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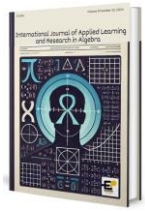

An Analysis of High School Students' Mathematical Representation Skills on Relations and Functions

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Abstract

This research was carried out to analyze the abilities of high school-level students in solving relationship and function problems. This research method is a qualitative method with a descriptive research type. This research was carried out at one of Pekanbaru High School subjects in classes X.1 and X.2 at YLPI Pekanbaru High School, with 6 students. The data collection technique used in this research is a written test technique in the form of a description consisting of 2 questions. After the students have completed the questions, the answers will be analyzed by the researcher as a percentage of the students' results, and the researchers will conduct interviews with the students regarding the answers they made. Based on the research results, the "Visual Representation" indicator percentage was 79.16%, which is included in the high category. Then, the indicator "Mathematical Equations or Expressions" was 66.66%, which was included in the high category. Finally, the "Words or Written Text" indicator is 50%, which is in the medium category. Furthermore, the percentage of questions for mathematical representation ability is 80% for question number 1, in the high category, and 88.33% for question number 2, in the very high category. So, a conclusion can be drawn from the score obtained by the students, namely 84.16%, which is included in the very high category. It is hoped that the results of this research will provide maximum guidance for teachers to develop students' abilities in mathematics, especially relation and function material.

Keywords: Analysis of student abilities, Mathematical representations, Relations and function.

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1. Introduction

One of the important subjects in the education process is mathematics. One of the benefits of mathematics is that it provides a structured way of thinking, enabling students to become rational, logical, systematic, creative, critical, and precise individuals. Mathematics is a science whose truths are absolute and not subject to revision, as it is based on pure deduction, a unified mathematical proof system. Additionally, mathematics equips students with the ability to solve problems logically, critically, systematically, and creatively. Mathematics learning must be connected to real-life contexts, be relevant to daily life, and be aligned with societal values (Tarigan, 2021). Mathematics has a significant role in education (Erowati & Wetan, 2014). This is evident because mathematics is studied at every level of education, from elementary school to higher.

One of the important subjects in the education process is mathematics. One of the benefits of mathematics is that it provides a structured way of thinking, enabling students to become rational, logical, systematic, creative, critical, and precise individuals. Mathematics is a science whose truths are absolute, not subject to revision, as it is based on pure deduction, a unified mathematical proof system. Additionally, mathematics equips students with the ability to solve problems logically, critically, systematically, and creatively. Mathematics learning must be connected to real-life contexts, be relevant to daily life, and be aligned with societal values (Tarigan, 2021). Mathematics has a significant role in education (Erowati & Wetan, 2014). This is evident because mathematics is studied at every level of education, from elementary to higher education, with more instructional hours than other subjects.

Mathematics has long been a mandatory subject in education aimed at preparing students for future life. One of the benefits of learning mathematics is that it provides a structured way of thinking, enabling students to become rational, logical, systematic, creative, critical, and precise individuals (Hapsari & Munandar, 2020). Learning is an effort to improve the quality of education. Effective learning activities involve active, reciprocal interaction between teachers and students. Therefore, students are expected to be active, creative, and innovative in responding to the material taught by teachers so that it can be well understood. The learning process no longer emphasizes one-way learning, where teachers explain and students listen and take notes. Instead, active learning is emphasized, where students actively solve problems and discover new things to learn.

The objectives of mathematics learning in the 2013 Curriculum are outlined in the Minister of Education Regulation No. 59 of 2014 as follows: a) Understanding mathematical concepts, including the competence to explain relationships between concepts and apply concepts or algorithms effectively in problem-solving; b) Applying reasoning in mathematical properties, manipulating mathematics in simplifications, or analyzing components of problem-solving both within and outside the context of mathematics; c) Having an appreciation for the

usefulness of mathematics in life, demonstrated through curiosity, attention, and interest in learning mathematics, as well as perseverance and confidence in problem-solving.

In mathematics learning, students must possess several mathematical abilities. One such ability is representational skills. Representation is an excellent method for presenting ideas and relationships in mathematics. Students must understand forms of representation such as symbols, charts, and graphs to communicate mathematical ideas to others (Fajriah et al., 2020; Triono, 2017; Widakdo, 2017; Yulinawati & Nuraeni, 2021; Yusepa, 2017). This aligns with Sabirin (2014:35), who stated that representation can facilitate students in building concepts and mathematical thinking, enabling them to have a strong and flexible understanding of concepts constructed by teachers through mathematical representation. Mathematical representation skills are essential for students to create tools or methods of thinking to represent abstract mathematical ideas concretely, making them easier to understand (Lisarani & Qohar, 2021; Marudi et al. 2019; Muhayaroh & Pertiwi, 2023; Lisarani & Qohar, 2020; Maulana, 2018; Nurwati & Sari, 2021).

In reality, educational objectives in Indonesia have not been achieved effectively. According to the Programme for International Student Assessment (PISA) in 2015, Indonesian students ranked 62nd out of 70 countries, with a mathematics achievement score of 386, compared to the global average score set by the Organisation for Economic Co-operation and Development (OECD) in 2016, which was 490. According to Karimah (2017:25), one of the factors contributing to Indonesia's low PISA results is that students are generally not trained to solve PISA-type problems. PISA problems are contextual, requiring reasoning and understanding of the question before solving it. Students accustomed to solving routine problems and mimicking the teacher's methods struggle with non-routine problems. This indicates that Indonesian students generally face difficulties solving problems requiring analytical skills. Students struggle to translate story problems into visual representations or mathematical expressions. They also find it challenging to express ideas, either mathematically or verbally (Mulyaningsih et al., 2020; Rohana et al., 2021; Samad et al., 2020; Mardiana & Fatmawati, 2019; Lestari & Retta, 2017).

Students' mathematical representation skills are still lacking. Research by Abdi (2012) and Amalia, Rusdi, and Kamid (2021) shows that the average score of high school students in mathematics tests equivalent to PISA is below level one, indicating students are unable to solve PISA-level mathematics problems. PISA problems require mathematical literacy and representation skills for their resolution. Additionally, research by Lestari, Andinasari, and Retta (2020) indicates that high school students' mathematical representation skills are still categorized as low. Furthermore, data from research shows that the percentage of mathematical representation aspects used by high school students in solving test problems is 36.1%, reflecting the insufficient representation skills of students.

Moreover, the learning outcomes of students in mathematics are not yet promising. According to the TIMSS survey, Indonesian students' performance in mathematics learning remains far below the international average. The 2011 TIMSS survey results show that Indonesia is significantly below the international average of 500. Based on TIMSS standards, the advanced category is 625, the high is 550, the intermediate is 475, and the low is 400. Indonesian students have not reached the low category (400), let alone the advanced category (625). These results highlight the low mathematics learning outcomes of middle school

students in Indonesia, which relate to their inadequate mathematical representation skills (Silviani et al., 2021; Sulastri, Marwan & Duskri, 2017; Suningsih & Istiani, 2021; Tarigan & Simarmata, 2020; Syamsuddin & Rizki, 2021)

Although mathematical representation is not explicitly stated in the government's mathematics learning objectives, its importance can be seen in problem-solving and mathematical communication goals. To solve mathematical problems, students must create mathematical models and present mathematical ideas through symbols, tables, diagrams, or graphs to clarify problems and arrive at solutions—key indicators of representation skills.

On the other hand, the lack of optimal representation skills is influenced by school-based learning approaches, such as limited teacher knowledge and students' habits of conventional learning. Teachers often dominate learning as the primary information providers, making students less involved in constructing their knowledge. The limited representation skills lead to a tendency for students to rely on symbolic representations when solving problems, neglecting other forms of representation. This underscores the need for efforts to enhance students' mathematical representation skills. The abovementioned issues must be addressed promptly, necessitating mathematics learning approaches to improve students' mathematical representation skills.

2. Methods

The method used in this research is a qualitative method with a descriptive type of research. The purpose is to analyze students' mathematical representation abilities in solving problems related to relations and functions. Qualitative descriptive research involves collecting data and presenting it directly in the form of descriptions or comprehensive depictions of the situation or condition of the object as it is, in the form of written or spoken words from people or observed behavior. In this study, the subjects were students from classes X.1 and X.2 at SMA YLPI Pekanbaru, totaling 3 students from each class. The selected subjects were those who participated in the learning process and had already been taught the material. The students were given a test on the topic of relations and functions. This test was designed to diagnose students' mathematical representation abilities related to relations and functions. The research was conducted on May 20 and 21, 2024.

The data collection techniques used in this research were written tests supplemented by interviews. The research instrument consisted of several questions. The written test technique involved administering a test to the students selected as research subjects. The test was conducted individually and consisted of two descriptive questions based on mathematical representation abilities in relations and functions. The students' mathematical representation scores were measured based on mathematical representation indicators. The scoring guidelines for mathematical representation, modified from Ahmad Nizar Rangkuti, were used to analyze the questions on relations and functions.

In the mathematical representation scoring guidelines, the researcher did not use a score of 0 because, based on the assessment of the mathematical equations or expressions indicator, no student left their answer sheet completely blank. At the very least, students could identify the known aspects of the problem and write them down, which meant the student received a score of 1. These guidelines are as follows:

Table 1 - Mathematical representation scoring guidelines

Score	Visual Representation	Mathematical Equations or Expressions	Written Words or Text
1	The diagram is irrelevant to the problem, indicating a lack of understanding of the material.	Only identifies the known aspects of the problem.	There is an explanation, but it is incorrect, doubtful, and shows a lack of understanding of the material.
2	The diagram contains many errors, but there is some understanding of the material.	Only a tiny part of the mathematical model is correct.	The mathematical explanation is reasonable but incomplete.
3	The diagram is somewhat inaccurate.	Creates a correct mathematical model but still lacks accuracy.	The mathematical explanation is reasonable and complete, and important aspects are correctly expressed.
4	The diagram is complete and accurate, consistent with the problem.	Creates a correct mathematical model, performs calculations, and obtains a correct and complete solution.	-

The data analysis technique in this study involved calculating the percentage of scores and categorizing students' mathematical problem-solving abilities into five categories. The table from Muhibbin Syah (2017) is as follows:

Table 2. Kualifikasi persentase skor

Percentage Score	Measurement Category
0%-20%	Very Low
21%-40%	Low
41%-60%	Medium
61%-80%	High
81%-100%	Very High

3. Results and Discussion

The results of the research represent the scores obtained by students from two essay questions. The test data was derived from student answers analyzed based on the scoring rubric for mathematical representation skills. From the two questions given to the students, the following percentages of the indicators for mathematical representation abilities are presented:

Table 3. Percentage of indicators for mathematical representation skills

Indicator	Persentage	Category
Visual Representation	79,16%	High
Mathematical Equations or Expressions	66,66%	High
Written Words or Text	50%	Medium

Based on Table 3, students demonstrated 79.16% visual representation, meaning most students could represent the problems visually. For the indicator of mathematical equations or expressions, the percentage was 66.66%, indicating that most students could construct mathematical equations or expressions. Meanwhile, for the written words or text indicator, the percentage was 50%, meaning some students could express the concepts in written form. Next is the percentage of item scores for the students' mathematical representation skills:

Table 4 - Percentage of test items for mathematical representation skills

Student	Score		Grade
	Question 1	Question 2	
High 1	10	10	100
High 2	10	9	95
Medium 1	9	9	90
Medium 2	6	10	80
Low 1	6	7	65
Low 2	7	8	75
Total	48	53	505
Persentage	80%	88,33%	84,16%
Category	High	Very High	Very High

Based on Table 4, it was found that for question 1, the percentage was 80%, indicating that most students fell into the high category, meaning they could understand the problems accurately but still made errors in solving them. For question 2, the percentage was 88.33%, indicating that most students were in the very high category, meaning they could understand the problems accurately. Therefore, the overall percentage obtained by the students was 84.16%, which is very high. Below is a discussion of the answers of students from classes X.1 and X.2, analyzed based on the indicators of mathematical representation ability for each question on relations and functions:

Question 1: Three families live nearby in RT XI. The first family consists of four members: Mr. Teddy, Mrs. Mahira, and their children, Edward and Disya. The second family includes Mr. Adam, Mrs. Diva, and their three children, Ellina, Aletta, and Allina. The third family consists of Mr. Pram and Mrs. Qila. a) Create three sets of family members; b) Suppose the sets created in part (a) are named sets K, L, and M. Fill in the members of each set in a diagram! Besides these three sets, are there other sets with different members from sets K, L, and M that you can create? If so, illustrate those sets in a diagram!

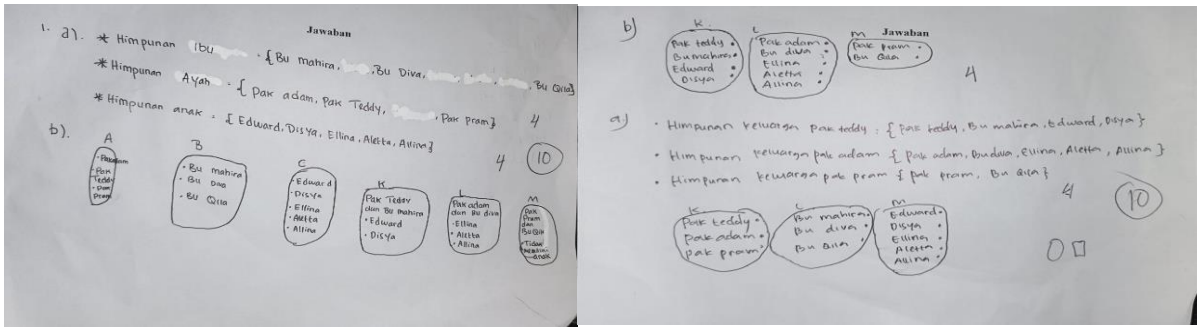

Figure 1 Answer of high student 1 and answer of high student 2

In Figure 1, the answers of High Student 1 and High Student 2 demonstrated that they could represent visuals, create mathematical equations or expressions, and write words or texts very well. Based on the interview results, High Student 1 explained their approach to solving the problem as follows: "For question 1, the first thing I did was group the families into Family Set 1, Family Set 2, and Family Set 3, as well as sets of fathers, mothers, and children. Then, I created diagrams of the six sets I had formed." Similarly, High Student 2 explained their approach as follows: "For question 1, the first thing I did was create Family Set 1, Family Set 2, and Family Set 3, as well as sets of fathers, mothers, and children. Then, I created diagrams of the six sets I had formed." The results showed that both High Student 1 and High Student 2 achieved a score of 100%, indicating that they had very high proficiency in mathematical representation skills.

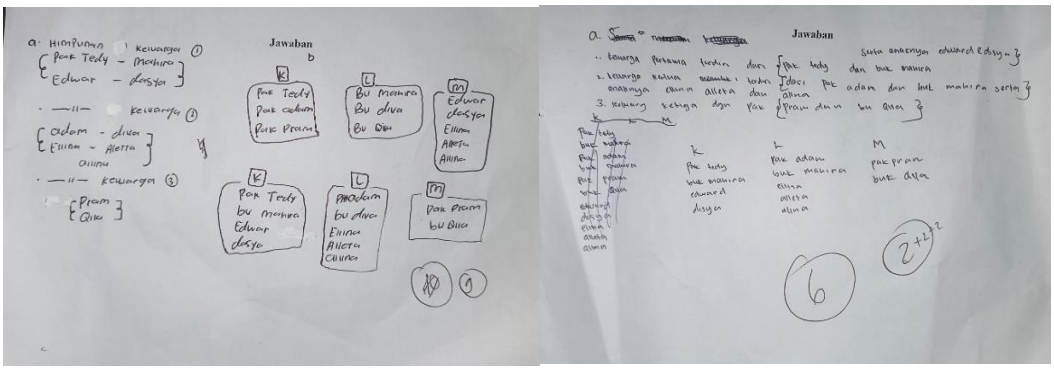

Figure 2 Answer of medium student 1 and answer of medium student 2

In Figure 2, the answers of Moderate Student 1 showed that they could represent visuals, create mathematical equations or expressions, and write words or texts well. Meanwhile, Moderate Student 2 demonstrated the ability to represent visuals, create mathematical equations or expressions, and write words or texts fairly well. Based on the interview results, Moderate Student 1 explained their approach to solving the problem as follows: "For question 1, the first thing I did was group the families into Family Set 1, Family Set 2, and Family Set 3, as well as sets of fathers, mothers, and children. Then, I created diagrams of the six sets I had formed." Similarly, Moderate Student 2 explained their approach as follows: "For question 1, the first thing I did was create Family Set 1, Family Set 2, and Family Set 3, as well as sets of fathers, mothers, and children. Then, I created diagrams of the six sets I had formed." The results showed that Moderate Student 1 scored 90%, indicating that they had very high proficiency in mathematical representation skills, while Moderate Student 2 scored 60%, which indicates moderate proficiency in mathematical representation skills.

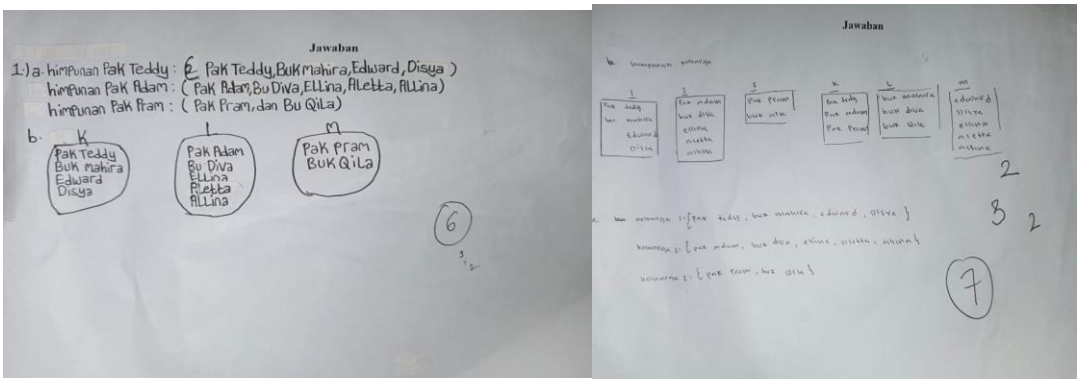

Figure 3 Answer of low student 1 and answer of low student 2

In Figure 3, the answers of Low-Level Student 1 showed that they could represent visuals, create mathematical equations or expressions, and write words or texts fairly well. Similarly, Low-Level Student 2 demonstrated the ability to represent visuals, create mathematical equations or expressions, and write words or texts fairly well. Based on the interview results, Low-Level Student 1 explained their approach to solving the problem as follows: "For question 1, the first thing I did was group the families into Family Set 1, Family Set 2, and Family Set 3, then create diagrams of the three sets I had formed." Meanwhile, Low-Level Student 2 explained their approach: "For question 1, the first thing I did was create Family Set 1, Family Set 2, and Family Set 3, as well as sets of fathers, mothers, and children. Then, I created diagrams of the six sets I had formed." The results showed that Low-Level Student 1 scored 60%, indicating moderate proficiency in mathematical representation skills, while Low-Level Student 2 scored 70%, which indicates high proficiency in mathematical representation skills.

Question 2: Given: T = {1,2,3,4,6} T = \ {1, 2, 3, 4, 6\} T = {1,2,3,4,6} and H = {2,4,6,8,10,12} H = \ {2, 4, 6, 8, 10, 12\}H = {2,4,6,8,10,12}. If the relationship "half of" connects TTT to HHH, determine:
a) An arrow diagram from TTT to HHH.
b) The function derived from the arrow diagram.

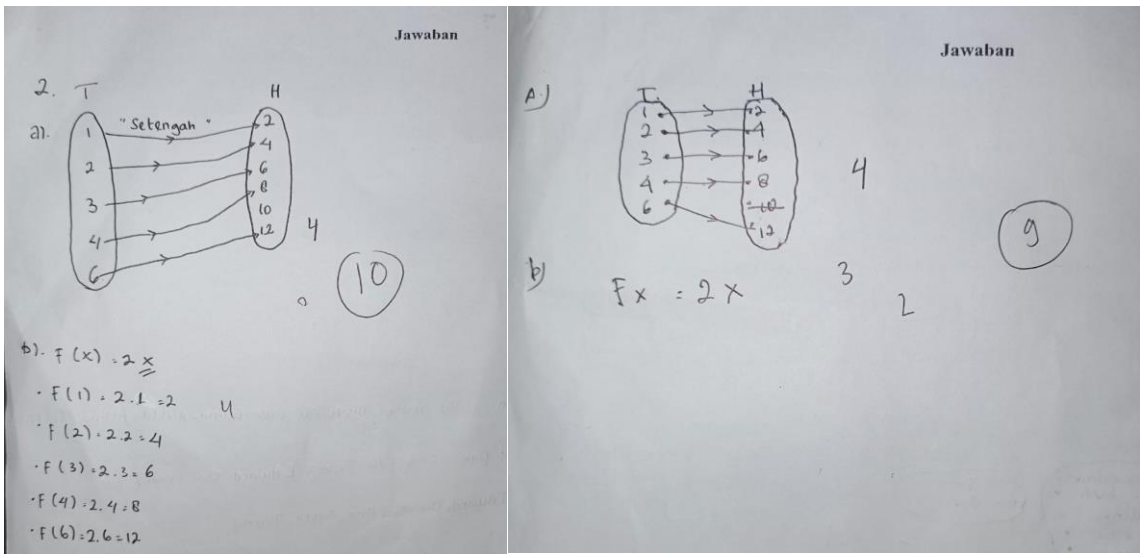

Figure 4 Answer of high student 1 and answer of high student 2

In Figure 4, the answers of High-Level Student 1 showed that they could represent visuals, create mathematical equations or expressions, and write words or texts very well. Meanwhile, High-Level Student 2 demonstrated the ability to represent visuals, create mathematical equations or expressions, and write words or texts well. Based on the interview results, High-Level Student 1 explained their approach to solving the problem as follows: "For question 2, I understood the phrase 'half of' from the problem, then drew arrows to the correct answers, and finally created the function from the arrow diagram I had made." Similarly, High-Level Student 2 explained their approach: "For question 2, I understood the phrase 'half of' from the problem, then drew arrows to the correct answers, and finally created the function from the arrow diagram I had made."

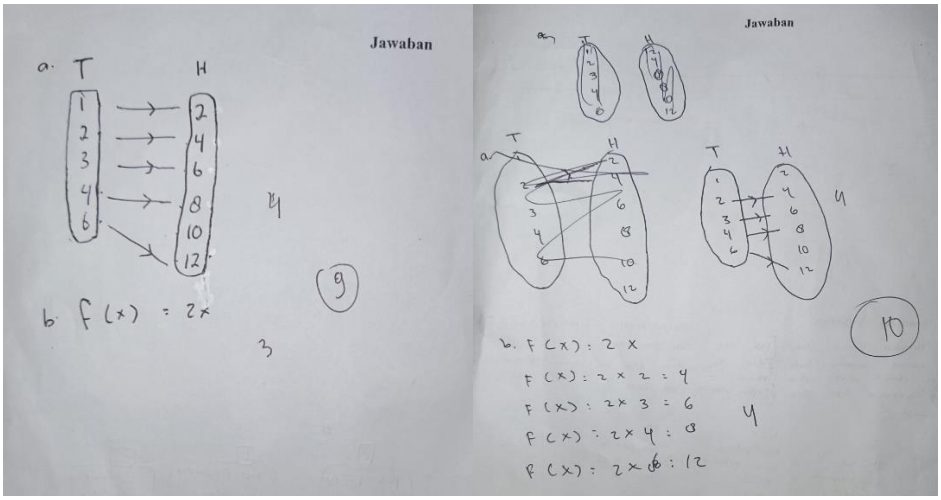

Figure 5 Answer of medium student 1 and answer of medium student 2

In Figure 5, the answers of Intermediate-Level Student 1 showed that they could represent visuals, create mathematical equations or expressions, and write words or texts well. Meanwhile, Intermediate-Level Student 2 demonstrated the ability to represent visuals, create mathematical equations or expressions, and write words or texts well. Based on the interview results, Intermediate-Level Student 1 explained their approach to solving the problem as follows: "For question 2, I understood the phrase 'half of' from the problem, then drew arrows to the correct answers, and finally created the function from the arrow diagram I had made." Similarly, Intermediate-Level Student 2 explained their approach: "For question 2, I understood the phrase 'half of' from the problem, then drew arrows to the correct answers, and finally created the function from the arrow diagram I had made." The results showed that Intermediate-Level Student 1 scored 90%, indicating mathematical representation skills in the very high category, while Intermediate-Level Student 2 scored 100%, indicating mathematical representation skills in the very high category.

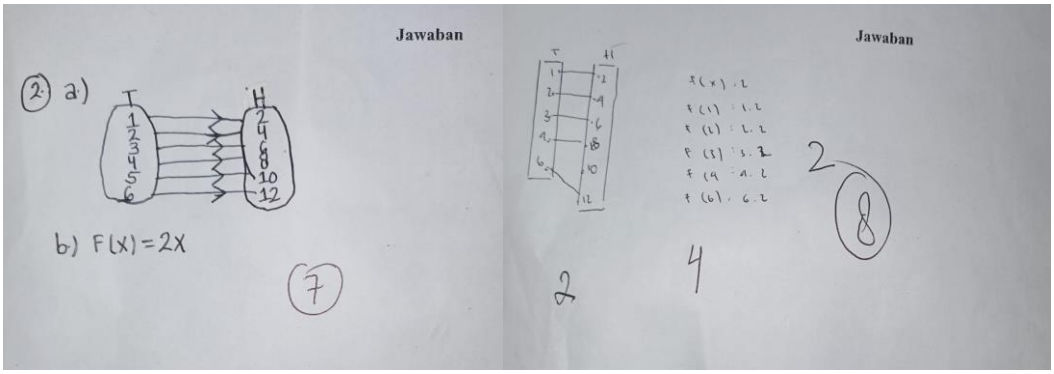

Figure 6 Answer of low student 1 and answer of low student 2

In Figure 6, the answers of Low-Level Student 1 showed that they could represent visuals, create mathematical equations or expressions, and write words or texts adequately. However, in terms of visual representation, Low-Level Student 1 made errors in constructing the diagram, as only a tiny portion of the mathematical model they created was correct. Consequently, their mathematical explanation was logical but incomplete. Meanwhile, Low-Level Student 2 demonstrated the ability to represent visuals, create mathematical equations or expressions, and write words or texts well. However, although their written explanation was

reasonable, it was incomplete because there were no variables for numbering. Thus, their mathematical explanation was also incomplete. Based on the interview results, Low-Level Student 1 explained their approach to solving the problem as follows: "For question 2, I understood the phrase 'half of' from the problem, then drew arrows to the correct answers, and finally created the function from the arrow diagram I had made." Similarly, Low-Level Student 2 explained their approach: "For question 2, I understood the phrase 'half of' from the problem, then drew arrows to the correct answers, and finally created the function from the arrow diagram I had made." The results showed that Low-Level Student 1 scored 70%, indicating mathematical representation skills in the high category, while Low-Level Student 2 scored 80%, indicating mathematical representation skills in the high category.

Based on the results of your research, here are some suggestions and recommendations for improving and developing students' mathematical representation abilities, particularly in the topic of relations and functions: Since the "Written Words or Text" indicator scored at 50%, it indicates that students may struggle with explaining their reasoning or expressing mathematical ideas clearly in written form. Teachers should provide more opportunities for students to practice writing detailed explanations for their problem-solving process. This could include exercises where students must explain their steps to solve a problem in their own words. Although the "Mathematical Equations or Expressions" indicator was rated highly (66.66%), there is still room for improvement. Teachers can emphasize the importance of translating real-world problems into mathematical expressions and provide more varied practice problems that require students to write and interpret mathematical expressions and equations.

The "Visual Representation" indicator had a high percentage (79.16%), showing that students are relatively skilled at visualizing mathematical concepts. However, teachers should continue to encourage students to use visual aids, such as diagrams, charts, and graphs, better to understand abstract mathematical concepts like relations and functions. Regularly practicing graphing functions and interpreting visual data can further strengthen their skills. To increase students' mathematical representation abilities, provide a mix of problem types, including more complex questions that combine all three indicators: visual, mathematical expressions, and written explanations. This will allow students to practice integrating all forms of representation when solving problems.

Encouraging collaborative learning can help students learn to explain and express their mathematical reasoning more clearly. Teachers could create opportunities for peer discussions where students explain their solutions to each other and give constructive feedback on the representations and explanations. To make the material more engaging, integrate real-life scenarios that require students to represent relationships and functions visually and mathematically. By linking abstract concepts to real-world applications, students are more likely to understand their relevance and improve their ability to represent mathematical ideas in multiple forms.

Teachers should regularly assess students' progress in all areas of mathematical representation, especially focusing on areas where they score lower. Periodic formative assessments that allow students to demonstrate their skills in different types of representation will help identify and address weaknesses more effectively. Based on the research findings, it may also be helpful for teachers to engage in professional development opportunities that focus on improving their ability to teach mathematical representation. This can help educators develop strategies to better guide students in expressing their mathematical reasoning in visual, symbolic, and written forms. These recommendations aim to build on students'

strengths while addressing areas where further development is needed. Students' mathematical representation abilities, particularly in relations and functions, can be further enhanced by providing more targeted instruction and practice.

4. Conclusions

Based on the research results and discussion, the mathematical representation abilities of students in classes X.1 and X.2 at SMA YLPI Pekanbaru on Relations and Functions were analyzed. Six students were studied, and their mathematical representation abilities were categorized into three levels: high, medium, and low. The "Visual Representation" indicator percentage was 79.16%, categorized as high. For the "Equations or Mathematical Expressions" indicator, the percentage was 66.66%, also categorized as high. Lastly, for the "Words or Written Text" indicator, the percentage was 50%, categorized as medium. Furthermore, the percentage scores for mathematical representation abilities by question were 80% for question 1, categorized as high, and 88.33% for question 2, categorized as very high. In conclusion, the overall score achieved by the students was 84.16%, which falls into the very high category.

Conflict of Interest

The authors declare no conflicts of interest.

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