*good category*). These findings indicate that the learning process proceeded as planned and effectively involved students, creating a collaborative and meaningful learning environment. The discussion-based nature of the MEA model encouraged active peer interaction and small group collaboration, supporting Daud (2021) findings that MEA can stimulate students' critical thinking skills and foster an active learning atmosphere, thereby positively impacting learning outcomes.

The use of GeoGebra proved effective in helping students visualize problems, select problem-solving strategies, and explore mathematical concepts more deeply. This finding is consistent with research by Mukarramah et al. (2022), which showed that GeoGebra use can enhance student participation and understanding when solving contextual problems. However, student involvement in group discussions did not reach the excellent category, possibly due to differences in student readiness and confidence in using technology. It is in line with Astrilia et al. (2020), who found that some students faced technical difficulties when first introduced to GeoGebra. Nonetheless, the study confirms that with proper teacher guidance, students can adapt and use the technology effectively. Evaluation of students' responses to MEA learning supported by GeoGebra showed positive results. The average score of 78.33% (*good category*) indicates that students enjoyed and actively engaged in the learning process. It supports the notion that interactive and technology-based learning environments can enhance students' enjoyment and motivation in learning mathematics. According to Tabriji (2025), an enjoyable learning environment increases student engagement, which positively affects learning quality.

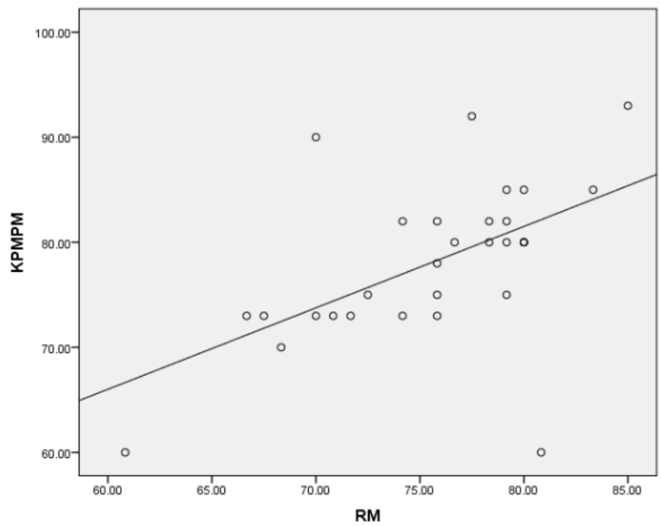
The effectiveness of MEA learning supported by GeoGebra was also demonstrated through statistical tests. A one-sample t-test showed a result of $t_{calculated} = 4.336$, which is greater than t_{table} = 1.699. Since $t_{calculated} > t_{table}$, the hypothesis was accepted, indicating that the average MMPSA score met the Minimum Mastery Learning Criteria (MMLC). Additionally, a test of proportion yielded. $z_{calculated}$ = 1.898, exceeding z_{table} = 1.645, $z_{calculated} > z_{table}$, the hypothesis was accepted, with 27 out of 30 students (90%) achieving mastery. These findings confirm that the majority of students successfully met the KKTP, reinforcing the effectiveness of GeoGebra-assisted MEA in mathematics learning.

A comparative test between the MEA and PBL models showed that the MEA model, supported by GeoGebra, outperformed the PBL model. The independent samples t-test yielded $t_{calculated}$ = 2.829, which is greater than t_{table} = 1.67. Since $t_{calculated} > t_{table}$, the hypothesis was accepted, indicating that the average MMPSA score in the MEA group (78.07) was significantly higher than that in the PBL group (73.27). This result was further supported by a proportion test, where $zcalculated$ = 1.898 exceeded z_{table} = 1.645. As $z_{calculated} > z_{table}$, the hypothesis was also accepted, indicating that the proportion of students achieving mastery in MMPSA was higher in the MEA group compared to the PBL group. It aligns with findings by Miranti et al. (2015), who concluded that MEA is more effective than PBL. The integration of the MEA approach with GeoGebra technology enables students to be more active and structured in solving mathematical problems.

Paired sample t-tests showed a significant improvement between pretest and posttest scores, with N-Gain values of 54.49% for MMPSA and 31.01% for mathematical resilience, both categorized as moderate. It suggests that MEA learning supported by GeoGebra positively impacts both cognitive and affective aspects. These findings confirm the effectiveness of MEA in improving mathematical problem-solving ability, in line with research by Siregar et al. (2017). Additionally, Hermawan et al. (2020) found that GeoGebra enhances conceptual understanding and problem-solving skills. Integrating mathematical modelling into the learning process also fosters curiosity and interest in learning (Ramadannia et al., 2024). The observed improvement in mathematical resilience demonstrates the model's effectiveness in nurturing students' perseverance when facing challenges. Therefore, the integration of MEA and GeoGebra not only enhances cognitive competence but also strengthens the affective domain, which is essential for long-term academic success.

The Influence of Mathematical Resilience on MMPSA

The results of the linear regression test indicate that mathematical resilience significantly influences students' MMPSA, with the regression equation $\hat{Y} = 19.513 + 0.775X$ and a significance value of $0.002 < 0.05$. The coefficient of determination (R^2) is 0.300, meaning that 30% of the variation in MMPSA is explained by mathematical resilience, while the remaining 70% is influenced by other factors. This finding aligns with the research of Athiyah et al. (2020), which confirms that mathematical resilience positively affects students' mathematical problem-solving abilities. Although resilience is an essential factor, these results suggest that problem-solving skills are also shaped by other variables such as conceptual understanding, motivation, and learning strategies.



Picture 1. Scatter Plot Graph

Picture 1 (*Scatter Plot*) illustrates a positive linear relationship between mathematical resilience and MMPSA, indicating that, in general, the higher the students' resilience, the better their performance in solving mathematical problems. Strong mathematical resilience plays a crucial role in learning, as it enhances students' ability to handle challenges effectively (Fatimah et al., 2020). However, the data also show some variation, as some students who exhibit high resilience do not necessarily achieve high MMPSA scores. It supports Farhan (2020) findings, which emphasize that resilience does not always correlate directly with students' cognitive performance. Other factors, such as conceptual mastery, problem-solving strategies, and psychological conditions during assessments, also contribute to learning outcomes. While mental endurance is essential, without a solid understanding of concepts and practical strategies, problem-solving ability may still be hindered. Zulkarnain and Budiman (2019) assert that conceptual understanding significantly contributes to students' mathematical problem-solving success. Therefore, problem-solving ability is influenced by a combination of mathematical resilience, conceptual knowledge, learning strategies, and the learning environment.

Analysis of MMPSA Based on Mathematical Resilience

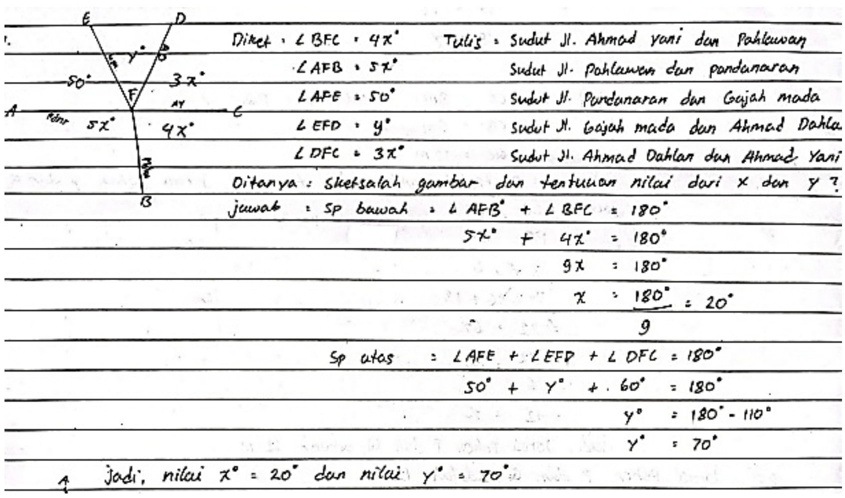
The determination of research subjects is presented in the following Table 1:

Table 1. Research Subject Determination Results

No	Subject	Code	Mathematical Resilience	
			Value	Category
1	S-1	E-1	85	High
2	S-2	E-10	77.5	High
3	S-3	E-22	80.83	High
4	S-4	E-4	76.7	Moderate
5	S-5	E-29	70	Moderate
6	S-6	E-30	70	Moderate
7	S-7	E-16	68.33	Low
8	S-8	E-25	60.83	Low

High Mathematical Resilience

a. Building New Mathematical Knowledge through Problem Solving, as well as Monitoring and Reflecting on the Problem-Solving Process.



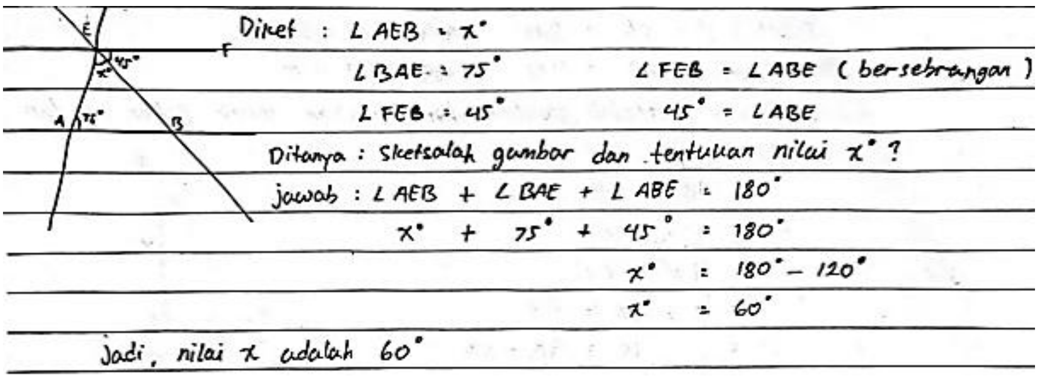
Picture 2. S-1's Work Results

As illustrated in Picture 2, Subject S-1 constructs new mathematical knowledge through a systematic problem-solving process. S-1 demonstrates the ability to monitor and reflect on this process by accurately interpreting the solution, as further confirmed during the interview. S-1 exhibited excellent capabilities in developing new mathematical understanding through the structured application of mathematical modelling steps. In the initial stage, identifying all quantities involved in problem S-1 successfully abstracted the contextual situation by representing the street names as angles, using mathematical notation such as $\angle BFC$ = $4x$°, $\angle AFB$=5x°, $\angle AFE$=50°, $\angle EFD$ = y°, and $\angle DFC$ = $3x$°. The subject was able to differentiate between variables (x and y) and constants, and recognized that all quantities were interconnected within a single system, namely angles in a plane.

In the next stage, which involved determining the governing principles of the problem, S-1 identified that some angles formed straight angles, mathematically interpreted as supplementary angles. The subject formulated two key equations: $\angle AFB$ + $\angle BFC$ = 180° and $\angle AFE$ + $\angle EFD$ + $\angle DFC$ = 180°, indicating the ability to construct a mathematical model based on relevant geometric principles. In the model-solving stage, S-1 developed a coherent and systematic algebraic strategy to solve both equations, resulting in the values x = 20° and y = 70°. This strategic approach suggests that S-1 not only understood the underlying mathematical concepts but was also able to apply them effectively in a more complex modelling context.

In the final stage, where the model's solution is interpreted as the solution to the original problem, S-1 demonstrated a high level of metacognitive awareness. The subject verified the obtained values by substituting them back into the original equations to ensure their accuracy. This step reflects monitoring and reflective activities that are essential to mathematical problem solving. Such reflective practices underscore that S-1 was not merely focused on obtaining the final answer but also actively evaluated the reasoning and problem-solving process. These findings confirm that S-1 possesses strong competence in constructing new mathematical knowledge, supported by the comprehensive application of mathematical modelling steps as well as effective monitoring and reflection throughout the problem-solving process.

b. Applying and Adjusting Various Appropriate Strategies to Solve Problems, as well as Monitoring and Reflecting on the Mathematical Problem-Solving Process.

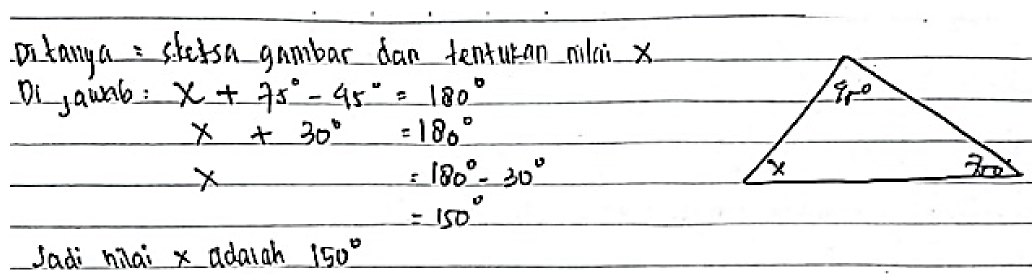


Picture 3. S-1's Work Results

As shown in Picture 3, S-1 successfully applied and adjusted various appropriate strategies to solve the problem. S-1 was able to monitor and reflect on the problem-solving process by correctly interpreting the solution, as confirmed in the interview. Subject S-1 demonstrated the ability to apply and adapt various appropriate strategies to solve mathematical problems. It was reflected in the flexible and systematic implementation of mathematical modelling steps. In the first stage, identifying all quantities involved in the problem, S-1 actively engaged in constructing visual information into a diagram. The subject stated, *"I input the given information into the diagram and labelled the angles accordingly, so we have ∠AEB = x°, ∠BAE = 75°, and since ∠FEB and ∠ABE form a pair of vertically opposite angles, we get ∠ABE = 45°."* It indicates that S-1 not only copied the information but also conceptually interpreted the relationships among quantities and distinguished between variables and constants.

In the next stage, determining the governing principles of the problem, S-1 employed two different approaches based on geometric principles. The first strategy utilized the angle sum property of triangle ABE by constructing the equation: ∠AEB + *∠BAE* + *∠ABE* = 180°, while the second strategy applied the concept of consecutive interior angles, in which *∠BAE*, *∠AEB*, and *∠FEB* form consecutive interior angles that also sum to 180°. These two approaches demonstrate S-1's ability to select and adapt the most appropriate rule or concept to match the structure of the problem. In the model-solving stage, S-1 solved the first model by substituting the constant values into the equation and then manipulating the algebraic expression to arrive at the solution x = 60°.

In the final stage, the model's solution addresses the original problem. S-1 exhibited a high level of metacognitive awareness through activities of monitoring and reflecting on the problem-solving process. The subject explicitly stated that they checked the answer: *"I substituted 60° into the equation to make sure the result was correct."* This process shows that validating the result was not merely a closing step but an integral part of their thinking strategy. Thus, S-1 not only demonstrated the ability to apply appropriate strategies but also showed flexibility in adjusting approaches to the specific characteristics of the problem. The ability to evaluate and verify the solution independently indicates a high level of reflection. Therefore, S-1 meets the indicators, both in applying problem-solving strategies and in thoroughly monitoring and reflecting on their thinking process.



Picture 4. S-3's Work Results

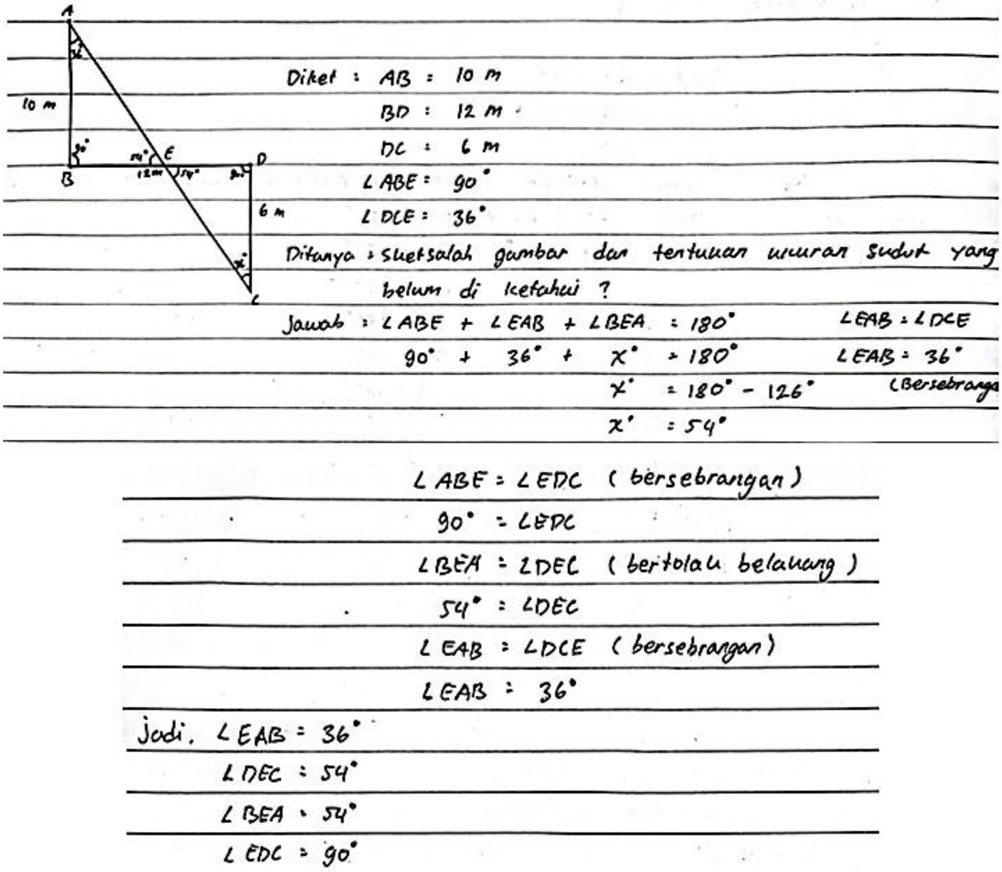
As shown in Picture 4, S-3 was unable to apply and adjust various appropriate strategies to solve the problem. S-3 could neither monitor nor reflect on the problem-solving process correctly, as revealed in the interview. Subject S-3 demonstrated difficulties in applying and adapting appropriate strategies to solve mathematical problems. In the initial stage of modelling, the subject was unable to systematically identify all quantities involved and construct information from the problem. It was evident when the subject stated, *"I'm confused by the question,"* in response to why no information from the problem had been noted. There was no attempt to label the angles or to distinguish between variables and constants, which hindered the process of identifying relevant quantities. When progressing to the stage of determining the governing principles of the problem, S-3 mentioned the use of the angle sum property of a triangle. However, the mathematical model constructed was invalid: "x + 75°-45° = 180°." It equation reflects a misapplication of geometric principles, as the subtraction of angles lacked any logical or mathematical justification. It suggests a weak conceptual understanding and a mismatch between the chosen strategy and the structure of the problem at hand.

In the model-solving stage, the subject did not exhibit a systematic solution process or correct algebraic manipulation. The answer was produced without logical steps grounded in a valid model, and therefore cannot be considered mathematically justifiable. Furthermore, in the stage of interpreting the model's solution as the solution to the original problem, S-3 also showed no evidence of reflection on the result obtained. When asked whether the answer had been verified, the subject responded, *"No."* There was no indication of any monitoring or evaluation of the solution's accuracy. When prompted to consider alternative strategies, S-3 replied, *"None,"* indicating a rigid thinking pattern and low strategic flexibility.

The absence of reflection and monitoring highlights a lack of metacognitive awareness during the problem-solving process. Therefore, S-3's performance does not yet meet the indicators of the ability to apply and adapt various problem-solving strategies appropriately, nor does it demonstrate the capacity to monitor and reflect on their mathematical thinking process. It suggests that the subject's mathematical resilience remains low, both cognitively and metacognitively.

c. Solving Problems Arising in Mathematics and Other Contexts, as well as Monitoring and Reflecting on the Mathematical Problem-Solving Process.

As shown in Picture 5, S-1 was able to solve problems arising in mathematics and other contexts. The problem sketch drawn was also correct. Additionally, S-1 monitored and reflected on the problem-solving process, taking appropriate steps supported by the interview. Subject S-1 demonstrated a high level of problem-solving ability, both in pure mathematical contexts and in real-life-related situations. In the initial stage of modelling, S-1 was able to identify all quantities involved in the problem and extract key information in a detailed and systematic manner. The subject stated: "AB = 10m, BD = 12m, DC = 6m, $\angle ABE$ = 90°, and $\angle DCE$ = 36°," indicating the ability to organize data, assign symbols to quantities, and distinguish between variables and constants. This information was then transformed into a visual representation in the form of a sketch, which served as the foundation for constructing a mathematical model. This action reflects a strong initial mastery of the mathematical modelling process.

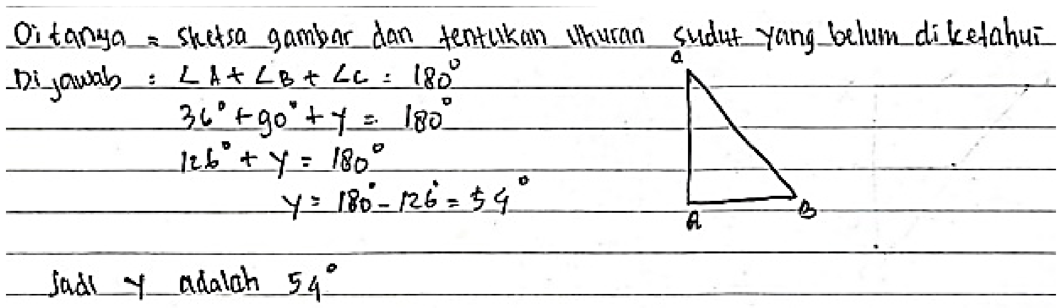


Picture 5. S-1's Work Results

In the next stage, determining the governing principles of the problem, S-1 correctly applied geometric principles, particularly the relationships among angles and the angle sum property of a triangle. The subject explained: *"I used the relationships among angles and the sum of angles in a triangle,"* and constructed mathematical models such as: "$\angle ABE + \angle EAB + \angle BEA = 180°$." It model was not only mathematically valid but also connected to other relevant concepts, such as opposite and supplementary angles, along a straight line. It demonstrates a strong conceptual understanding and the ability to integrate multiple mathematical rules simultaneously.

In the model-solving stage, S-1 correctly solved the equations and exhibited a logical and well-structured line of reasoning, including appropriate manipulation of values and substitutions. Furthermore, in the final stage, where the model's solution is interpreted as the solution to the original problem, S-1 demonstrated a high level of metacognitive control through monitoring and reflection. The subject explicitly stated: "I substituted 54° for x in the equation $90° + 36° + x = 180°$," as a means of verifying the accuracy of the solution. Additionally, S-1 was able to conclude by identifying several angle measures at once: "So, $\angle EAB = 36°$, $\angle DEC$=54°, $\angle BEA = 54°$, and ∠EDC = 90°." It statement demonstrates that the solution was interpreted comprehensively, consistently, and in a manner relevant to the problem's context.

In conclusion, Subject S-1 not only demonstrated the ability to apply mathematical modelling steps to solve problems but also effectively integrated information from various contexts. The subject was able to monitor and reflect on their thinking process and independently verify the solution. Therefore, S-1's performance reflects a high level of mathematical resilience, both cognitively and metacognitively, and demonstrates strong problem-solving ability across domains.



Picture 6. S-3's Work Results

As shown in Picture 6, S-3 was unable to solve problems arising in mathematics and other contexts. S-3 also did not understand directionality, leading to an inaccurate problem sketch. Additionally, S-3 failed to effectively monitor and reflect on the problem-solving process, as supported by the interview. In contrast to S-1, Subject S-3 experienced significant difficulties in understanding and solving problems, both in pure mathematical contexts and in those involving real-life applications. In the initial stage of modelling, S-3 failed to identify all quantities involved in the problem, record important information, and even showed a lack of understanding about the problem's direction. When asked, the subject responded briefly, *"I don't understand, Miss,"* indicating that the obstacle had occurred as early as the stage of contextual comprehension. There was no evidence that the subject attempted to transform information from the problem into appropriate visual or symbolic representations, resulting in an ineffective identification of variables and constants.

In the stage of determining the governing principles of the problem, S-3 stated that they applied the angle sum property of a triangle. However, the application appeared mechanical and was not aligned with the structure of the problem. The mathematical model constructed "$\angle A + \angle B + \angle C = 180°$" was valid in general form, yet it was not built based on concrete relationships among the quantities provided in the problem. When asked about the final result or interpretation of the model, S-3 explained that "y represents $\angle C$", indicating a lack of understanding of the geometric meaning of the symbols used. It suggests that S-3 had not yet developed the ability to connect the mathematical model to the problem's context meaningfully.

Furthermore, in terms of monitoring and reflecting on their thinking process, S-3 did not demonstrate adequate metacognitive activity. When asked whether the answer had been reviewed, the subject responded briefly: *"No, Miss."* There was no indication of efforts to verify results, assess the correctness of the solution, or consider alternative approaches. This absence of self-evaluation indicates a weak level of metacognitive control, which plays a critical role in comprehensive mathematical problem solving. In conclusion, Subject S-3's performance showed an inability to solve mathematical problems across various contexts, as well as a lack of flexible problem-solving strategies and awareness to reflect on or monitor their own thinking process.

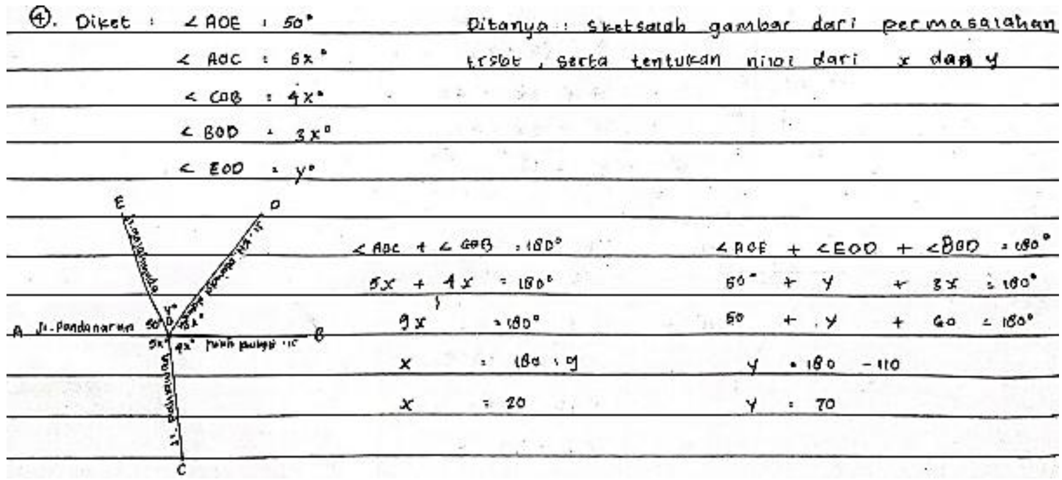
The difference in mathematical problem-solving abilities through modelling between S-1 and S-3 is quite significant, even though both students demonstrated high mathematical resilience. S-1 was able to meet all problem-solving indicators systematically using an appropriate modelling approach, while S-3 failed to do so. These findings support previous research by Haerani et al. (2021), which stated that students with high resilience tend to complete more problems correctly despite occasional errors in procedural skills.

In the stages of identifying and developing a mathematical model, S-1 demonstrated superior abilities compared to S-3. S-1 successfully identified essential information, organized the data logically, and created a model using relevant mathematical concepts. In contrast, S-3 encountered difficulties from the very beginning, failing to recognize key information and being unable to connect existing mathematical concepts to the problem at hand. Differences were also evident in the stages of solving and interpreting the model. S-1 systematically solved the model and verified the results within the context of the problem, whereas S-3 frequently made errors in both calculation and interpretation due to constructing an inappropriate model. It indicates a lack of structured problem-solving skills on the part of S-3.

The findings suggest that although students with high mathematical resilience often attempt to solve problems, they may still lack mastery of fundamental concepts, which can lead to difficulties in selecting appropriate strategies and analyzing issues systematically. It aligns with the research of Maharani and Bernard (2018), who found that insufficient understanding and mastery of tested concepts result in students being unable to solve problems using correct procedures. Instead, they rely on formulas they assume to be accurate without considering their accuracy.

Moderate Mathematical Resilience

a. Constructing New Mathematical Knowledge Through Problem Solving, as well as Monitoring and Reflecting on the Mathematical Problem-Solving Process.



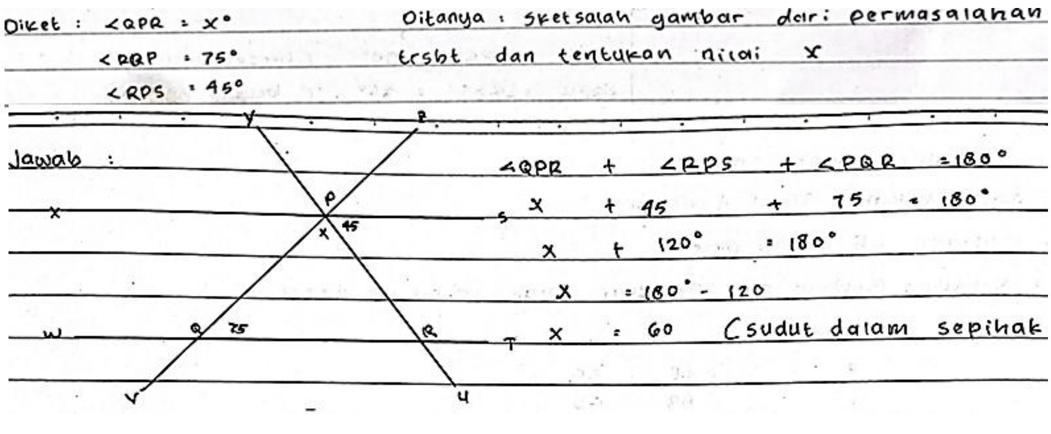
Picture 7. S-4's Work Results

As shown in Picture 7, S-4 encountered difficulties in constructing new mathematical knowledge through problem-solving. Additionally, S-4 did not effectively monitor and reflect on the problem-solving process, as supported by the interview. Subject S-4 demonstrated a moderate ability to construct new mathematical knowledge through problem-solving, as reflected in the relatively systematic application of mathematical modelling steps. In the first stage, identifying all quantities involved in the problem, S-4 abstracted the contextual situation by interpreting the street names in the problem as angles represented with mathematical notation, such as $\angle AOE = 50°$, $\angle AOC = 5x°$, $\angle COB = 4x°$, $\angle BOD = 3x°$, and $\angle EOD = y°$. It representation indicates that S-4 was able to translate verbal information into symbolic form and distinguish between variables and constants.

In the next stage, determining the governing principles of the problem, S-4 recognized that certain angles formed straight angles, indicating that these angles are supplementary. The subject formulated two main equations: "$\angle AOC + \angle COB = 180°$ and $\angle AOE + \angle EOD + \angle BOD = 180°$," showing an ability to construct a mathematical model based on appropriate geometric principles. In the model-solving stage, S-4 applied algebraic strategies to solve both models sequentially. S-4 correctly solved the equation $5x + 4x = 180°$, resulting in $x = 20°$, and then substituted this value into the second equation, $50° + y + 60° = 180°$, to obtain $y = 70°$. It demonstrates S-4's ability to apply algebraic procedures to solve the developed model accurately.

In the final stage, where the model's solution is interpreted as the solution to the original problem, S-4 did not fully carry out this step independently. When asked whether they had checked the calculation results, S-4 answered no and also failed to state the conclusion without prompting. Only after guidance from the interviewer did the subject declare the values of $x = 20°$ and $y = 70°$. It suggests that S-4's ability to monitor and reflect on the mathematical problem-solving process remains limited and still requires external support. Therefore, although S-4 demonstrated competence in constructing mathematical knowledge through modelling, their reflective ability has not yet developed optimally. As such, the mathematical resilience demonstrated by S-4 is considered moderate, as the problem-solving was accurate but lacked independent evaluation of the process.

b. Applying and Adjusting Various Appropriate Strategies to Solve Problems, as well as Monitoring and Reflecting on the Mathematical Problem-Solving Process.



Picture 8. S-4's Work Results

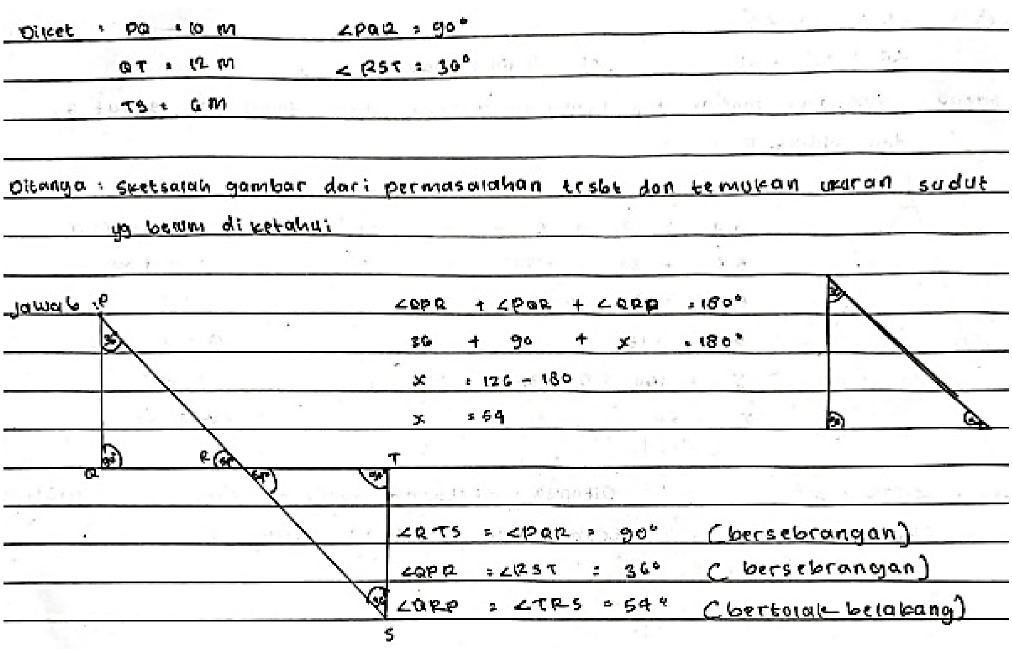
As shown in Picture 8, S-4 encountered difficulties in applying and adjusting various appropriate strategies. Additionally, S-4 did not effectively monitor and reflect on the problem-solving process, as supported by the interview data. Subject S-4 demonstrated a basic understanding of applying problem-solving strategies but has not yet shown the ability to adapt strategies flexibly according to the problem context. In the initial stage of modelling, identifying all quantities involved in the problem, S-4 was able to mention several key pieces of information: $\angle QPR = x°$, $\angle RQP = 75°$, and $\angle RPS = 45°$. It indicates that the subject could distinguish between variables and constants, although there was no explicit effort to label the diagram or consistently state angle measurements.

In the stage of determining the governing principles of the problem, S-4 employed an approach based on the concept of consecutive interior angles and formulated the mathematical model: ∠QPR + ∠RPS + ∠RQP = 180°. It strategy shows an initial understanding of geometric principles and the ability to establish mathematical relationships between angles. Although the subject relied on only one approach, the model constructed was valid for solving the problem. In the model-solving stage, S-4 correctly solved the equation $x + 75 + 45 = 180°$ and obtained the value x = 60°. It suggests that the subject was capable of performing basic algebraic manipulations to derive a solution from the developed model. However, when asked about possible alternative strategies, S-4 responded, “No, Miss,” indicating limited flexibility in thinking and a lack of exploration of potentially more efficient or relevant approaches. It reflects an underdeveloped ability to adapt strategies as needed.

In the final stage, where the model solution is interpreted as the solution to the original problem, S-4 initially forgot to state the conclusion and only provided it after prompting: “So, the value of x is 60°.” Nevertheless, S-4 demonstrated some awareness of the need to verify the result, stating, “I substituted 60° into the model.” This action reflects an element of monitoring during the solution process, although deeper reflection, analyzing the efficacy of the plan, or contemplating other ideas, was not evident. In summary, Subject S-4 has demonstrated an initial ability to apply problem-solving strategies and construct a simple, valid mathematical model. The subject has also begun to show signs of monitoring through the verification of results. However, the ability to flexibly adjust strategies and engage in more profound reflection on the thinking process still needs further development.

c. Solving Problems Arising in Mathematics and Other Contexts, as well as Monitoring and Reflecting on the Mathematical Problem-Solving Process.

As shown in Picture 9, S-4 demonstrates strong problem-solving skills in mathematics and other contexts, including sketching diagrams and understanding cardinal directions. However, S-4 struggles with monitoring and reflecting on the problem-solving process, as supported by the interview results. Subject S-4 demonstrated good competence in solving mathematical problems, particularly those arising from real-world contexts. In the initial stage of modelling, identifying all quantities involved, S-4 was able to state the information comprehensively: “The length of side PQ = 10m, QT = 12m, TS = 6m, $\angle PQR = 90°$, and $\angle RST = 36°$.” It reflects the ability to read and extract key information from the text, transforming it into a visual representation in the form of a diagram, which indicates a relatively strong spatial and conceptual understanding. S-4 was also able to distinguish between known quantities as constants and those treated as variables in the modelling process.



Picture 9. S-4's Work Results

At the stage of determining the governing principles of the problem, S-4 applied the angle sum property of a triangle and connected angles with certain relationships. She stated, "I started from $\angle QPR$ and $\angle RST$, which are vertically opposite angles, so both are equal to 36°," then formulated the mathematical model: "$\angle QPR + \angle PQR + \angle QRP$ = 180°." This process continued with substituting the known angle values and logically solving the model: "90° + 36° + x = 180°, so x = 54°." Furthermore, S-4 demonstrated a more profound understanding by relating other angle values based on corresponding and vertically opposite angles: "$\angle RTS = \angle PQR$ = 90°, $\angle QPR = \angle RST$ = 36°, and ∠TRS = $\angle QRP$ = 54°." It indicates that S-4 was able to solve problems in both mathematical and non-mathematical contexts consistently and conceptually.

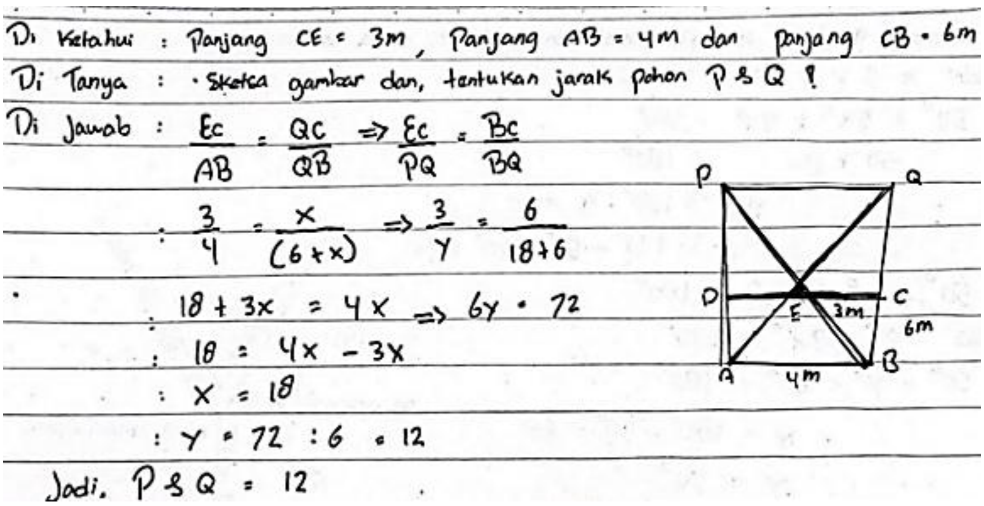
However, regarding monitoring and reflection, S-4's abilities are still limited. Although she mentioned performing a check: "I substituted 54° into the equation 36° + 90° + x = 180°," this action appeared more procedural than reflective. When asked why the conclusion was not written down, S-4 replied, "For this problem, I'm not sure how to write it." This response suggests that, although the problem-solving process was executed well, the ability to communicate the final result systematically has not been fully developed, even though this is an essential part of interpreting and reflecting on the model solution. In conclusion, Subject S-4 has demonstrated reasonably good ability to solve mathematical problems from various contexts, especially in identifying information, constructing models, and determining solutions. However, the capacity to monitor and reflect on the problem-solving process, including evaluating and thoroughly presenting the results, still needs further development.

S-4's ability to build new mathematical knowledge through problem-solving indicates that students with a moderate level of resilience are capable of engaging in the mathematical modelling process. S-4 successfully transformed verbal information into symbolic representations and constructed models based on relevant geometric principles. In applying strategies, S-4 demonstrated the ability to choose appropriate solution methods and solve models using correct algebraic logic. However, the inability to adjust or explore alternative strategies reveals limitations in cognitive flexibility. In terms of solving contextual problems, S-4 demonstrated a good conceptual understanding and effectively transferred knowledge to real-world situations. She effectively related geometric concepts across different contexts. Nonetheless, S-4's ability to monitor and reflect on the problem-solving process remains limited. Independent evaluation of thinking processes and confident communication of conclusions have not yet been demonstrated.

These findings align with the research of Nurfitri and Jusra (2021), which found that students with moderate resilience often face difficulties in applying problem-solving strategies due to a lack of thoroughness. However, they still show effort and perseverance in facing challenges. Additionally, Athiyah et al. (2020) revealed that students with moderate resilience tend to struggle with fully understanding problems. Rahmatiya and Miatun (2020) added that students in this category generally have difficulty following systematic problem-solving procedures, tend to be less meticulous, and easily lose motivation when encountering challenges. Therefore, the mathematical problem-solving abilities of students with moderate resilience still require reinforcement, particularly in strategic flexibility, monitoring, and reflection, to enable them to solve problems more independently and confidently.

Low Mathematical Resilience

a. Constructing New Mathematical Knowledge through Problem Solving, as well as Monitoring and Reflecting on the Problem-Solving Process.



Picture 10. S-7's Work Results

As shown in Picture 10, S-7 is capable of constructing new mathematical knowledge through problem-solving. S-7 can effectively monitor and reflect on the problem-solving process, although there are some shortcomings. At the first stage, identifying all quantities involved in the problem, S-7 was able to interpret information presented in the diagram and identify relevant quantities, as shown in the statement: "Length of CE = 3m, length of AB = 4m, and length of CB = 6m." This information then formed the basis for an initial understanding of the problem's structure.

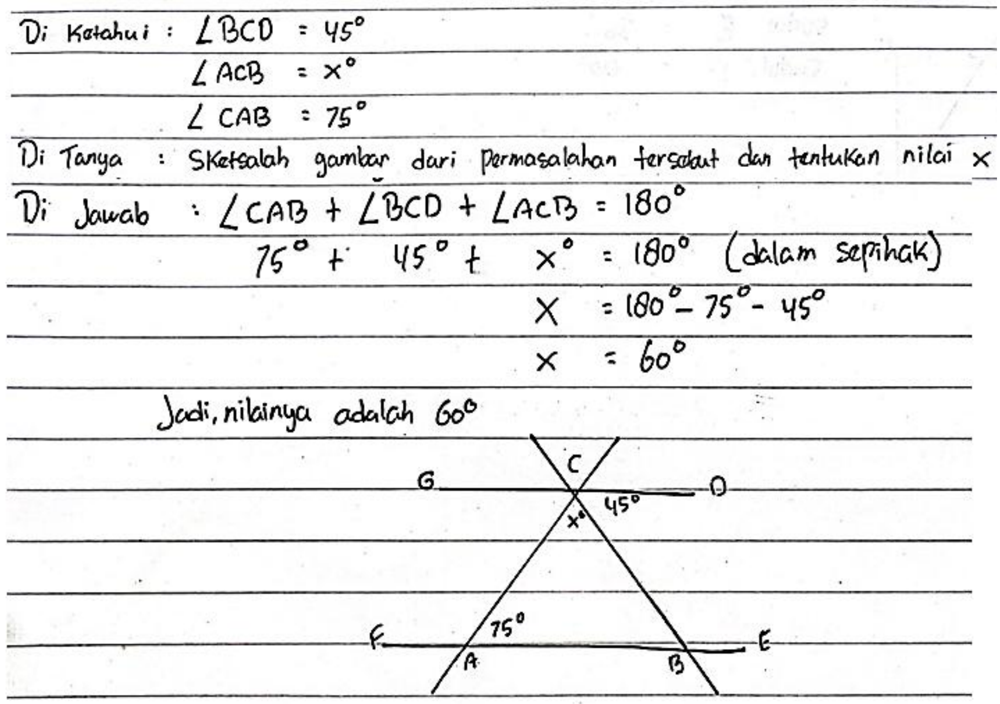
At the stage of determining the governing laws of the problem, S-7 showed understanding of the principle of segment ratios, an important concept in geometry. She stated, "From the picture, it seems this is usually solved with line segment ratios," then formulated two mathematical models, namely: $\frac{CE}{AB} = \frac{QC}{QB}$ *and* $\frac{EC}{PQ} = \frac{BC}{BQ}$. These models indicate that S-7 was able to construct appropriate mathematical representations based on geometric relations relevant to the context of the problem. At the model-solving stage, S-7 solved two equations involving two different variables, x for QC and y for BQ, obtaining final results of x = 18 and y = 12. This problem-solving strategy shows that S-7 can apply conceptual and procedural knowledge accurately to reach correct solutions.

However, at the stage of interpreting the model solution as the solution to the problem, S-7 did not demonstrate a strong ability to monitor and reflect on the mathematical problem-solving process. When asked whether she reviewed the results, S-7 answered, "No, Ma'am," and the conclusion given was brief and not elaborated: "So, P and Q = 12 meters." It indicates that reflection on the thinking process was not conducted independently, and evaluation of the accuracy or appropriateness of the results was not part of the problem-solving strategy.

Thus, S-7 shows sufficient ability in building mathematical knowledge through modelling, particularly in identifying quantities, constructing models, and correctly solving models. However, the aspects of monitoring and reflecting on the mathematical problem-solving process still need to be strengthened. The low mathematical resilience category assigned to S-7 reflects more limitations in metacognitive elements, rather than in conceptual understanding or procedural ability in solving problems.

b. Applying and Adjusting Various Appropriate Strategies to Solve Problems and Monitoring and Reflecting on the Mathematical Problem-Solving Process

As seen in Picture 11, S-7 can apply and adjust various appropriate strategies to solve the problem. S-7 is also able to monitor and reflect on the problem-solving process. Subject S-7 demonstrates fairly good basic skills in applying problem-solving strategies, but has not yet been able to adjust the strategy flexibly according to the problem context. At the initial modelling stage of identifying all quantities involved in the problem, S-7 was able to recognize and name angles based on the points available in the diagram. When asked about the reason for naming the angles, S-7 replied, "I named them based on the points in the diagram," showing initiative in converting visual information into symbolic form and distinguishing involved quantities, although not explicitly separating variables and constants or stating their units.

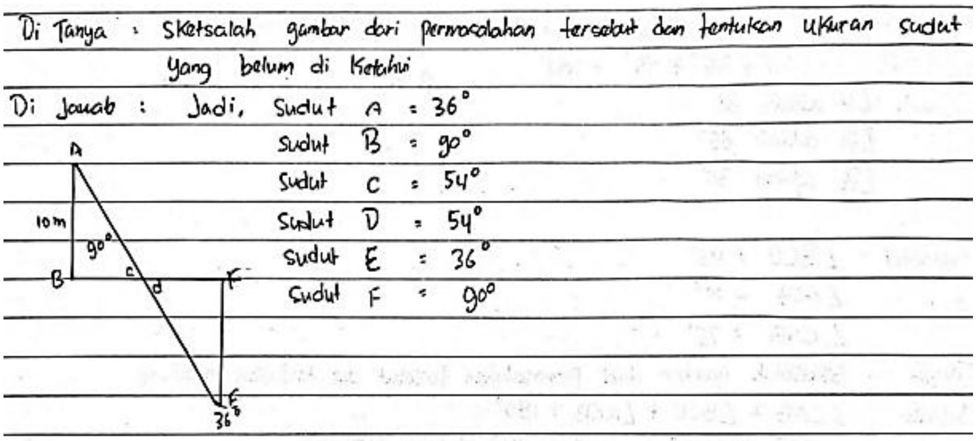


Picture 11. S-7's Work Results

At the stage of determining the governing law, S-7 used the concept of corresponding angles and formed a mathematical model: "$\angle CAB$ + $\angle BCD$ + $\angle ACB$ = 180°." She explained that the relation was constructed based on "the relationship of corresponding angles," indicating that S-7 was able to select relevant geometric principles and build a logical model according to the problem structure. Next, at the model-solving stage, S-7 substituted angle values into the equation: $\angle CAB$ = 75° and $\angle BCD$ = 45°, so the model became x + 120° = 180°, yielding x = 60°. This step shows that S-7 was able to apply appropriate strategies procedurally with a systematic and organized thought process. However, when asked whether there was an alternative strategy that could be used, S-7 answered: "No." This answer reveals that mathematical thinking flexibility is still limited, and S-7 is not accustomed to evaluating or exploring more efficient approaches.

At the stage of interpreting the model solution as the problem solution, S-7 was able to conclude by stating: "The value of x is 60°." However, when asked if she checked the answer, S-7 answered: "No, Ma'am," indicating that monitoring and reflection have not yet become habitual parts of her thinking. Metacognitive awareness of the problem-solving process remains limited, often focusing on procedural execution without a deep evaluation of the strategy's correctness or efficiency. Therefore, Subject S-7 has been able to apply appropriate problem-solving strategies and construct valid mathematical models, but has not yet demonstrated the ability to adjust strategy or reflect comprehensively on the problem-solving process flexibly. Active monitoring has also not been carried out, so S-7's mathematical resilience is classified as limited. However, there is potential for further development with appropriate guidance, particularly in exploring strategies and deeply reflecting on thinking processes.

c. Solving Problems Arising in Mathematics and Other Contexts, as well as Monitoring and Reflecting on the Mathematical Problem-Solving Process



Picture 12. S-7's Work Results

Based on Picture 12, S-7 encountered difficulties in solving problems that arise in mathematics and other contexts. S-7 struggled with monitoring and reflecting on the problem-solving process, as supported by the interview data. Subject S-7 faces quite fundamental difficulties in solving problems that arise both in mathematical contexts and other contexts. At the initial modelling stage of identifying all quantities involved, S-7 did not record important information and showed confusion in understanding the problem's direction. When asked why she did not write down the known information, S-7 replied: "*I'm confused, Ma'am. I can only draw an illustration of the problem*." After being prompted to recall the information, S-7 was only able to mention some known angles: "$\angle B$ = 90° and $\angle E$ = 36°." However, when asked to identify unknown angles, S-7 randomly mentioned all angles: "$\angle A$, $\angle B$, $\angle C$, $\angle D$, $\angle E$, and $\angle F$," without distinguishing which were variables to focus on and which were already known. It indicates that the process of identifying quantities and classifying information as variables or constants has not been done correctly.

At the stage of determining the governing law, S-7 also experienced obstacles. She admitted difficulty explaining the solution strategy by saying, "*I'm confused about how to write it down*." It shows that the selection of relevant mathematical principles or laws has not been clearly done. Although S-7 eventually stated the angle values, such as: "So, $\angle A$ = 36°, $\angle B$ = 90°, $\angle C$ = 36°, $\angle D$ = 54°, $\angle E$ = 54°, and $\angle F$ = 90°," the explanation of how these results were obtained was still unsystematic. She explained that some angles "*face each other*" or "*share vertex points*," for example: "$\angle A$ faces $\angle C$, and $\angle B$ faces $\angle F$," and "$\angle D$ and $\angle E$ share a vertex." It explanation indicates spatial intuition that is not yet fully structured within proper geometric principles.

At the stage of interpreting the model solution, S-7 showed uncertainty about the results obtained. She said, "*I'm not sure, Ma'am. I feel my answer is incomplete*," indicating a lack of confidence in linking the mathematical solution to the problem being solved. In addition, monitoring and reflection activities during the problem-solving process remain very limited. There is no apparent effort to verify answers or evaluate the strategies used. The entire process proceeds without sufficient self-supervision, and the final decisions are made more based on guesswork than precise conceptual analysis.

Overall, Subject S-7's performance indicates that she struggles to solve mathematical and other contextual problems effectively. The processes of information identification, model construction, and conclusion have not been performed fully and consistently. Monitoring and reflection on the thinking process are also weak, so S-7's mathematical resilience is considered low in terms of both contextual problem-solving and supervising her own cognitive processes.

Based on the findings, Subject S-7 demonstrates a pretty good ability to build new mathematical knowledge through problem-solving. She can identify important information from problems and transform it into relevant mathematical models, such as using the principle of segment ratios or corresponding angles in geometry problems. It shows that although classified as having low resilience, S-7 can still develop conceptual understanding through modelling activities. In applying and adjusting problem-solving strategies, S-7 has been able to select and use an appropriate procedural strategy but has not yet shown flexibility in evaluating or seeking alternative strategies. The third indicator, solving problems in mathematical and real-life contexts, has not been fully mastered by S-7. She has difficulty understanding contextual problems, incorrectly identifies quantities, and has not been able to construct models systematically.

For the final indicator, monitoring and reflecting on the problem-solving process, S-7 has not shown adequate metacognitive ability. She does not recheck answers and is unsure about the obtained solutions. Reflection on the thinking process is not performed independently, resulting in a mechanical problem-solving process without evaluation. It is consistent with the research of Harahap and Manurung (2022), who stated that students with low resilience can understand problems but have not yet developed the ability to apply correct solution steps. It is supported by Maharani and Bernard (2018), who stated that students with low resilience tend to solve problems using strategies they think are suitable, without considering whether the strategies are actually correct and effective.

S-7's difficulties in solving problems also reflect low interest, curiosity, and persistence. In difficult situations, she tends to wait for answers from peers rather than trying independently. These findings align with Ansori (2020), who found that students with low resilience tend to give up easily, fail to analyze problems correctly, and rush to complete tasks. Additionally, they often feel anxious, confused, and unsure about their answers, and tend to avoid mathematics problems (Rohmah et al., 2020; Fitriani et al., 2023).

Conclusions and Suggestions

The GeoGebra-assisted MEA learning has been proven to be effective in enhancing MMPSA and mathematical resilience. Mathematical resilience positively influences MMPSA by 30%. Students with high mathematical resilience demonstrate problem-solving abilities ranging from very good to adequate, with the excellent category meeting all four indicators and the "*adequate*" category meeting two indicators. Students with moderate mathematical resilience meet three indicators, whereas those with low mathematical resilience fulfill only two indicators.

Based on the research findings, the following suggestions are proposed: (1) The GeoGebra-assisted MEA learning can be used as an alternative instructional model to improve students' MMPSA and mathematical resilience. (2) Further research on this topic should be conducted to obtain more comprehensive information regarding MMPSA through the GeoGebra-assisted MEA learning, considering students' mathematical resilience.

Acknowledgements

The researcher is grateful to thank all parties involved, including the participants, for their assistance throughout the research process in successfully conducting and completing this study.

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