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Analysis of Students' Mathematical Critical Thinking Skills Solving HOTS-Based Problems

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Abstract. Abstracts The rapid development of technology in the digital era demands the readiness of students to compete and face various problems that arise. This requires critical thinking skills in formulating problems, finding solutions, and determining the resolution path. Critical thinking skills are needed in the 21st century, where information flows rapidly through digital technology. Critical thinking skills are needed to analyze information that benefits individual students. Innovation in the learning process to develop critical thinking skills involves familiarizing students with problem-based mathematical problems to hone critical thinking skills. HOTS questions are questions that stimulate critical thinking skills. This study will show students' critical thinking skills based on their initial abilities. The type of research used is descriptive quantitative. The instruments used are standard HOTS questions. Samples were taken from representatives of high, medium, and low initial ability students. Data analysis is carried out on student answer sheets. The results showed several critical thinking characteristics of students at every level of initial ability. Students with high initial abilities have maximized critical thinking skills based on indicators. Students with early, medium, and low abilities still do not master all indicators of critical thinking skills. Students must be trained by solving problems using HOTS questions to maximize critical thinking skills. HOTS-based problem-solving exercises are carried out regularly in lectures.

Keywords: Mathematical Critical Thinking, HOTS-Based Problems, Initial Skills

INTRODUCTION

Information technology in learning makes the learning process effective and efficient. Technological advances also have implications for disseminating information, such as information regarding references to the concepts of the material being studied. The dissemination of information using technological media does not necessarily mean that one has to accept the truth value of the information fully; filtering and concluding a truth from information requires critical

thinking skills. Thus, students' critical thinking skills must be developed in the learning process. Critical thinking skills are developed and improved in the learning process through analysing, clarifying, and concluding (Suparman et al., 2021). Educators are encouraged to maximise and develop mathematical abilities through reasoning activities, generalisation, and evaluation skills in the lecture process (Anugraheni & Sartono, 2022). The process of mathematical reasoning activities is a logical thinking process that helps students understand the relationships between concepts, find patterns, and apply methods to solve problems; these activities require students' critical thinking skills. Mathematical generalization is the ability of students in the mathematical thinking process to understand a mathematical concept. Thus, students need to have good critical thinking skills.

In the learning process that integrates information technology, educators ensure that students are ready to participate in learning by being actively involved, collaborative, reflective, critical, enthusiastic, and so on. Applying E-learning in learning makes students accustomed to independently training their critical thinking skills to understand the material. It is supported by discussions held at face-to-face meetings to discuss the problems faced and strengthen students' ability to solve problems by utilising critical thinking skills. (Dewi et al., 2020).

Mathematics aims to enable students to develop critical thinking skills. Critical thinking involves understanding mathematical material, which can be trained and developed through mathematics. (Dewi et al., 2020)Understanding mathematics and abstract learning material requires students to develop critical thinking skills. Developing critical thinking skills is an important task for educators. Educators must be skilled in innovating so that abstract mathematics learning becomes meaningful. One way to make mathematics learning meaningful is by contextualising the studied material. In contextual learning, there are principles of constructivism, inquiry, questioning, learning community, modelling, reflection, and authentic assessment. These principles can develop students' critical thinking skills (Kurniati et al., 2015).

Mathematical critical thinking skills are a process of processing information that involves mathematical knowledge, reasoning, and proof so that it can solve a problem or practice problems in learning mathematics (Rahmaini et al, 2024). The learning process that can develop students' critical thinking skills is to familiarize and train students to work on problems that require a high level of analysis (Hainora Hamzah et al., 2022; Spiller et al., 2023). In the Bloom taxonomy, the questions that require a high level of analysis are problems in the C4 category of Analyzing, evaluating, and creating. The questions in this category are higher-order thinking skills (HOTS) questions. HOTS is a question that can test whether students can analyze, compare, evaluate, discover, and more (Meng et al., 2020; Mitani, 2021).

In the initial observation in class, the researcher observed the lecture process. Students cannot analyse and complete the task when they are tasked with solving mathematical problems. With such problems, the lecturer needs to direct and emphasise the purpose of the given task several times. Even when students have started working on the task, questions are still asked, and the lecturer guides students in completing the task. When researchers were interviewed, information was obtained that "students have not been able to understand the problems given, are unable to formulate problems, and are unable to find solutions to problems". The researcher concluded that students' critical thinking skills were still low based on the information obtained. This is evidence that students have not been able to solve problem-based tasks.

The problems above, of course, must be overcome by educators. Students must be familiar with solving problem-based problems to develop critical thinking skills. One of the questions that can develop students' critical thinking skills is a HOTS question (Fanani, 2018) HOTS questions measure the metacognitive dimension, not just the factual, conceptual, or procedural dimensions. The metacognitive dimension describes the ability to connect different concepts, interpret, solve problems, choose problem-solving strategies, find new methods, argue, and make the right decisions.

One of the innovations that educators can do in the lecture process to develop critical thinking skills is to train students to solve problems that can lead students to identify, find solutions to, and solve problems (Kirana & Kholifah, 2020; Lu et al., 2021). HOTS questions are one of the types of questions that can train students to think at a higher level. Students are trained with HOTS questions in lectures so that they are accustomed to solving problems, especially facing the era of the 4.0 revolution, which is all digital, and competition is increasing rapidly (Dori & Lavi, 2023; Satsangi & Sigmon, 2023).

21st-century education requires students to think critically when solving problems. In working on HOTS questions, it is hoped that students' critical thinking skills can develop. Students' critical thinking skills are expected to develop, as expressed by Edward Saputra below. According to Edward Glaser, (Saputra, 2020) Indicators of critical thinking skills include: a) recognising problems; b) looking for ways that can be used to deal with these problems; c) collecting data and compiling the necessary information; d) recognising assumptions and values that are not stated; e) understanding and using language precisely, clearly, and distinctively; f) analysing data; g) assessing facts and evaluating questions; h) recognising logical relationships between problems; i) drawing conclusions and similarities between problems; and ii) drawing necessary conclusions and similarities.

Several studies examine mathematical critical thinking skills, including Syabhana, which examined students' critical thinking skills using the CTL approach. This revealed an increase in the critical thinking skills of students taught with the CTL approach compared to the conventional approach. (Syabhana, 2012). Then, Tresnawati's research regarding the ability to think critically mathematically and high school students' self-confidence found that students' critical thinking ability was positively influenced by their self-confidence by as much as 74.6%. In comparison, 25.4% was influenced by factors other than students' self-confidence (Tresnawati, Hidayat, & Rohaeti, 2017).. Further research by Haeruman et al regarding the Effect of the Discovery Learning model on Increasing Mathematical Critical Thinking and Self-Confidence in terms of the initial mathematical ability of high school students in East Bogor, revealed that there was an increase in critical thinking of students who received Discovery Learning learning compared to students who used conventional learning. This research will look at the Critical Thinking Skills of Students through HOTS-based questions in terms of Students' Initial Ability.

METHOD

This study uses quantitative descriptive research. It will describe the critical thinking skills of students in solving HOTS questions based on their initial ability with flat building material. The students' critical thinking skills are described through numerical data, namely the data from the students' answer sheets answering HOTS questions.

Initial ability consists of low, medium, and high initial ability. The results of initial ability are seen in students' daily grades when working on daily math test questions. The researcher categorized the initial ability from the documentation of student daily test results, where the results of student daily tests were obtained in the range of student scores from 40 to 100, with an average score of 66 and a standard deviation of 14,8. There were seven students with low initial ability, 16 with medium initial ability, and 5 with high initial ability.

Table 1. Classification of Students' Initial Abilities

No	**Score**	**Initial capabilities**
1	$X \geq 81$	High initial ability
2	$52 \leq X \leq 80$	Medium initial ability
3	$X \leq 51$	low initial ability

This research was conducted on third-semester students of the PGMI Study Programme at IAIN Curup, Academic Year 2022/2023. The subjects in this study were selected from 28 students: 1 student of low initial ability, one of medium initial ability, and one of high initial ability. The reason for taking one student for each ability is based on the student's answer pattern. Researchers found several similar answer patterns from each student, judging from their initial abilities.

The research data was obtained from student-answer documents that answered HOTS questions on flat building material. The students' answers will describe their critical thinking ability in terms of their initial abilities. The HOTS questions are two; the HOTS questions used are sourced from critical thinking questions that are standard in the teaching materials used. The indicators of students' critical thinking skills in this study are; a) Interpretation, being able to group information and explain in more detail about the statement in the question, b) Analysis, determining and describing the right problem solving strategy, c) Evaluation, checking the correctness of a statement that has been described, d) Inference, providing logical evidence through settlement steps in concluding.

The research instruments used include: 1) HOTS questions designed to develop students' critical thinking skills; 2) unstructured observation to support other data results. Data analysis techniques were used, including those proposed by Miles and Huberman, including collecting data from the test results of working on HOTS questions based on critical thinking skills. b) Data reduction: selecting student answers that can represent and reveal students' critical thinking skills. c) Data presentation is done by correcting and giving scores on student answer sheets; d) Describe students' critical thinking skills based on initial abilities and draw a conclusion.

FINDINGS

Critical Thinking Skills of Students with High Initial Ability in Answering HOTS Questions

In the lecture process, the lecturer delivered material based on daily life problems related to mathematical concepts. The lecturer presented the material about Build Flat. Students, as prospective educators, must be trained to master the material as well as present problems and answer problem-based questions. The problem given by the lecturer is a problem that can measure the students' critical thinking skills. Students' critical thinking skills are measured using an assessment rubric that researchers have designed. The assessment rubric includes the assessment of each critical thinking indicator, namely interpretation, analysis, evaluation, and inference. From the four indicators, the maximum score for each question is 25.

The following is a critical thinking problem: "The perimeter of a rectangle is 28cm; determine the area of the rectangle if the length is 2 cm more than the width!" These questions determine that the students can think critically, and the answers are obtained from the students. Figure 1 below shows the work of students with high initial ability in answering question No. 1.

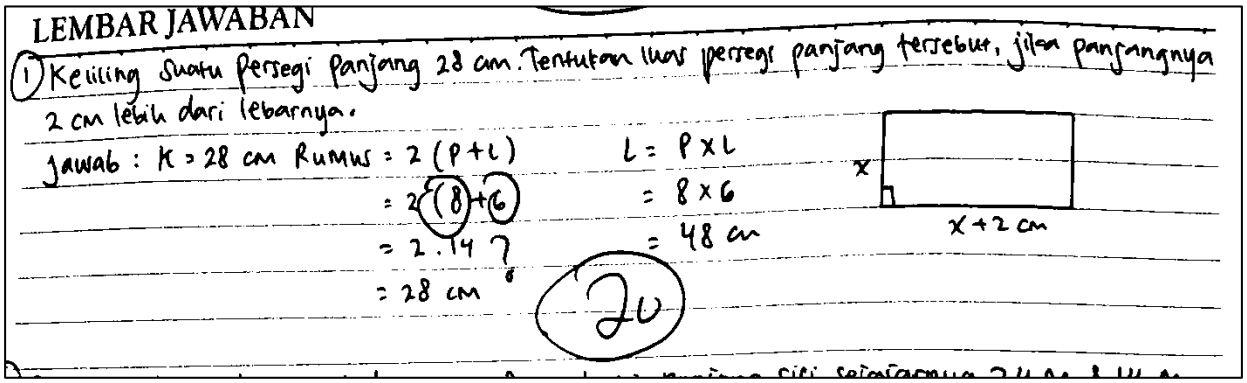


Figure 1. Answers of High-Initial-Ability Students Answering Problem Number 1

From Figure 1, it can be seen and analysed that the student's answer at the end of the work is correct, namely that the square's area is 48 cm, its length is 8 cm, and its width is 8 cm. However, the way to find the answer to the rectangle's length and width has not been explained or generalized.

The student's answer is given a 20 out of a maximum score of 25, because the student has not been able to explain how to find the length and width of the rectangle. From the students' answers, it can be seen that students have not been able to give reasons why the length of the rectangle is eight and the width is 6. Based on the assessment rubric that the researcher has designed, the student's interpretation indicator has not received the maximum score for the interpretation indicator. For other indicators of critical thinking, students can answer questions correctly.

From these results, it can be concluded that students' critical thinking skills have not been maximized. Students have not been able to interpret the length and width of the rectangle. However, the students' answers show the ability to analyse, evaluate, and infer. Students' critical thinking abilities will be at their highest if they use the first step of determining the rectangle's length and width. The interview results found that "students have not been able to analyse the problem well, have not fully understood the meaning of the problem, and have not been able to use the information in the problem to find answers. Observation results also show that students only guess the length and width without adequately describing the correct answer to find the length and width of the rectangle.

Furthermore, an analysis of the critical thinking ability of students with high initial ability is carried out to solve Problem Number 2, *"A plot of land in the form of an isosceles trapezium, the length of the parallel sides is 24 m and 4 m and the distance between the parallel sides is 12 m. if the perimeter of the land is made a fence. What is the total length of the fence?" The* student's answer can be seen in Figure 2:

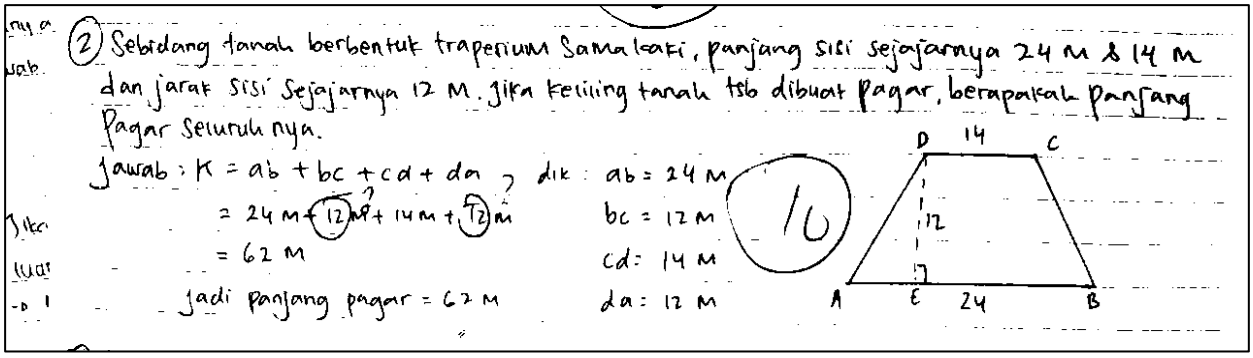


Figure 2. Answers of High-Initial-Ability Students Answering Problem Number 2

In Figure 2, the final result of the student's answer is wrong due to the student's error in finding a solution to a problem. If the student uses the Pythagorean formula to find the length of lines AD and CB, they will produce the correct answer. From the answer in Figure 2, it suddenly appears that the length of lines AD and BC is 12, without presenting the steps in finding the length of the line. In problem number 2, students were given a 10 out of a maximum score of 25. In problem number 2, students did not understand or use the information presented in the problem.

The results in Figure 2 show that students understand what the question is asking; they have presented the perimeter formula of the trapezoid. However, the students' steps are wrong when interpreting the length of the AD rib, which is not the same as the length of the DE rib. This shows that students do not understand the information presented in the problem well, and their critical thinking skills are still low.

The interview results found that "students still have difficulty understanding and analysing these HOTS-based questions; students need continuous exercises to get used to working on HOTS questions". Observation results are also obtained; students still look confused when answering

HOTS questions, and are still seen asking their friends. Such conditions must be given HOTS questions in the lecture process so that students are familiar with and proficient in solving them.

Critical Thinking Skills of Students with Moderate Initial Ability in Answering HOTS Questions

In this study, it is very necessary to reveal the critical thinking skills of students with moderate initial abilities in answering HOTS questions. The following are the answers of students with medium initial ability in answering HOTS question number 1:

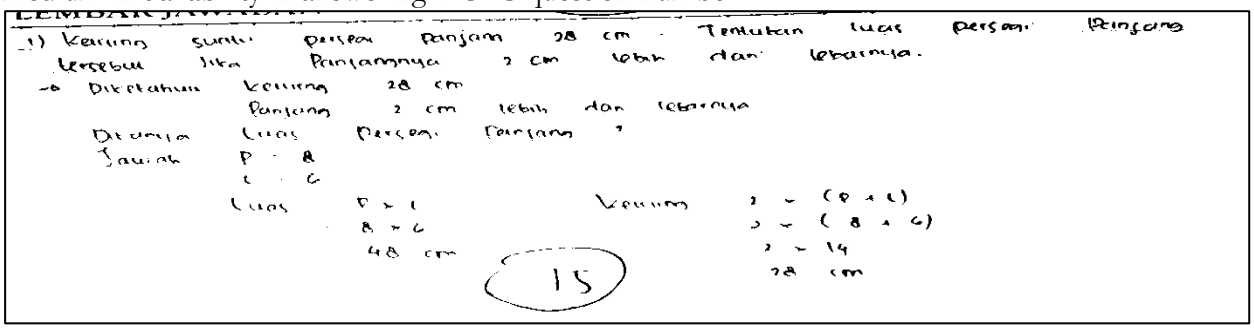


Figure 3. Answers of Students with Moderate Initial Ability Answering Problem No. 1

Figure 3 shows that the student's answer at the end is wrong, where the question asks how much the area of the rectangle is. However, students identified and found the perimeter of the rectangle. Representatives of students with high and medium initial abilities encountered similar issues, such as not using the proper method to determine the length and width of a rectangular flat. The answers of students with medium initial ability in problem number 1 were given a 15 out of a maximum score of 25. The students' steps in solving problem number 1 were incorrect. Students have not been able to understand the problem or utilise the information in the problem to formulate problem-solving steps. The analysis indicator is good, but students are not maximising the evaluation indicator, so their answers do not match what is asked in the problem.

From the students' answers above, guidance is necessary so that students can analyze the mathematical problems presented correctly and understand the problem well. This will allow them to solve the mathematical problems presented with correct identification and the right solutions. Students also need to get used to working on problems requiring high-level thinking skills in teaching and learning. The interview results found that "students have difficulty understanding problems when presented with problem-based problems; they can only solve problems such as problems to find the area of a square, where the length and width are known, or routine problems. Observation results also show that students' scores in answering HOTS-based problems have not reached satisfactory targets.

Figure 4 below presents the answers of medium-ability students in answering question no. 2, following the answers of these students:

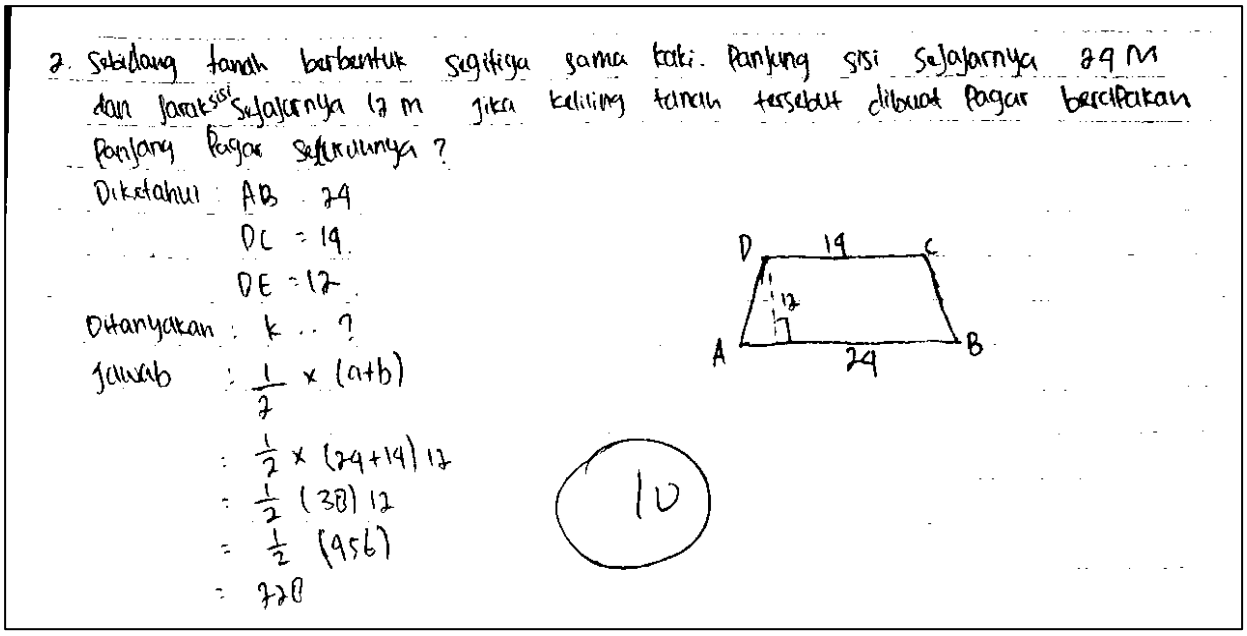


Figure 4. Answers of Students with Moderate Initial Ability Answering Problem No. 2

Like question no. 1, students with moderate initial abilities in answering question no. 2 are incorrect. It can be seen that students do not understand the problem, so the concept used to answer the problem is wrong. If students understand the problem well, they will use the Pythagorean formula to find the length of lines AD and BC. From the student's answer, the lecturer only gave a 10 out of the ideal score of 25. The answer sheet shows that students have been unable to use the right solution to solve the problem.

Researchers conducted interviews and found that "students do not understand the meaning of the problem, and students also do not understand what concepts should be used in solving this problem. The observation results also align with student answers and interviews, which conclude that the critical thinking skills of students with moderate initial abilities are still low and not maximised.

Critical Thinking Skills of Students with Low Initial Ability in Answering HOTS Questions

This study also looked at the critical thinking skills of students with low initial ability to answer HOTS questions. The results can be seen in Figure 5 below:

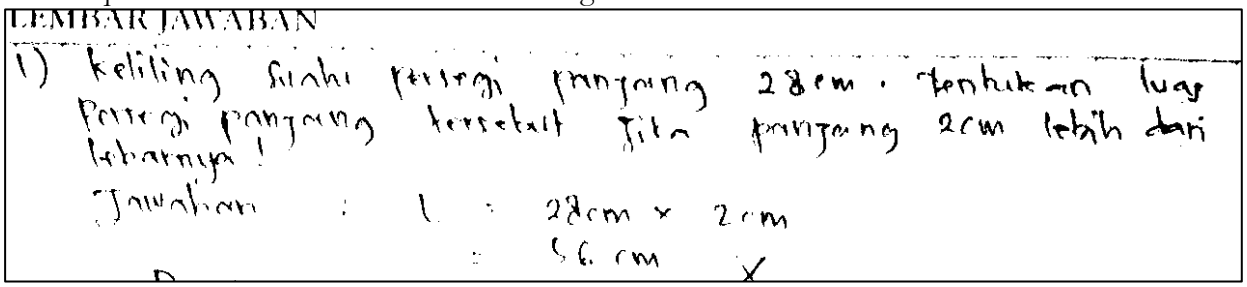


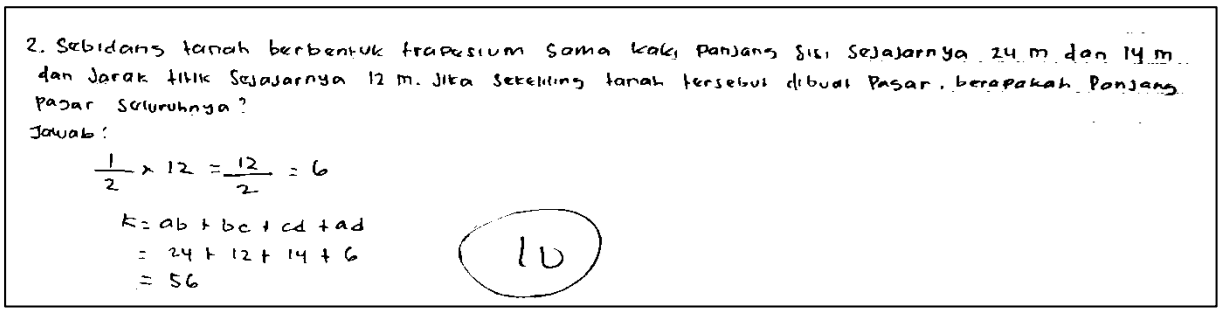
Figure 5. Low Initial Ability Students' Answers to Question No. 1

Figure 5 shows the answers of students with low initial ability to question no. 1. Students with low initial ability seemed careless in answering the question. This can be seen from the students directly answering the question with the available information, multiplying 28 by 2 to find the final result. The student's answer was given a 5 out of a maximum score of 25.

It can be concluded that students with low initial ability do not understand the problem well. They have not found the right problem-solving solution. Furthermore, they have not been able to identify the information available to solve the problems presented, so the final result of problem-solving is incorrect.

The researcher interviewed students with low initial ability. It was found that students did not understand the problem and had difficulty solving problem-based problems. Students also did not construct the problem through images, so they had difficulty solving problems. The observations also found that students looked confused and had difficulty solving the problems presented by the teacher.

In addition to the answer to question no. 1, researchers also analysed the answers of students with low initial abilities in answering question no. 2. The presentation of student answers is presented in Figure 6 below:



Low Initial Ability Students' Answers to Question No. 2

In Figure 6 above, it can be seen that students' answers are still wrong, and the way they identify the problem is not appropriate. Identification like $\frac{1}{2}\ x\ 12 = \frac{12}{2} = 6$ Is an error in understanding the problem. Here, it can be seen that students have not mastered the concept of flat buildings and have been unable to generalise the concept of Pythagoras. Students are given a 10 out of a maximum score of 25. The score is given based on the student's answer, which indicates that the student has not understood the problem well and has not found the right solution, and the final result of the student's answer is wrong.

According to the results of interviews obtained by researchers, "Students find it very difficult to solve these problems. Students hope lecturers can get used to presenting HOTS questions in learning so that students' critical thinking skills are trained and developed". Observation results are also obtained because the final score of students answering these questions is still low.

DISCUSSION

Critical thinking skills are critical to hone in mathematics learning. This aims to ensure that students can sort out good and correct information, take part in developing knowledge, solve problems faced in daily life critically, develop creativity, and make the right decisions.

Lecturers can improve students' critical thinking skills through various efforts, including learning models, assignments, and learning experiences. In this study, the researcher will discuss students' critical thinking skills through assignments like HOTS-based test questions.

Critical Thinking Skills of Students with High Initial Ability in Answering HOTS Questions

Students' mathematical critical thinking skills are identified through their answers to HOTS-based questions. Lecturers, as educators, really need to identify the level of students' mathematical critical thinking skills. From the results of the student answers presented above, it can be concluded that

the critical thinking skills of students with high initial abilities have not been maximized and need to be improved.

Students are not yet proficient in finding ways that can be used to deal with these problems. Students directly present the length and width values of the rectangle without presenting ways of dealing with the problem of finding the length and width values of the rectangle. To find the length and width of the rectangle, students should have substituted the information on the perimeter value and the information on the length of 2 cm more than the width into the formula for the perimeter of a square. Then they can find the actual length and width and continue to find the area of the rectangle.

The problem is related to the indicator of critical thinking ability, namely analysis, students have not been able to analyze information that supports the completeness of the data, which helps determine a problem-solving strategy. This analytical ability is crucial in solving mathematical problems and honing critical thinking skills. The application of the principles of reading, analyzing, and proving is very important in mathematics learning, especially in improving critical thinking, because critical thinking skills allow individuals to get used to facing challenges and solving problems by analyzing their thinking to decide a choice and draw conclusions, so that qualified graduates are printed and able to compete in the development of the times (Kalra et al., 2020; Patiño et al., 2023).

The ability to analyze that has not been maximized can also be seen because the students cannot recognize assumptions and values that are not stated. The length and width values are not stated in the problem, and it requires skills to find the assumptions of these values. Mistakes in assuming values in the problem will impact determining the wrong way to solve the problem; for that, students need to analyze the assumptions of correct and incorrect values when solving mathematical problems. In overcoming this problem, lecturers can design a collaborative learning model so that students who cannot analyze well can discuss with their peers to get ideas for solving mathematical problems. Afriadi revealed in his research that collaborative learning can improve students' understanding of concepts, communication, and critical thinking skills (Afriadi et al., 2024).

Familiarising students with HOTS questions can overcome these problems. Continuous action must be taken to develop students' thinking skills by regularly giving and training them problem-based problems in the mathematics lecture process. Jumaisyaroh revealed that the improvement in mathematical critical thinking skills of students who were given problem-based learning was higher than that of those given direct learning. (Jumaisyaroh, Napitupulu, & Hasratuddin, 2014). Problem-based learning significantly affects individual investigations, work presentation, good cooperation in groups, the ability to provide and explain basic concepts, and the ability to analyse and evaluate the process of solving good problems. (Herman et al., 2022).

Critical Thinking Skills of Students with Moderate Initial Ability in Answering HOTS Questions

The critical thinking skills of students with moderate initial abilities in answering the questions presented at the finding points above are still not optimal. Action is needed to overcome the problem. Students with early abilities are not optimal in mastering critical thinking, evaluation, and inference skills. Students have not recognised the logical relationship between problems; this can be seen from the answers of students who do not utilise the relationship between length and width, namely the length of 2 cm more than the width. In this case, students are still low on the evaluation indicators, as students are still wrong in analyzing the algorithm, which indicates that students have not performed optimally in analyzing the data presented in the questions.

To overcome this problem, lecturers need to strengthen their understanding of student concepts in the learning process and train students to apply concepts to mathematical problems. There are many solutions for strengthening students' understanding of mathematical concepts,

including problem-based learning (Aba-Oli et al., 2025; Rehman et al., 2023). Problem-based learning presents problems that students in daily life often encounter and are then applied and solved using the mathematical concepts being studied. Realistic problems are used as a source of the emergence of mathematical concepts or mathematical knowledge or formal mathematical knowledge that can encourage problem-solving activities, find problems, and organize the subject matter (Albay, 2020; Burgos et al., 2024).

Students with moderate initial abilities need to develop critical thinking skills, and action is needed to solve problems in their critical thinking skills. There is little difference in students' critical thinking ability with high initial and moderate initial ability; it only lies in introducing the problem. Students with moderate initial ability cannot understand and recognise the problem in the problem. Yuliantaningrum revealed that students' assessment can be done through the quality of questions developed and applied by educators; good questions will improve students' HOTS abilities. (Yuliantaningrum & Sunarti, 2020). For this reason, educators always train students with HOTS-based questions in the lecture process. The mathematics learning process should be varied, emphasizing the ability to examine information, integrated learning, and critical thinking skills. (Sundari et al., 2021).

Critical Thinking Skills of Students with Low Initial Ability in Answering HOTS Questions

The critical thinking skills of students with low initial ability in this study will be described through data on the results of working on HOTS questions, interviews, and observations. The critical thinking ability of students with low initial ability is obtained by looking at the indicators of critical thinking skills. Students with low initial ability are still not optimal in interpretation indicators. Problems that are incorrectly identified will impact the solution of inappropriate answers; therefore, it is necessary to identify the correct and appropriate problem to solve the problem in the HOTS problem.

Students have not understood the problem. The problems presented in the problem have not been understood, such as the purpose and intention of the presentation, what the problem command is, and what the right solution is for solving the problem. Identifying what is known, the elements needed, and what is asked in the math problem shows that students already understand the problem well and have some solutions they want to implement. This ability is important to master in mathematics learning and can develop students' critical thinking skills. To be able to give an answer accompanied by a reason, Students must have the skills to know information well to provide the right reason according to the information obtained (Novtiar et al., 2017). Effective training and resources can significantly improve HOTS outcomes in students (Kosasih et al., 2022)

Other indicators of critical thinking that have not been maximized in students with low initial ability are the analysis indicators in planning problem-solving strategies. Students still seem careless in finding ways to solve problems. Students' lack of careful attention in finding ways to solve problems can be overcome with an open-ended approach. In mathematics learning, there is learning that presents many appropriate ways to solve mathematical problems, namely, open-ended (Erickson et al., 2020; Normann & Sanders, 2020). The lecturer presents mathematical questions allowing several right ways to solve problems. This open-ended approach can train students to find ways and solutions to a problem (Brîncuş, 2021; Ozmantar & Agac, 2023). By solving open-ended problems, students can pour their ideas freely without interference from teachers, so that the active role of students can be seen (Hidayat et al., 2018).

Critical thinking indicators of student evaluation are visible, but students have been unable to test the results of the problem identification they get. Students have not been able to assess the problems related to daily life appropriately. This is the impact of student errors in identifying problems and determining solutions. Thus, students need to identify the elements known in the problem and plan the right problem-solving strategy. Soedjadi revealed that students will

experience misconceptions when solving problems when they cannot correctly understand what is being asked in the question. Moreover, Students cannot use formulas to solve math problems (Listiani et al., 2019).

The critical thinking skills of students with low initial abilities obtained from the analysis have not fulfilled the four indicators of critical thinking. Students with low initial ability tend to make more mistakes on the four indicators of critical thinking. (Khishaaluhussaniyyati et al., 2023). Students with low initial ability only fulfil the interpretation indicator (Puspitasari et al., 2020). (Puspitasari et al., 2021). Students with low initial ability need to be trained on non-routine problems to develop and improve their ability to interpret, analyse, evaluate, and infer.

Students' critical thinking skills are critical to develop. Critical thinking skills are helpful for students on campus, in society, and in the surrounding environment. As future educators, students must master all mathematical concepts so that they are ready to become role models when they plunge into the field. Based on the explanations above, the conclusion in writing HOTS-based questions is that the questions are designed to test students in the realm of analysing (C4), evaluating (C5), and creating (C6) abilities. Providing HOTS-based questions on assessments can train students to practice their high-level thinking abilities and skills in order to adjust to the demands of competencies that must be possessed to face the era of the 21st century so that they can compete in life later (Kunanti, 2020). HOTS-oriented learning can measure and determine students' high-level thinking readiness. (Arifin, 2017).

CONCLUSION

Students' critical thinking skills need to be developed in the face of information technology-oriented education. This aims to enable students to compete and develop all their potential through critical thinking skills. The learning innovation lecturers use to develop students' critical thinking skills is presenting HOTS questions in the mathematics learning process. The researcher found that a sample of students with high initial ability had mastered three indicators of critical thinking ability, namely interpretation, analysis, and evaluation. However, students' abilities were not maximized in the inference indicators. Students with early intermediate abilities have mastered interpretation and analysis, but their abilities have not been maximized in the evaluation and inference indicators. Students with low initial ability have not mastered the interpretation indicators, so they find answering questions in other indicators difficult. Students with high, medium, and low initial abilities have critical thinking characteristics when working on HOTS questions. However, this must be developed continuously in the lecture process. So that students are trained and accustomed to solving HOTS questions. Giving HOTS questions to develop critical thinking skills is not enough to be done only once or rarely; this cannot maximise students' critical thinking skills.

REFERENCES

Aba-Oli, Z., Koyas, K., & Husen, A. (2025). Higher-order thinking skills-oriented problem-based learning interventions in mathematics: A systematic literature review. *School Science and Mathematics*, *125*(3), 214–231. https://doi.org/10.1111/ssm.12676

Albay, E. M. (2020). Towards a 21st century mathematics classroom: Investigating the effects of the problem-solving approach among tertiary education students. *Asia-Pacific Social Science Review*, *20*(2), 69–86. https://doi.org/10.59588/2350-8329.1303

Anugraheni, I., & Sartono, E. K. E. (2022). Analisis Kemampuan Berpikir Kritis Matematis Berbasis Realistik. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, *12*(3), 244–249. https://doi.org/10.24246/j.js.2022.v12.i3.p244-249

Arifin, Z. (2017). Mengembangkan Instrumen Pengukur Critical Thinking Skills Siswa pada

Pembelajaran Matematika Abad 21. *Jurnal THEOREMS (The Original Research of Mathematics)*, *1*(2), 92–100.

Brîncuş, C. C. (2021). Are the open-ended rules for negation categorical? *Synthese*, *198*(8), 7249–7256. https://doi.org/10.1007/s11229-019-02519-9

Burgos, M., Tizón-Escamilla, N., & Chaverri, J. (2024). A model for problem creation: implications for teacher training. *Mathematics Education Research Journal*, *37*(1), 55–84. https://doi.org/10.1007/s13394-023-00482-w

Dewi, K. A. I. D., Suarsana, I. M., & Juniantari, M. (2020). Pengaruh E-Learning Berbasis Rumah Belajar Terhadap Kemampuan Berpikir Kritis Matematika Siswa. *Wahana Matematika Dan Sains: Jurnal Matematika, Sains, Dan Pembeljarannya*, *14*(1), 65–77.

Dori, Y. J., & Lavi, R. (2023). Teaching and Assessing Thinking Skills and Applying Educational Technologies in Higher Education. *Journal of Science Education and Technology*, *32*(6), 773–777. https://doi.org/10.1007/s10956-023-10072-x

Erickson, J. A., Botelho, A. F., McAteer, S., Varatharaj, A., & Heffernan, N. T. (2020). The automated grading of student open responses in mathematics. *ACM International Conference Proceeding Series*, 615–624. https://doi.org/10.1145/3375462.3375523

Hainora Hamzah, Mohd Isa Hamzah, & Hafizhah Zulkifli. (2022). Systematic Literature Review on the Elements of Metacognition-Based Higher Order Thinking Skills (HOTS) Teaching and Learning Modules. *Sustainability (Switzerland)*, *14*(2), 1–15. https://doi.org/10.3390/su14020813

Herman, T., Hasanah, A., Nugraha, R. C., Harningsih, E., Ghassani, D. A., & Marasabessy, R. (2022). Pembelajaran Berbasis Masalah-High Order Thinking Skill (HOTS) pada Materi Translasi. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *6*(1), 1131–1150. https://doi.org/10.31004/cendekia.v6i1.1276

Kalra, S., Thevathayan, C., & Hamilton, M. (2020). Developing Industry-Relevant Higher Order Thinking Skills in Computing Students. *Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education*, 294–299. https://doi.org/10.1145/3341525.3387381

Khishaaluhussaniyyati, M., Faiziyah, N., & Sari, C. K. (2023). Analisis Kemampuan Berpikir Kritis Siswa Kelas 10 SMK dalam Menyelesaikan Soal HOTS Materi Barisan dan Deret Aritmetika Ditinjau dari Self Regulated Learning. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *7*(1), 905–923. https://doi.org/10.31004/cendekia.v7i1.2170

Kirana, A., & Kholifah, S. (2020). Approach Higher Order Thinking-Problem Based Learning in Learning Mathematics Material Linear Equations Absolute Value One Variable. *Innovation Research Journal*, *1*(1), 20. https://doi.org/10.30587/innovation.v1i1.1188

Kosasih, A., Supriyadi, T., Firmansyah, M. I., & Rahminawati, N. (2022). Higher-Order Thinking Skills in Primary School: Teachers' Perceptions of Islamic Education. *Journal of Ethnic and Cultural Studies*, *9*(1), 56–76. https://doi.org/10.29333/ejecs/994

Kurniati, K., Kusumah, Y. S., Sabandar, J., & Herman, T. (2015). Mathematical Critical Thingking Ability Through. *IndoMS-JMS*, *6*(1), 53–62.

Lu, K., Yang, H. H., Shi, Y., & Wang, X. (2021). Examining the key influencing factors on college students' higher-order thinking skills in the smart classroom environment. *International Journal of Educational Technology in Higher Education*, *18*(1), 1–13. https://doi.org/10.1186/s41239-020-00238-7

Meng, Q., Jia, J., & Zhang, Z. (2020). A framework of smart pedagogy based on the facilitating of high order thinking skills. *Interactive Technology and Smart Education*, *17*(3), 251–266.

https://doi.org/10.1108/ITSE-11-2019-0076

Mitani, H. (2021). Test Score Gaps in Higher Order Thinking Skills: Exploring Instructional Practices to Improve the Skills and Narrow the Gaps. *AERA Open*, *7*(1). https://doi.org/10.1177/23328584211016470

Normann, D., & Sanders, S. (2020). Open sets in computability theory and reverse mathematics. *Journal of Logic and Computation*, *30*(8), 1639–1679. https://doi.org/10.1093/logcom/exaa049

Ozmantar, M. F., & Agac, G. (2023). Mathematics teacher educators' knowledge sources in teacher education practices. *Mathematics Education Research Journal*, *35*(1), 175–201. https://doi.org/10.1007/s13394-021-00382-x

Patiño, A., Ramírez-Montoya, M. S., & Ibarra-Vazquez, G. (2023). Trends and research outcomes of technology-based interventions for complex thinking development in higher education: A review of scientific publications. *Contemporary Educational Technology*, *15*(4). https://doi.org/10.30935/cedtech/13416

Puspitasari, R. J., Faridah, L., & Aini, K. N. (2021). Analisis Kemampuan Berpikir Kritis Siswa dalam Menyelesaikan Soal HOTS Ditinjau dari kecerdasan Logis Matematis. *INSPIRAMATIKA*, *7*(1), 16–26. https://doi.org/10.24127/ajpm.v11i4.5918

Rehman, N., Zhang, W., Mahmood, A., Fareed, M. Z., & Batool, S. (2023). Fostering twenty-first century skills among primary school students through math project-based learning. *Humanities and Social Sciences Communications*, *10*(1). https://doi.org/10.1057/s41599-023-01914-5

Satsangi, Rajiv, & Sigmon, Stephanie D. (2023). Teaching Multiplicative Thinking With Virtual Representations to Children With Mathematics Difficulty. *Remedial and Special Education*, *45*(4), 216–229. https://doi.org/10.1177/07419325231206483

Spiller, J., Clayton, S., Cragg, L., Johnson, S., Simms, V., & Gilmore, C. (2023). Higher level domain specific skills in mathematics; The relationship between algebra, geometry, executive function skills and mathematics achievement. *PLoS ONE*, *18*(11 November), 1–20. https://doi.org/10.1371/journal.pone.0291796

Sundari, S., Kahar, M. S., & Erwinda, E. G. (2021). Analisis Kemampuan Berpikir Tingkat Tinggi Menggunakan Instrumen Hots Berbasis Two Tier Diagnostic Test. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(4), 2726. https://doi.org/10.24127/ajpm.v10i4.4260

Suparman, Juandi, D., & Tamur, M. (2021). Problem-Based Learning for Mathematical Critical Thinking Skills : A Meta-Analysis. In *Journal of Hunan University (Natural Sciences)* (Vol. 48, Issue 2, pp. 133–144).