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Analysis of Students' Higher Order Thinking Skills in Solving Open-Ended Problems on the Topic of the System of Linear Equations in Two Variables

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Abstrak

Penelitian ini bertujuan untuk mengetahui mendeskripsikan *Higher Order Thinking Skill* (HOTS) siswa dalam menyelesaikan soal o*pen ended* pokok bahasan sistem persamaan linear dua variabel. Jenis penelitian ini adalah penelitian deskriptif dengan menggunakan pendekatan kualitatif. Instrument penelitian ini adalah tes berupa soal o*pen ended* pokok bahasan sistem persamaan linear dua variabel dan pedoman wawancara. Subjek yang dipilih pada penelitian ini berjumlah 3 siswa, yang dibagi menjadi tiga kelompok yaitu 1 siswa dari kelompok berkemampuan tinggi, 1 siswa dari kelompok berkemampuan sedang dan 1 siswa dari kelompok berkemampuan rendah. Berdasarkan hasil penelitian dapat disimpulkan bahwa HOTS siswa yang berkemampuan tinggi dapat menyelesaikan soal *open ended* pada tingkat kognitif menganalisis (*analyze)*, mengevaluasi (*evaluate)* dan mencipta *(create)*. HOTS siswa yang berkemampuan sedang dapat menyelesaikan soal *open ended* pada tingkat kognitif menganalisis, dan mengevaluasi saja, sedangkan untuk soal *open ended* ada tingkat mencipta siswa belum mampu menyelesaikannya. HOTS siswa yang berkemampuan rendah hanya mampu menyelesaikan soal *open ended* pada tingkat kognitif menganalisis saja. Implikasi penelitian ini menegaskan pentingnya strategi pembelajaran dan pengembangan soal open-ended yang disesuaikan dengan tingkat kemampuan siswa, serta pelatihan guru dalam merancang kurikulum yang mendukung pengembangan HOTS secara bertahap hingga tingkat mencipta.

Abstract

This study aims to describe students' Higher Order Thinking Skill (HOTS) in solving open-ended problems on two-variable linear equation systems. This type of research is descriptive research using a qualitative approach. The research instrument is a test in the form of open-ended problems on the subject of two-variable linear equation systems and interview guidelines. The subjects selected in this study were three students, divided into three groups: 1 student from the high-ability group, one from the medium-ability group, and one from the low-ability group. Based on the study's results, HOTS students with high abilities can solve open-ended problems at the cognitive levels of analyzing, evaluating, and creating. HOTS students with medium abilities can only solve open-ended problems at the cognitive levels of analyzing and evaluating. In contrast, for open-ended problems, there is a level of creating that students have been unable to solve. HOTS students with low abilities can only solve open-ended problems at the cognitive analysis level. The implications of this study emphasize the importance of learning strategies and the development of open-ended problems that are adjusted to the level of student ability, as well as teacher training in designing a curriculum that supports the development of HOTS gradually up to the level of creating.

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Introduction

The development of 21st-century science and technology (IPTEK) is experiencing rapid progress. Provide quality education related to advancing science and current technology; the learning system must remain innovative. Mathematics is a basic science whose role is crucial in everyday life, so Mathematics learning needs to be continuously updated or innovated (Rafiq Badjeber, 2018). Therefore, mathematics subjects must be taught to all students from elementary school. To develop logical, analytical, systematic, critical, creative, and collaborative thinking skills (Situmorang, 2022).

With various existing advances, competition at the national and international levels will increase, thus requiring everyone to have 21st-century skills to prepare themselves to face increasingly fierce competition (Qirom et al., 2021). 21st-century education requires students to master the 4Cs, namely critical thinking, communication, collaboration, and creativity (Saefullah et al., 2018). To further facilitate honing the 4C abilities, students are required to Higher Order Thinking Skills in 21st-century education to facilitate honing the ability to analyze, evaluate and create as we know that to produce something of quality requires critical thinking, good communication, collaboration, creativity, innovation, being able to analyze the problems to be solved, being able to re-evaluate what has been done or obtained and being able to create it to be more interesting and enjoyable.

HOTS (Higher Order Thinking Skills) in this study is the students' ability to solve open-ended questions at the cognitive levels of analyzing, evaluating, and creating based on the revised Bloom's taxonomy, as expressed by Febryana et al., (2023) Higher Order Thinking Skill (HOTS) is the ability to analyze, evaluate, and transform existing knowledge and experience to think logically, critically, and creatively in order to make decisions to solve problems in new situations. HOTS is the ability to think at a higher cognitive level, beyond simply remembering concepts or facts presented to us (Irawati, 2018). HOTS is the ability to connect, transform, and manipulate existing knowledge to solve new problems through creative and critical thinking (Losi, 2020). HOTS can also be defined as the ability of a more complex thinking process consisting of explaining known material, critiquing it, and creating solutions (Rismawati et al., 2022). Based on the explanation above, we can conclude that HOTS is a complex thinking skill for finding solutions to problems.

According to Bloom's taxonomy revised by Anderson and Krathwohl, the cognitive level consists of lower-order thinking skills (including the ability to remember (C1), understand (C2), and apply (C3) low-order thinking). Higher-order thinking skills, including the functions of analysis (C4), evaluation (C5), and creation (C6) (Dinni, 2018).

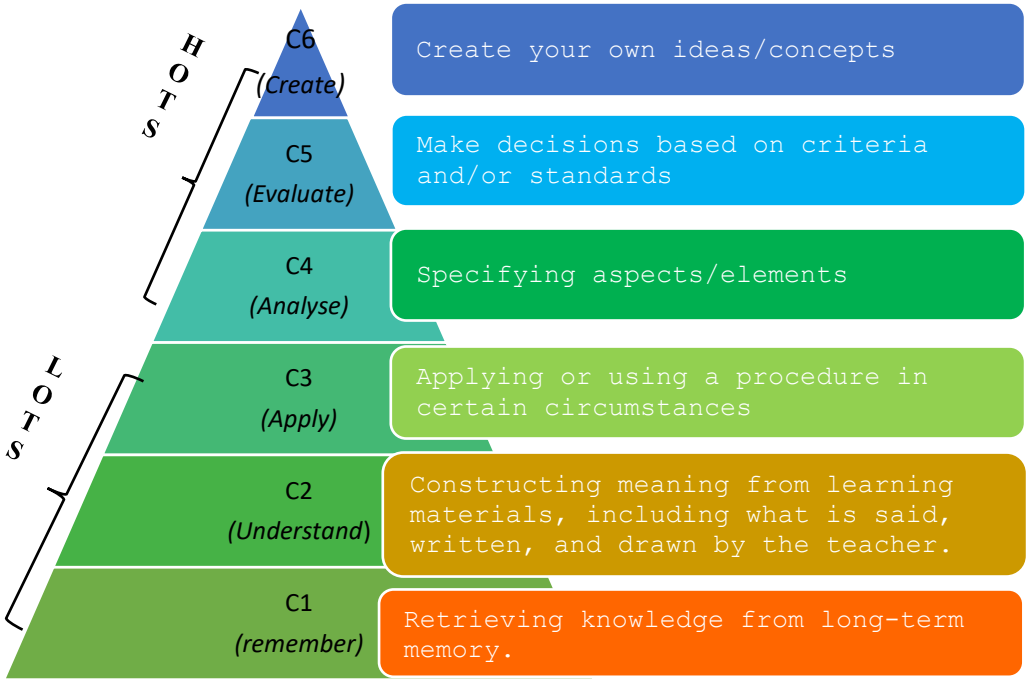


Figure 1. Bloom's Taxonomy Cognitive Domain Diagram
Source: (Anderson & Krathwohl, 2015)

Because each student has different thinking skills when solving problems, open-ended questions are an alternative to develop students' thinking skills. Open-ended problems are designed to have more than one correct answer (Putrian & Kurniasari, 2022). Open-Ended Problems (OEP) or learning with open problems is learning that presents problems that can be solved in various ways (flexibility) and have diverse solutions (multi-answer, fluency) (Hasyim & Andreina, 2019). Students' HOTS can be developed by presenting OEP in the mathematics learning process. OEP can be done in various ways so that students become more critical and creative in solving these problems (Losi, 2020).

Giving open-ended problem questions can help teachers assess students' varied knowledge and can motivate students to think creatively (Utami Putri, 2017). Some of the advantages of giving open-ended questions in mathematics learning are: (1) Students become more active in learning, and convey more of the ideas they have in learning, (2) Students become more likely to use their mathematical abilities and knowledge, (3) Students with low skills can solve problems with their ways and methods, (4) motivate students to do proof, (5) Students can have a lot of experience and discovery and can accept opinions from their friends (Mardayanti et al., 2016).

HOTS is a crucial skill for students to possess; therefore, various studies have been conducted from various perspectives. For example, Sadijah et al., (2021) study examined the differences in teaching methods between female and male teachers in HOTS. Furthermore, (Tanujaya et al., 2017) study showed a relationship between HOTS and student achievement. This research demonstrates the importance of HOTS mastery for students, so it is also crucial to first analyze students' HOTS

abilities. This is evident in Ismawati & Yuliastuti (2024) research, which analyzed problem-solving abilities in solving HOTS questions. It was found that students could not fulfill all the problem-solving activities in the evaluation and creativity indicators. In line with this, Mita Miranda Sitanggang & Edi Syahputra, (2023) stated that the high group of students found it challenging to understand principles, the medium group of students found it difficult to understand operations and principles, and the low group experienced difficulties with facts, concepts, operations, and principles. This research was also strengthened by interviews conducted at SMP Negeri 10 Kerinci.

Based on the interviews conducted by researchers with eighth-grade mathematics teachers at SMP Negeri 10 Kerinci, information was obtained about student activities in learning mathematics. Mathematics teachers at this school understand HOTS-based learning and have implemented it, although there are still obstacles. Then, regarding students' HOTS abilities, teachers said that it is not yet known precisely how students' HOTS are, both the ability to analyze, evaluate, and create. Information obtained from interviews with mathematics teachers at SMP Negeri 10 Kerinci encouraged researchers to analyze students' HOTS in solving open-ended problems on the subject of two-variable linear equation systems.

The description above is the reason for researching the analysis of students' higher-order thinking skills in solving open-ended problems on the topic of two-variable linear equation systems, because no similar research has been conducted that discusses students' HOTS in solving open-ended problems on the topic of two-variable linear equation systems.

Method

This study uses qualitative descriptive research because it is in accordance with the research objective, namely, to describe students' HOTS abilities in solving open-ended problems for the subject of two-variable linear equation systems. The research instrument is a test using open-ended questions and interview guidelines. Before the instrument is used, validation has been carried out on the instrument so that it is suitable for use. Furthermore, the subjects in this study were 29 students of class VIII A of SMP Negeri 10 Kerinci who were selected using a purposive sampling technique. After conducting the test on the 29 students, the answer sheets were assessed using the HOTS assessment rubric. After the test results were obtained, the students were grouped into three categories: students with high, medium, and low abilities. From the three categories, one student was selected for each category to be interviewed using interview guidelines that experts have validated. The interview was conducted to obtain more in-depth information from students who had worked on the test questions that had been given. Data were collected and then analyzed; data analysis in this study started from data reduction, data presentation, verification, and conclusion.

Research Results and Discussion

Research Results

Based on the results of the open-ended test questions given to 29 students of class VIII A of SMP Negeri 10 Kerinci regarding the material of two-variable linear equation systems. The data obtained are that seven students are included in the group with high HOTS, with a percentage of 24.14%, 16 students are included in the group with medium HOTS, with a percentage of 55.17%, and six students are included in the group with low HOTS, with a percentage of 20.69%. These results were obtained by correcting the students' answer sheets using the following rubric.

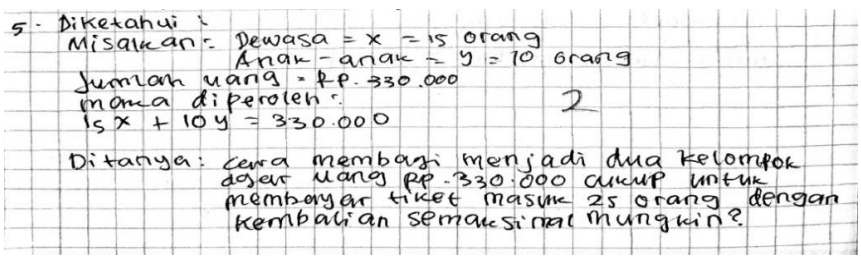
Table 1. Assessment Rubric

Aspects Higher Order Thinking Skill	Indicator	Score
Analyze (C4)	Students are not able to do any analysis at all.	0
	Students can check and analyze information accurately and formulate problems, but there are still errors in the solution steps and final answers.	1
	Students can examine and analyze information accurately, formulate problems, and provide appropriate solution steps and final answers.	2
Evaluate (C5)	Students cannot assess, deny, or support an idea and provide reasons that can strengthen the answers obtained.	0
	Students cannot provide reasons to strengthen the answers obtained correctly, but the answers almost lead to the correct solution.	1
	Students can provide reasons that can strengthen the answers obtained correctly, but do not provide final decisions/conclusions.	2
	Students can assess, deny, or support an idea and provide reasons that can strengthen the answers obtained correctly.	3
Create (C6)	Students cannot devise a way to solve a problem or integrate information into a strategy.	0
	Students can design a way to solve problems or combine information into a strategy that is almost correct or still contains a few errors in writing the answer.	1
	Students can design a way to solve a problem or combine information into an appropriate strategy.	2

Source: Imani (2019)

Students were divided into three groups: high, medium, and low ability. The following presents sample answer sheets for students in the three high, medium, and low ability groups when answering open-ended questions.

Student Groups with High HOTS



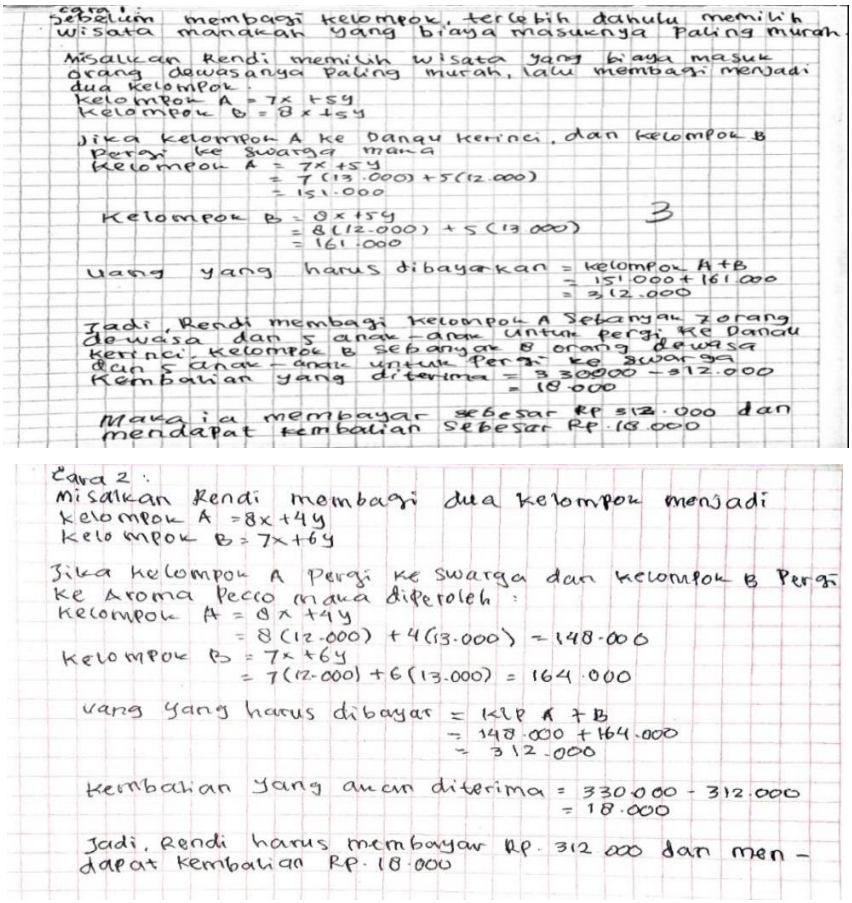


Figure 2. Scan the answer to question number 5 subject S-23

In solving question number 5, subject S-23 fulfills analyzing, evaluating, and creating indicators. In solving question number 5 for the analyzing indicator, subject S-23 can write down what is known and asked in the question, namely, it is known for example that x = adults = 15 people, y = children = 10 people, the amount of money = 330,000, then the equation is obtained 15 x + 10 y, what is asked is how to divide into two groups so that Rp. 330,000 is enough to pay for the entrance ticket for 25 people with the maximum possible change. Then, subject S-23 can solve the problem in the evaluation indicator with the proper and systematic steps. Furthermore, subject S-23 can design a different way to solve problems or combine information into the right strategy in the creative indicator. The subject can solve problems with different strategies, namely the first way, dividing group A into seven adults and five children to go to Lake Kerinci, the equation is 7x + 5y, with an entrance ticket cost of Rp. 13,000 for adults and Rp. 12,000, so that group A must pay Rp. 151,000, group B into eight adults and five children to go to Swarga, the equation is 8x + 5y, with an entrance ticket cost of Rp. 12,000 for adults and Rp. 13,000, so that group B must pay Rp. 161,000, and the total amount that must be paid by groups A and B is Rp. 312,000 and will get a change of Rp. 18,000. The second way, dividing group A into eight adults and four children to go to Swarga, is 8x + 4y, with an entrance ticket cost of Rp. 12,000 for adults and Rp. 13,000, so that group A must pay Rp. 148,000, group B into seven adults and six children to go to Aroma Pecco, the equation is 7x + 6y,

with an entrance ticket cost of Rp. 14,000 for adults and Rp. 11,000, so that group A must pay Rp. 164,000, and the total amount that groups A and B must pay is Rp. 312,000 and will get a change of Rp. 18,000.

The following is an excerpt from an interview conducted with subject 23 to explain her understanding of question 5.

P : What information did you get from question 5?

S-23 : Rendi wants to take his family of 15 adults and 10 children on a trip to Kerinci. Rendi has Rp. 330,000 and needs to get the maximum change.

P : What are your steps in solving this problem?

S-23 : My first step is to assume that 15 adults and 10 children are 10. The total amount of money is 330,000. This gives me: 15 adults + 10 children = 330,000. I then divide the group into two groups, each spending Rp. 312,000, so Rendi gets Rp. 18,000 in change.

P : Is there another way to solve this problem?

S-23 : Yes, sis. In the question, it is stated that in one group there must be an adult accompanying the children, and the number must not be less than the number of children, so there may be several groups with different numbers of adults and children. The tourist attractions can also be different.

Student Group with Moderate HOTS

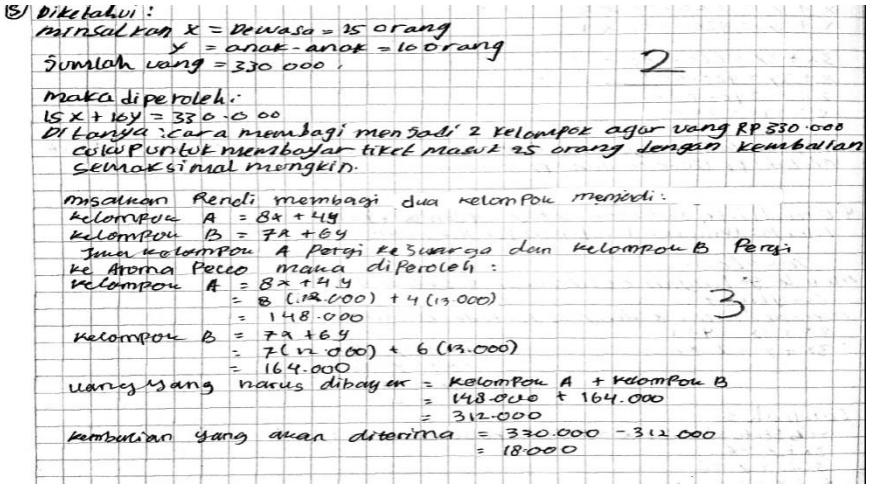


Figure 3. Scan the answer to question number 5 subject S-18

In completing question number 5, subject S-18 fulfills the indicators of analyzing and evaluating, but has not fulfilled the creating indicator. This can be seen in the analyzing indicator, subject S-18 understands the problems that are known and asked in the question, namely, it is known for example x = adults = 15 people, y = children = 10 people, the amount of money = 330,000, then the equation is obtained 15 x + 10 y and what is asked is how to divide into two groups so that the money of Rp. 330,000 is enough to pay for the entrance ticket for 25 people with the maximum possible change. Then, in the evaluation indicator, subject S-18 can solve the problems asked in the

questions with the proper and systematic steps, namely by dividing group A into eight adults and four children to go to Swarga, the equation 8x + 4y is obtained with an entrance ticket cost of Rp. 12,000 for adults and Rp. 13,000, so that group A must pay Rp. 148,000, group B consisting of 7 adults and six children, to go to Aroma Pecco, the equation 7x + 6y is obtained with an entrance ticket cost of Rp. 14,000 for adults and Rp. 11,000, so that group A must pay Rp. 164,000, and the total amount that must be paid by groups A and B is Rp. 312,000 and will get a change of Rp. 18,000. Meanwhile, in the creative indicator, subject S-18 was unable to design a different strategy to solve the problem or combine information into an appropriate strategy, and the subject was unable to provide a conclusion that could support the answer he gave.

The following is an excerpt from an interview conducted with subject 18 to explain his understanding of question number 5.

P : What information did you obtain from question number 5?

S-18 : I assumed x = adults = 15 people, y = children = 10 people, and Rendi's money = 330,000. Therefore, the equation is 15x + 10y = 330,000.

P : What were your steps in solving the problem?

S-18 : My first step was to assume that x = adults = 15 people and x = children = 10 people, then the amount of money = 330,000. Therefore, I obtained: 15x + 10y = 330,000. Then, I divided the group into two groups, each spending Rp. 312,000, so Rendi received Rp. 18,000 in change.

Student Groups with Low HOTS

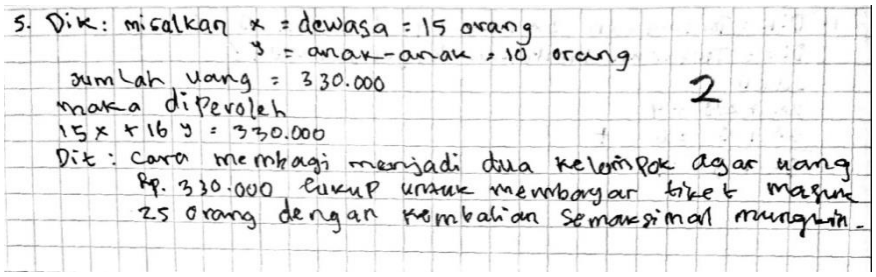


Figure 4. Scan the answer to question number 5 subject S-11

Subjects in the low-ability group could only complete open-ended questions on the analysis indicator. However, they could not complete open-ended questions on evaluating and creating indicators. In question 5 for the analysis indicator, subject S-11 could describe what was known and what was asked in the question. In the evaluation indicator, the subject could not solve the problem correctly. In the create indicator, the subject could not design a way to solve the problem or combine information into a strategy.

The following is an excerpt from an interview with subject 11 to explain his understanding of question 5.

P : What information did you obtain from question 5?

S-11 : It is known that there are 15 adults and 10 children, and Rendi has 330,000 rupiah. Then, the question was asked about dividing the two groups so that the 330,000 rupiah would be enough to cover the entrance fees for 25 people.

P : Then, what did you do next?

S-11 : I do not understand this question, so I will not answer. I will list what is known and what is asked.

P : Have you ever worked on a question like this before?

S-11 : Never before.

Discussion

Student Groups with High HOTS

Based on the test and interview data analysis, the group of students with high HOTS skills was able to solve open-ended questions across all HOTS indicators: analyze, evaluate, and create. The following describes the abilities of the group of students with high HOTS skills based on the HOTS indicators:

a. Analyze

In the analysis indicator, the students with high HOTS skills could write down what was known and what was asked in the open-ended questions on systems of linear equations in two variables.

b. Evaluate

In the evaluation indicator, students with high HOTS skills solved problems using precise and systematic steps.

c. Create

In the creative indicator, the group of students with high HOTS skills was able to devise a different way to solve a problem or combine information into an appropriate strategy.

The results of this study indicate that the group of students with high Higher Order Thinking Skills (HOTS) was able to comprehensively solve open-ended problems on the topic of systems of linear equations in two variables across all HOTS indicators, namely analyzing, evaluating, and creating. This can be attributed to students' in-depth conceptual mastery and flexible thinking strategies. They can analyze information, find patterns, and identify relationships between concepts. During the evaluation stage, they can assess the accuracy or effectiveness of a method and compare several solution strategies. Furthermore, they can also create new, more creative and varied solutions, extending beyond standard procedures.

These findings align with the theoretical framework developed by Anderson and Krathwohl (2015), which asserts that higher-order thinking skills encompass complex activities such as analyzing, evaluating, and creating, requiring students to understand information and use it reflectively and innovatively. Supporting this, Purwasi & Fitriyana, (2020) found that students with

high HOTS skills performed better in solving open-ended problems because they could think flexibly and explore various solutions. Furthermore, the study's results on the development of HOTS LKPD show that learning oriented towards developing the three indicators (analyze, evaluate, create) provides space for students to develop critically and creatively in mathematics.

Student Group with Moderate HOTS

Based on the test and interview data analysis, the group of students with moderate HOTS solved open-ended questions using the HOTS indicators of analyze and evaluate. However, it was unable to solve questions using the create indicator. The following describes the abilities of the group of students with moderate HOTS based on the HOTS indicators:

a. Analyze

   In the analysis indicator, the students with moderate HOTS could understand the known problems and the questions asked.

b. Evaluate

   In the evaluation indicator, the group of students with moderate HOTS solved the problems asked in the questions using appropriate and systematic steps.

c. Create

   In the create indicator, the students with moderate HOTS could not design a different strategy to solve the problem or integrate information into an appropriate strategy.

The findings of this study indicate that the group of students with a moderate HOTS level was able to solve open-ended questions on the analysis and evaluation indicators, but had not yet demonstrated the ability in the creation indicator. This occurs because their thinking flexibility is still limited despite their good conceptual understanding. They can identify important information in problems and assess the accuracy of a solution, but they tend to use previously taught procedures without attempting to develop new strategies. As a result, their abilities remain at the analytical and evaluative level, without producing innovative solutions.

Student Groups with Low HOTS

Based on data analysis from open-ended test results and interviews, the students with low HOTS could only complete open-ended questions on the analysis indicator. It could not complete open-ended questions on the evaluation and creation of indicators. The following describes the abilities of the group of students with low HOTS based on the HOTS indicators:

a. Analyze

   In the analysis indicator, the students with low HOTS can describe what is known and what is asked in the problem.

b. Evaluate

   In the evaluation indicator, the students with low HOTS cannot solve the problem correctly.

c. Create

In the creative indicator, the students with low HOTS cannot devise a method to solve the problem or integrate information into a strategy.

Based on the test and interview analysis results, students with low HOTS skills could only demonstrate ability in the analysis indicator. However, they were unable to achieve the evaluation or creation indicators. Their abilities were limited to describing known and requested information from the problem. However, they struggled to choose appropriate solution procedures and could not devise new strategies to solve the problem. This occurs because they can decipher the information contained in the problem, but their understanding is superficial and limited to what is explicitly presented. The skills to assess the correctness or effectiveness of solutions (C5) or create new strategies (C6) are underdeveloped. This is generally caused by a weak grasp of concepts, limited experience solving challenging problems, and a tendency to rely on memorization rather than critical or creative thinking.

This finding is consistent with a study by Ismawati & Yuliastuti (2024) that observed students' abilities on HOTS problems on the Pythagorean theorem at MTs. They found that the students with low HOTS skills generally only managed to meet the analysis indicator, while failing to complete all problem-solving activities in the evaluation and creation indicators. Furthermore, research by Utariningsih (2018) in the context of developing a HOTS cognitive diagnostic test also reported that students with low HOTS levels experienced significant difficulties in evaluating (32.7%) and creating (43.5%) indicators, and were unable to integrate information effectively in non-routine problems. This condition is closely related to students' limited experience with open-ended problems and the lack of learning stimulation that facilitates in-depth exploration of ideas, reflection, and problem-solving.

The implications of this research indicate the need for teachers to design learning strategies and develop open-ended questions in stages according to students' abilities, so that low-ability students can be strengthened in the analysis aspect, while medium- and high-ability students are challenged to develop their evaluation and creation skills; therefore, teacher training in compiling questions and curricula that support the gradual development of HOTS is essential.

Conclusion

Based on the research results and discussion, it was concluded that students' higher-order thinking skills (HOTS) vary according to their ability level. Students with high ability can solve open-ended problems up to the cognitive levels of analyzing, evaluating, and creating. This indicates that they are not only able to analyze information and assess the accuracy of solutions, but are also able to design new, creative solution strategies. Meanwhile, students with average ability can only solve open-ended problems up to the level of analyzing and evaluating, but have not yet reached the level of creating. This condition indicates that they can understand and assess information, but still have difficulty generating new ideas or strategies. Meanwhile, students with low ability can only solve

open-ended problems at the analysis level, and are not yet able to evaluate or create, which indicates limitations in critical and creative thinking.

These findings imply the importance of designing tiered learning strategies tailored to student abilities. Teachers need to reinforce analysis for students with low abilities, and provide additional challenges in the form of questions that encourage evaluation and creativity for students with medium and high abilities. Therefore, teacher training in developing open-ended questions and developing a curriculum that supports the gradual development of HOTS is essential to ensure all students can develop according to their potential.

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