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Analysis of the high-level thinking abilities of class VIII students on relationship and function material through the problem-based learning model

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Abstract

By using HOTS in learning, the information obtained will be documented in memory longer than using LOTS. HOTS can be trained to students through several learning models including Problem-Based Learning (PBL). PBL is a problem-based learning model and can be chosen by mathematics teachers as the best solution to develop students' low problem solving, reasoning, critical thinking and creative abilities. The junior high school (SMP) education level is an important stage in mathematics education, where students begin to learn more complex mathematical concepts. One of the essential concepts is relationship and function. The aim of this research is to describe the high-level thinking abilities of class VIII students in solving problems related to the concepts of relationships and functions after being given learning using the Problem-Based Learning model. This research uses qualitative research methods with a descriptive approach. The research subjects were class VIII students who had studied relationship and function material with PBL. Data collection techniques were carried out by giving written tests at the level of analyzing, evaluating and creating based on Bloom's taxonomy and interviews. The research results show that not all stages of the high-level thinking process appear simultaneously in problem solving carried out by students for each indicator of high-level thinking.

Keywords: Analysis; High Order Thinking Skills; Problem-Based Learning; Qualitative Research Relationships and Functions.

1. Introduction

In 21st century education, the goal of learning is to encourage students to become active learners, where they can search, discover, construct, process and use their knowledge independently. This aims to create meaningful and relevant learning for students.

In Indonesia, the education system has adopted this series of active student actions through the implementation of the 2013 Curriculum with a scientific approach. Students are required to be able to develop high-level thinking skills through the application of a scientific approach to learning at school (Fernanda et al., 2019).

The scientific approach to learning involves the 5M procedures, namely observing, asking, trying, reasoning and communicating. In this context, students are encouraged to observe the surrounding environment, ask questions about phenomena they encounter, try to explore and test hypotheses, carry out reasoning and problem solving processes, and communicate and collaborate with classmates in conveying the results of their thoughts.

With a scientific approach, learning does not only focus on solving predetermined problems, but also encourages students to formulate problems that are relevant to the context of everyday life. The main aim is to arouse students'

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motivation to seek information from various existing sources, through observation or direct observation, so that they can develop critical and creative thinking skills.

In a scientific approach, students are not only passive recipients of information, but also become main actors in the learning process. They are encouraged to develop higher-order thinking skills, such as connecting the knowledge they have with real situations, identifying problems that need to be solved, and formulating effective problem-solving strategies.

A person must master various abilities and skills, including the ability to think. Thinking ability is a reflective, critical and creative reasoning activity that is oriented towards an intellectual process that involves forming concepts (conceptualizing), application, analysis, assessing information collected (synthesis) or produced through observation, experience, reflection, communication as a basis for a belief (trust) and action (Nurhayati & Angraeni, 2017).

There are two types of thinking abilities, namely lower-order thinking skills (LOTS) and higher-order thinking skills (HOTS) (Ramadhanti et al., 2022; Selegi, 2019) (Ramadhanti et al., 2022). HOTS is a capability that must be possessed in the 21st century (Wijaya & Astuti, 2022; Zulfah et al., 2022).

One aspect of HOTS is students' critical and creative mathematical thinking abilities, mathematical problem solving, and mathematical reasoning. HOTS is more than just the ability to remember, know, or repeat, but rather problem solving, creative thinking, argumentativeness, and reasoning decision making.

Based on Bloom's taxonomy, indicators that can be used to measure HOTS are: analyzing, evaluating, and creating (Zulfah et al., 2022). HOTS is the ability to retrieve new information from related information in memory and then rearrange and expand the information to find alternative answers in making decisions, innovating, and being able to create something (Sanuaka et al., 2022).

By using HOTS in learning, the information obtained will be documented in memory longer than using LOTS. The growth of HOTS in learning is marked by: cooperation or collaboration between teachers, students, and across sciences; encourage curiosity, exploration, and inquiry; learning relies on students; failure is seen as a learning opportunity; recognition of effort, not just achievement; and learn contextually in real life (Zulfah et al., 2022).

There are facts that show that student HOTS in Indonesia is still relatively low. This can be seen from the results of international studies such as the International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA), which show that the achievements of Indonesian students are not yet satisfactory (Ramadhanti et al., 2022).

To build a high-level thinking process (HOTS), innovation is needed in the Learning either in the form of methods, assessment or Learning media (S. et al., 2018).This means that it is necessary to apply an appropriate learning model that can help students improve their HOTS abilities.

By implementing a synchronous learning model, students can be facilitated to develop higher order thinking skills. This learning model must allow students to interact and place students as the center of learning, and the use of problems that are unstructured and have many solutions can be an effective way to stimulate students to get used to solving problems that require high-level thinking abilities.

In this context, students are given the opportunity to think critically, analyze, find solutions, and collaborate with fellow students in solving complex problems. By focusing on unstructured problems, students are faced with situations where they must apply various problem-solving strategies, engage in creative thinking, and make the right decisions.

By implementing this learning model, it is hoped that students will become accustomed to and trained in facing challenges that require high-level thinking abilities. By gaining experience in working on questions classified as HOTS, students will improve their abilities in solving problems, formulating arguments, thinking critically, and producing creative solutions.

Therefore, it is necessary to implement appropriate and appropriate learning models to help Indonesian students improve their HOTS abilities. A learning model that emphasizes the role of students as the center of learning, uses problems that are unstructured and have many solutions, can be an effective way to trigger students to become accustomed and skilled in working on problems that require HOTS abilities.

Among the learning models that can be applied to increase HOTS in students is Problem-Based Learning (PBL) (Pia et al., 2021; Sanuaka et al., 2022; Wijaya & Astuti, 2022). HOTS can be trained to students through several learning models, including PBL.

PBL is a problem-based learning model and can be chosen by mathematics teachers as the best solution to develop students' low problem solving, reasoning, critical thinking and creative abilities (Ramadhanti et al., 2022; Ramadhany & Prihatnani, 2020). PBL requires a thinking process to find relationships between principles and concepts obtained from learning to solve problems so that students will be trained to think and get used to solving problems, especially those based on HOTS during the problem solving process, besides that it can increase self-confidence and curiosity. .

PBL can explore students' potential, build a learning process that is full of meaning for students because it relies on students where the teacher acts as a facilitator (Ramadhanti et al., 2022). PBL employs constructivist principles to foster application of prior knowledge, collaborative learning, and active engagement (Seibert et al., 2021). Thus, PBL is a good technique for better understanding lesson content, increasing learning activities, and transferring the knowledge received by students to be able to understand problems in real life (Ramadhany & Prihatnani, 2020).

The junior high school education level is an important stage in mathematics education, where students begin to learn more complex mathematical concepts. One of the essential concepts is relationship and function.

There are many problems in everyday life that are related to relationship and function material. Some of them are time conversion from hours to minutes, currency exchange rates, shopping prices for goods, blood donation and so on (Angraini et al., 2022). However, experience shows that many students at this level face difficulties in understanding and mastering these concepts properly.

The concepts of relations and functions are an important foundation in mathematics, and a good understanding of these concepts has a significant impact on the understanding of higher mathematical concepts. This concept also has wide applications in various fields of knowledge, including science, engineering, and economics.

Although there are many studies that examine the understanding of mathematical concepts or the use of PBL models separately, there is still a lack of research that focuses on the impact of using PBL models to improve junior high school students' high-level thinking abilities in solving problems related to relationships and functions.

This research has great potential to contribute to improving the quality of mathematics education at the junior high school level. The research results can provide valuable insights for teachers and education stakeholders to design learning that is more effective and relevant to the needs of students at this level.

By considering the background of the problem above, the researcher conducted research with the title "Analysis of Class VIII Students' High Level Thinking Abilities on Relationships and Functions Material Through the Problem-Based Learning Model". It is hoped that this research will provide valuable insight into how certain learning models can influence students' ability to understand important mathematical concepts and strengthen their higher-order thinking abilities.

2. Materials and methods

The research objective presents the results to be achieved after the research is completed (Lestari & Yudhanegara, 2017). The aim to be achieved in this research is to describe the high-level thinking abilities of class VIII students in solving problems related to the concepts of relations and functions after being given learning using the PBL model. What is described in this research is students' high-level thinking abilities in solving relationship and function problems based on Bloom's taxonomy thinking levels: analyzing (C4), evaluating (C5), and creating (C6).

The research was carried out at MTsN 1 Pandeglang with the consideration that it is one of the best schools in Pandeglang Regency. Determining the class for this research was through initial observations by interviewing several mathematics subject teachers at MTsN 1 Pandeglang. The selected class is class VIII-E which has studied relations and functions using the Problem-Based Learning model. The class was selected based on the category of students who had high learning outcomes in several subjects or were active and accomplished among other class VIII students. The time of the research was carried out in the even semester of the 2023/2024 academic year according to the mathematics lesson hours in the class of the students who were the research subjects.

This research uses qualitative research methods with a descriptive approach. A descriptive approach is research that attempts to describe or describe the data that has been collected as it is without intending to make generalizations (Lestari & Yudhanegara, 2017).

- The steps for this research are as follows:
- The teacher provides learning material on relations and functions using the PBL model.
- Collect written test scores.
- Determine the average score of the written test.
- The selection of research subjects was based on the results of grouping high-level thinking abilities.
- Researchers conduct interviews according to the selected subjects.
- Draw a conclusion.

Once the data has been collected, the data is classified into two groups, namely quantitative data in the form of numbers and qualitative data expressed in words or symbols (Arikunto, 2019). Qualitative data in the form of words is temporarily set aside, because it will be very useful to accompany and complete the picture obtained from quantitative data analysis.

The techniques used in collecting data in this research are:

2.1. Written test

The written test aims to determine students' high-level thinking abilities in solving high-level thinking ability test questions on relationship and function material after students are given learning using the PBL model and as reference material for selecting students to become research subjects. In its implementation, students are given a test sheet containing high-level thinking ability test questions on relationship and function material to be worked on individually in the form of descriptions totaling five questions consisting of the levels of analyzing, evaluating and creating.

Making this instrument begins with creating an instrument grid that includes indicators of high-level thinking abilities. After compiling the grid, then proceed with compiling questions and answer keys that refer to the scoring guidelines.

In the process of obtaining a valid instrument, the researcher validated the instrument to obtain several inputs regarding the language, content and form of questions. Researchers have discussed with expert validators so that the instrument fits the research objectives.

The techniques used to test instruments in research are validity tests, reliability tests, difficulty indexes, and distinguishing power. The theoretical validity test in this research was carried out by consulting the instrument with three experts, namely supervisor 1, supervisor 2, and mathematics teacher at MTsN 1 Pandeglang. The theoretical validity results from supervisor 1, supervisor 2, and mathematics teacher at MTsN 1 Pandeglang are generally good and can be continued for research classes. Meanwhile, empirical validity is validity obtained through empirical observations or observations and reviewed based on certain criteria (Lestari & Yudhanegara, 2017). The criteria for determining the high or low validity of research instruments are expressed by coefficients obtained through calculations.

In (Lestari & Yudhanegara, 2017) it is stated that the validity test for each question uses the product moment correlation coefficient formula as follows:

$$r_{xy} = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{(N\sum X^2 - (\sum X)^2)(N\sum Y^2 - (\sum Y)^2)}}$$

Information:

X = question item score or question item score
Y = total score
N = number of respondents
r_{xy}= correlation coefficient between variable X and variable Y, two variables that are correlated

The evaluation tool or instrument is declared valid if rcount ≥ rtable. In (Lestari & Yudhanegara, 2017) it is stated that the benchmark for interpreting the degree of validity of the instrument is determined based on the criteria according to Guilford (195 6) in Table 1 below:

Table 1 Instrument Validity Correlation Coefficient Criteria

Correlation coefficient	Correlation	Interpretation of Validity
$0.90 \leq \leq 1.00 r_{xy}$	Very high	Very precise/excellent
$0.70 \leq < 0.90 r_{xy}$	Tall	Correct/good
$0.40 \leq < 0.70 r_{xy}$	Currently	Appropriate enough/good enough
$0.20 \leq < 0.40 r_{xy}$	Low	Inappropriate/bad
$r_{xy} < 0.20$	Very low	Very inappropriate/very bad

To obtain results from empirical validity, the test instrument was given to the trial class, in this case class VIII_D with the following results: $r_{count} > r_{table}$ for the five questions given, so it can be determined that the five test questions are valid.

The reliability of an instrument is the constancy or consistency of the instrument, when given to the same subject even by different people, different times, or different places, it will give the same or relatively similar results (Lestari & Yudhanegara, 2017). The high or low degree of reliability of an instrument is determined by the correlation coefficient value between the test items or statement/question items in the instrument which is denoted by r.

In (Lestari & Yudhanegara, 2017), the reliability test of the test instrument is carried out using the following Cronbach's Alpha formula:

$$r = \left(\frac{n}{n-1}\right)\left(1 - \frac{\sum s_i^2}{s_t^2}\right)$$

Information:

r = reliability coefficient
n = number of questions
s_i^2 = variance of the score of the ith item
s_t^2 = total score variance

The evaluation tool or instrument is declared valid if rcount ≥ rtable. In (Lestari & Yudhanegara, 2017), it is stated that the benchmark for interpreting the degree of reliability of the instrument is determined based on the criteria according to Guilford (1956) in Table 2 below:

Table 2 Instrument Reliability Correlation Coefficient Criteria

Correlation coefficient	Correlation	Reliability Interpretation
$0.90 \leq \leq 1.00 r$	Very high	Very regular/excellent
$0.70 \leq < 0.90 r$	Tall	Still/good
$0.40 \leq < 0.70 r$	Currently	Fair enough/good enough
$0.20 \leq < 0.40 r$	Low	Not constant/bad
$r < 0.20$	Very low	Very unstable/very bad

From the results of testing the test instrument for class VIII-D, it was found that the Cronbach's Alpha value was > 0.70, this means that the test instrument was reliable.

The difficulty index is a number that states the degree of difficulty of a question item (Lestari & Yudhanegara, 2017). If the questions are too difficult or too easy, then the distinguishing power of the questions will be poor because both upper group students and lower group students will be able to answer the question correctly or not be able to answer

the question correctly. As a result, these questions will not be able to differentiate students based on their abilities. This means that an item is said to have a good difficulty index if the item is neither too easy nor too difficult. In (Lestari & Yudhanegara, 2017), to determine the difficulty index of the test instrument, the following formula is used:

$$IK = \frac{\overline{X}}{SMI}$$

Information:

IK = item difficulty index
$\overline{X}$= the average score of students' answers to a question item
SMI = ideal maximum score, namely the maximum score that students will get if they answer the questions correctly

The difficulty index of an item is interpretedin Table 3 following:

Table 3 Instrument Difficulty Index Criteria

IK	**Interpretation of the Difficulty Index**
IK = 0.00	Too difficult
0.00 < IK≤ 0.30	Hard
0.30 < IK≤ 0.70	Currently
0.70 < IK≤ 1.00	Easy
IK = 1.00	Too easy

From the results of testing the test instrument, it was found that for the five questions given the interpretation of the difficulty index was difficult.

The discriminating power of a question item states how far the ability of that question item differentiates between students who can answer the question correctly and students who cannot answer the question correctly (Lestari & Yudhanegara, 2017). In other words, the differentiating power of a question item is the ability of the question item to differentiate between students who have high ability, medium ability, and students who have low ability.

To determine the discriminating power index of the test instrument, the following formula is used:

$$DP = \frac{\overline{X}_A - \overline{X}_B}{SMI}$$

Information:

DP = index of differentiating power of test items
$\overline{X}_A$= average score of upper group students' answers
$\overline{X}_B$= average score of lower group students' answers
SMI = ideal maximum score, namely the maximum score that students will get if they answer the questions correctly

The criteria used to interpret the differentiation index are presented in Table 4 below:

Table 4 Instrument Discrimination Power Index Criteria

Mark	Interpretation of Discriminating Power
0.70 < ≤ 1.00DP	Too difficult
0.40 < ≤ 0.70DP	Hard
0.20 < ≤ 0.40DP	Currently
0.00 < ≤ 0.20DP	Easy
DP≤ 0.00	Too easy

From the results of testing the test instrument, it was found that questions number 1, 3, 4, and 5 interpreted the instrument's differentiating power as easy criteria, while for question number 2 it was moderate.

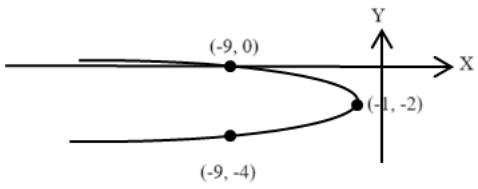
The test instrument consists of five questions in the form of descriptions with the test distribution as presented in Table 5 below:

Table 5 Distribution of Higher Order Thinking Ability Tests

No. Question	Levels of Thinking	Aspect	Number of Questions
1	Analyze	Differentiate	1
2		Connect	1
3	Evaluate	Inspect	1
4		Criticize	1
5	Create	Produce	1

Meanwhile, the high-level thinking ability test instrument (HOTS) on relations and functions material which will be validated by two supervising lecturers from the Mathematics Education Masters Study Program at Sultan Ageng Tirtayasa University and one Mathematics teacher at MTsN 1 Pandeglang is presented in Table 6.

Table 6 Indicators and Test Questions for Higher Level Thinking Abilities

No. Question	Indicators of Higher Level Thinking Ability	Higher Order Thinking Ability Test Questions
1	Able to recognize as well distinguish causal factors from the consequences of a problem complicated	Look at the following graph.  By analyzing the following four statements, determine whether each of the following statements is true or false! Give the reason. Graphs cannot show function presentation. Every point in X has a relation in Y. The graph shows the function presentation from Y to X. The graph shows the relationship from X to Y which is not a function
2	Analyze existing data and divide data into parts	It is known that set A consists of 4 letters, namely p, q, r, and s, and set B consists of 4 numbers, namely 1, 2, 3, and 4. From these two sets a one-to-

	the smaller one for knowing the pattern or relationship	one correspondence will be arranged. If the letter s and the number 4 are always paired, how many one-to-one correspondences can be formed?
3	Provide an assessment towards a solution or ideas withusing elements there to be sure assess its effectiveness	Given a function with the function formula g(x) = x2 + 3x + 2. By checking the value of the function, determine all x values that satisfy g(x) = 6.
4	Make a hypothesis, criticize and perform a research	Given a function with the function formula f(x) = 3x2 - 12x + 7. By evaluating the function value, determine the minimum or maximum value of this function and give a reason why you chose it?
5	Create a perspective or an idea for something problem	Known as a function formula f(x) = x2 – 4x + 3. Make a graph of the function by analyzing the properties of the graph, and provide an explanation of your process in creating the graph.

2.2. Interview

Data collection through interviews was carried out by providing a series of questions asked directly by the researcher to the research subjects (Lestari & Yudhanegara, 2017). In (Sugiyono, 2019) According to Esterberg (2002), there are 3 types of interviews, namely: structured interviews, semi-structured interviews and unstructured interviews.

In this research, the type of interview used is a semi-structured interview, where the implementation is freer compared to a structured interview with the aim of allowing the subject to express his opinions and ideas regarding solving problems that have been created in the written test by asking several questions to the research subject (Farib et al., 2019).

The indicators of high-level thinking abilities used in this research are in accordance with Bloom's Taxonomy which was discovered in research by (Aminah & Rohayati, 2021), namely analyzing (analyzing, evaluating, and creating as in Table 7 below.

Table 7 Indicators of Higher Level Thinking Ability

Higher Order Thinking Ability	**Indicator**
Analyzing	Analyze existing data and divide the data into smaller parts to find patterns or relationships. Able to recognize and differentiate the causal factors from the consequences of a complex problem. Identify/formulate questions.
Evaluating	Providing an assessment of a solution or idea using existing elements to ensure its effectiveness. Make hypotheses, criticize and conduct research. Accept or reject a question based on existing elements.
Creating	Create a perspective or idea about a problem. Design an action to solve the problem. Organizing criteria into a new structure that has never existed before.

The interview process in this research was carried out individually with students in turn. So it is easier for researchers to get conclusions about students' high-level thinking abilities in working on relationship and function questions after being given learning using the PBL model.

The steps for processing interview data according to Miles and Huberman (1984) are:

- Transcribe all interview excerpts.
- Determine the main idea or essence of the source's presentation.
- Transfer the main idea to conceptual language.
- Categorizing the same conceptual language aims to make thematization easier.
- The same categories, narrowed down again into the same themes.
- Group the main findings, linked to the research questions.

After the data has been collected, the next step is to analyze the data (Hendriana & Soemarmo, 2014). In general, data analysis includes 3 steps, namely: preparation, tabulation, and application of data in accordance with the research approach (Arikunto, 2019).

Data analysis in qualitative research is carried out before entering the field, while in the field, and after finishing in the field. Prior analysis in the field is carried out on data from preliminary studies, or secondary data, which will be used to determine the focus of the research. Meanwhile, data analysis in the field is carried out during data collection and after data collection has been completed within a certain period.

The data analysis technique used in this research is the qualitative data analysis technique proposed by Miles and Huberman (1984), which consists of 3 activity streams (Rahman & Sutarni, 2022), that is:

2.3. Data Reduction Stage

Reducing data means summarizing, selecting the main things, focusing on the important things, looking for themes and patterns (Sugiyono, 2019). In this way, the reduced data will provide a clearer picture, making it easier for researchers to collect further data and search for it if necessary.

In this research, data reduction activities were carried out, namely the researcher analyzed the results of students' answers in solving high-level thinking ability test questions related to the concepts of relationships and functions, analyzed the results of subject interviews regarding the completion of high-level thinking ability tests, compared the results of high-level thinking ability tests. and interviewing subjects with other sources as well as compiling interview transcripts so that it makes it easier for researchers when analyzing data.

In this research, student answer score data in solving high-level thinking ability questions will be analyzed using descriptive statistics. Descriptive statistics are statistics that are used to analyze data by describing or illustrating the data that has been collected as it is without the intention of providing generally accepted conclusions or generalizations (Sugiyono, 2019).

The steps for analyzing the results of students' answers in solving high-level thinking ability test questions in this research are:

2.4. Convert scores to grades.

Table 8 Categories of Students' Higher Level Thinking Ability

Mark	Category
81 – 100	Very good
61 – 80	Good
41 – 60	Enough
21 – 40	Not enough
0 – 20	Very less

Categorizing students' higher order thinking ability scores referring to the International Center for the Assessment of Higher Order Thinking (Prasetyani et al., 2016) according to Table 8 below:

Determine the percentage of students' ability to solve high-level thinking ability questions based on each indicator.

2.5. Data Presentation Stage

After the data has been reduced, the next step is to present the data in the form of brief descriptions, charts, relationships between categories, flowcharts and the like. By presenting data, it will be easier to understand what happened, plan further work based on what has been understood.

At the data presentation stage, the data presented is in the form of high-level thinking ability test results and data from interviews with subjects. The results of the high-level thinking ability test are described to describe each student's abilities and understanding. All data will be used by researchers to make it easier to determine whether the indicators for each aspect to be observed are fulfilled. Data classification is presented based on subject criteria.

2.6. Conclusion Drawing and Verification Stage

The initial conclusions put forward are still temporary, and will change if strong supporting evidence is not found at the next stage of data collection. When drawing conclusions, researchers draw from the data that has been analyzed and verify the conclusions.

The data is aimed at building a formal theory about students' high-level thinking abilities in solving problems related to the concepts of relationships and functions after being given learning using the Problem-Based Learning model, so that the description of students' high-level thinking abilities is explained clearly.

In this research, data analysis was carried out during and after the data collection process. This is done so that the data is arranged systematically and easy to describe.

Data are all facts and figures that can be used as material to compile information, while information is the result of data processing that is used for a purpose (Arikunto, 2019). Based on the problem to be studied, the data obtained in this research are:

- The results of students' tests in solving mathematics problems given by researchers were to determine students' high-level thinking abilities in solving problems related to the concepts of relations and functions after being given learning using the Problem-Based Learning model.
- The results of interviews between researchers and students as interview subjects were to determine students' high-level thinking abilities in solving problems related to the concepts of relationships and functions after being given learning using the Problem-Based Learning model.
- Documentation results were obtained during mathematics learning activities, when working on test questions, and during interviews.

The data source in research is the subject from which the data can be obtained (Arikunto, 2019). In this research, the data sources obtained were primary data and secondary data. Primary data sources are people who respond or answer researchers' questions, both written and verbal questions. The primary data source in this research was class VIII students at MTsN 1 Pandeglang. The data obtained from students are the results of tests and interviews. Secondary data sources are anything that can provide data or information that does not come from humans. Secondary data sources in this research are documentation of the results of learning activities, when working on questions, and during interviews. The data obtained is descriptive based on the results of tests and interviews conducted.

Data validity is carried out to prove whether the research carried out is truly scientific research and also to test the data obtained. Data validity tests in qualitative research include tests of credibility (internal validity), transferability (external validity), dependability (reliability), and confirmability (objectivity) (Sugiyono, 2019).

- **Credibility**

Testing data credibility or trust in data resulting from qualitative research is carried out, among other things, by extending observations, increasing persistence, triangulation, analyzing negative cases, using reference materials, and conducting Member Hacks.

- **Dependability**

In qualitative research, dependability testing is carried out by auditing the entire research process. This is done by an independent auditor or supervisor to audit all of the researcher's activities in conducting research.

- **Confirmability**

In qualitative research, the confirmability test is similar to the dependability test so that the tests can be carried out simultaneously. Testing confirmability means testing research results, linked to the process carried out. If the research results are a function of the research process carried out, then the research has met confirmability standards.

In this study, confirmability was tested by presenting research results obtained from the process of testing the high level thinking abilities of class VIII students on relationship and function material after being given learning using the PBL model, interviews, data analysis, to the validity of the data so that a degree of trustworthiness was achieved that could be agreed upon. many people.

3. Results and discussion

This research process begins with the preparation stage, followed by the data collection stage. The preparation stage began with obtaining a research permit at the madrasah in January 2024. Next, the researcher communicated directly with the head of the madrasah to explain the purpose of this research. After obtaining permission from the head of the madrasah, the researcher discussed with the class VIII mathematics teacher to determine the class that could be used as a research subject. The teacher explained that Class VIII-E was the right choice because the students belonged to a class that was superior compared to other classes. This is an added value for researchers in carrying out research in this class.

The next stage, namely the data collection stage, begins with providing material to be tested, namely about Relations and Functions through a problem-based learning (PBL) model. Then give a written test followed by an interview process. The written test is carried out offline in the form of essay questions according to the mathematics lesson schedule, namely on March 18 2024 at 08.00 – 09.00 WIB.

In research activities, researchers plan to take research subjects from a class consisting of 31 people. However, during the research process, only 27 people attended, consisting of 6 male students and 21 female students, 4 other students did not attend due to illness. The results of the higher order thinking ability test in the research class are given in Table 9 below.

Table 9 List of Higher Order Thinking Ability Test Scores for Research Class

NO	STUDENT CODE	SCORE					TOTAL SCORE	MARK	CATEGORY
		1	2	3	4	5			
1	E-1	0.5	1	1	1	1	4.5	23	NOT ENOUGH
2	E-2	1.5	1.5	1	1	4.5	9.5	48	ENOUGH
3	E-3	1.5	1	0.5	2	4	9	45	ENOUGH
4	E-4	1.5	2.5	2	1	4	11	55	ENOUGH
5	E-5	1.5	3	2	1	3	10.5	53	ENOUGH
6	E-7	1.5	3	2	1	4	11.5	58	ENOUGH
7	E-8	1.5	1	2.5	2	6	13	65	GOOD
8	E-9	1.5	2.5	2	2	3	11	55	ENOUGH
9	E-10	1.5	2.5	2	2	2	10	50	ENOUGH
10	E-11	1	1.5	2	1	2	7.5	38	NOT ENOUGH
11	E-12	1	1.5	2	1.5	4.5	10.5	53	ENOUGH

12	E-13	3	1.5	2	3	6	15.5	78	GOOD
13	E-14	0.25	3	2	2	3	10.25	51	ENOUGH
14	E-15	1.5	3	2	1	1.5	9	45	ENOUGH
15	E-16	2.25	1.5	4	2	4.5	14.25	71	GOOD
16	E-18	1	1.5	2	2	2	8.5	43	ENOUGH
17	E-20	1.5	1.5	4	2	5	14	70	GOOD
18	E-22	0.5	1.5	0.5	1	2	5.5	28	NOT ENOUGH
19	E-23	1.5	3	2	2	3	11.5	58	ENOUGH
20	E-24	1.5	2.5	2	1	3	10	50	ENOUGH
21	E-25	2.25	2	3	2	2	11.25	56	ENOUGH
22	E-26	0.75	1.5	1	1	2	6.25	31	NOT ENOUGH
23	E-27	0.5	1	2	1	1	5.5	28	NOT ENOUGH
24	E-28	1.5	3	2	1	2	9.5	48	ENOUGH
25	E-29	1.5	1.5	3	2	4	12	60	ENOUGH
26	E-30	2.25	1	2	1	3	9.25	46	ENOUGH
27	E-31	1.5	3	2	1	2	9.5	48	ENOUGH

In Table 9 above, it is known that 14.81% of students are in the good category, 66.67% of students are in the fair category, and 18.52% of students are in the poor category.

The main research subjects selected to be interviewed were 5 students whose test results were categorized as good, sufficient and poor, based on the following criteria:

1. The subject agreed to be interviewed.
2. Subjects agreed to participate in research data collection.
3. The subject achieves the highest score on questions number 1, 2, 3, 4, or 5.

Based on these three criteria, five main research subjects were selected, namely: E-13 and E-16 for students in the good category because E-13 got the highest score on question number 5 and E-16 got the highest score on question number 3. Meanwhile for in the sufficient category, E-25 and E-7 were selected as the main research subjects because E-25 got the highest score on question number 1 and E-7 got the highest score on question number 2. Furthermore, for the poor category, E-11 was chosen as the main research subject, because it got the highest score in the poor category.

E-13 is a 14 year old male student and his test results are categorized as good because based on Table 8 for scores 61 – 80 are in the good category. E-16 is a 14 year old female student and her test results are categorized as good because based on Table 8 for a score of 61 – 80 in the good category. E-25 is a 14 year old female student and her test results are categorized as sufficient because based on Table 8 for scores 41 – 60 the category is sufficient. E-7 is a 14 year old female student and her test results are categorized as sufficient because based on Table 8 for scores 41 – 60 the category is sufficient. And E-11 is a 13 year old female student and her test results are categorized as poor because based on Table 8 for scores 21 – 40 the category is poor.

To facilitate understanding in the discussion in this section, the data will be presented sequentially starting from students' abilities in analyzing (C4), evaluating (C5), and creating (C6). This data was taken from the results of written tests and the interview process. Each test consists of two analyzing questions (C4), two evaluating questions (C5), and one creating question (C6). The results of completing the test are analyzed using Table 7.

After analyzing the results of the written test, an interview process was carried out with the selected subjects to understand in detail the students' thinking processes and ascertain whether the students were working on the questions based on their own ideas or the results of their own thinking or not. Researchers use recordings to record interview

results carefully, then create interview transcripts using an online application. Interviews were conducted face to face on March 25 - 27 2024 from 09.00 to 11.00 in the MTsN 1 Pandeglang computer laboratory.

Based on the results of the analysis of students' high-level thinking abilities in solving relationship and function problems, it appears that the five selected subjects were able to use their abilities, although not always optimally. Some students did not manage to answer the questions completely correctly, which shows the difference in ability between each subject. Understanding the questions greatly influences student work results, where students who can understand the questions well are able to solve them more effectively.

The high-level thinking abilities (HOTS) of the five subjects in solving relationship and function problems can be identified from each level based on Bloom's taxonomy revised by Anderson and Krathwohl (2001) which is a good basis for analyzing high-level thinking abilities (HOTS). This taxonomy divides cognitive skills into six levels, from the most basic to the most complex: remembering, understanding, applying, analyzing, evaluating, and creating (Aminah & Rohayati, 2021). For HOTS, we focus on the three highest levels, namely analyzing, evaluating, and creating which are explained in the following section.

In solving question number 1 at the level of analyzing differentiating aspects, good category subjects (E-13) are able to analyze existing data and divide the data into smaller parts to find out patterns or relationships, are able to recognize and differentiate the causal factors from the consequences of a problem. complex, and able to identify/formulate questions. Meanwhile, subjects in the sufficient category (E-25) are able to analyze existing data and divide the data into smaller parts to find out patterns or relationships, are not yet able to recognize and differentiate causal factors from the effects of a complex problem, and are able to identify/formulate questions. Furthermore, subjects in the poor category (E-11) have not been able to analyze existing data and divide the data into smaller parts to find out patterns or relationships, have not been able to recognize and differentiate causal factors from the effects of a complex problem, and have been able to identify/formulate questions. .

In solving question number 2 at the level of analyzing connecting aspects, good category subjects (E-16) are able to analyze existing data and divide the data into smaller parts to find out patterns or relationships, are able to recognize and differentiate the causal factors from the consequences of a problem. complex, and able to identify/formulate questions. Meanwhile, subjects in the sufficient category (E-7) are able to analyze existing data and divide the data into smaller parts to find out patterns or relationships, are able to recognize and differentiate causal factors from the effects of a complex problem, and are able to identify/formulate questions. Furthermore, subjects in the poor category (E-11) have not been able to analyze existing data and divide the data into smaller parts to find out patterns or relationships, have not been able to recognize and differentiate causal factors from the effects of a complex problem, and have been able to identify/formulate questions.

Based on the explanation of high-level thinking abilities in the analyzing stage, in the three categories only subjects in the good category can use their thinking abilities in analyzing the distinguishing and connecting aspects, this is because subjects in the good category have met the analytical ability indicators. This is in accordance with the results of research conducted by Siti Aminah and Ade Rohayati in (Aminah & Rohayati, 2021),

In solving question number 3 at the level of evaluating the checking aspect, good category subjects (E-16) are able to provide an assessment of a solution or idea using existing elements to ensure its effectiveness value, are able to make hypotheses, criticize and carry out research, and able to accept or reject a question based on existing elements. Meanwhile, subjects in the sufficient category (E-25) have not been able to provide an assessment of a solution or idea using existing elements to ensure its effectiveness value, have been able to make hypotheses, criticize and carry out research, and have not been able to accept or reject a question based on the elements. existing elements. Furthermore, subjects in the poor category (E-11) have not been able to provide an assessment of a solution or idea using existing elements to ensure its effectiveness value, have been able to make hypotheses, criticize and carry out research, and have not been able to accept or reject a question based on the elements. existing elements.

In solving question number 4 at the level of evaluating critical aspects, subjects in the good category (E-13) have not been able to provide an assessment of a solution or idea using existing elements to ensure its effectiveness value, are able to make hypotheses, criticize and carry out research, and not being able to accept or reject a question based on existing elements. Meanwhile, subjects in the sufficient category (E-25) have not been able to provide an assessment of a solution or idea using existing elements to ensure its effectiveness value, have been able to make hypotheses, criticize and carry out research, and have not been able to accept or reject a question based on the elements. existing elements. Furthermore, subjects in the poor category (E-11) have not been able to provide an assessment of a solution or idea

using existing elements to ensure its effectiveness value, have been able to make hypotheses, criticize and carry out research, and have not been able to accept or reject a question based on the elements. existing elements.

Based on the explanation of high-level thinking abilities in the evaluating stage, in the three categories only subjects in the good category, namely subject E-16, can use their thinking abilities in evaluating the examining aspect, this is because subjects in the good category (E-16) have met the ability indicators. evaluate. This is in accordance with the results of research conducted by Siti Aminah and Ade Rohayati in (Aminah & Rohayati, 2021),

In solving question number 5 at the level of creating the productive aspect, subjects in the good category (E-13) are able to create a perspective or idea about a problem, are able to design an action to solve the problem, and are able to organize a criterion into a new structure that has never existed before. . Meanwhile, subjects in the sufficient category (E-7) are able to create a perspective or idea about a problem, are not yet able to design an action to solve the problem, and are not yet able to organize criteria into a new structure that has never existed. Furthermore, subjects in the poor category (E-11) have not been able to create a perspective or idea about a problem, have not been able to design an action to solve the problem, and have not been able to organize criteria into a new structure that has never existed.

Based on the explanation of high-level thinking abilities in the creation stage, in the three categories only subjects in the good category, namely subject E-13, can use their thinking abilities in creating in the production aspect, this is because subjects in the good category (E-13) have met the ability indicators. create. This is in accordance with the results of research conducted by Siti Aminah and Ade Rohayati in (Aminah & Rohayati, 2021),

This means that the indicators of high-level thinking ability at the analyzing level are met in the good category, while those in the adequate and poor categories are not met. Indicators of high-level thinking abilities at the evaluating level were not met in the good, sufficient and poor categories. Indicators of high-level thinking abilities at the creating level were met in the good category, while those in the adequate and poor categories were not met.

In addition, based on the distribution of high-level thinking ability tests in table 5 and the test results from the five main research subjects, a description of students' high-level thinking abilities in analyzing, evaluating and creating for students in the categories of good, sufficient and poor can be shown in the table 10, 11, and 12 below.

Table 10 Description of Higher Order Thinking Abilities at the Analyzing, Evaluating and Creating Levels for the Good Category

Levels of Thinking	**Aspect**	**Subject E-13**	**Subject E-16**	**Similarities between Subjects E-13 and E-16**
Analyze	Differentiate	Subject E-13 has written the correct answer along with the appropriate reasons for the four statements	Subject E-16 has not written the correct answer along with the appropriate reasons for the four statements	Subjects E-13 and E-16 were able to recognize and distinguish causal factors from the consequences of a problem complicated
	Connect	Subject E-13 has not written all the answers correctly, because he only answered 3 one-to-one correspondences	Subject E-16 has not written the answer completely correctly, because it does not show the one-to-one correspondence obtained	Subjects E-13 and E-16 have not been able to analyze existing data and divide data into parts the smaller one for knowing the pattern or relationship
Evaluate	Inspect	Subject E-13 has written how to calculate function values correctly, but has not written down the complete value of x that satisfies g(x) = 6	Subject E-16 has written how to calculate function values correctly and has completely written down the	Subjects E-13 and E-16 were able to calculate the value of a function using the function formula

			value of x that satisfies g(x) = 6	
	Criticize	Subject E-13 has not completely written down the answer correctly in determining the minimum or maximum value	Subject E-16 has not completely written the answer correctly in determining the minimum or maximum value	Subjects E-13 and E-16 have not been able to make a hypothesis, criticize and perform a research
Create	Produce	Subject E-13 has completely written answers correctly in making function graphs and explaining the process of creating these graphs	Subject E-16 has completely written the correct answer in making a function graph, but has not explained the process of creating the graph	Subjects E-13 and E-16 are able to draw graphs of functions on Cartesian coordinates

Table 11 Description of Higher Order Thinking Abilities at the Analyzing, Evaluating and Creating Levels for the Sufficient Category

Levels of Thinking	**Aspect**	**Subject E-7**	**Subject E-25**	**Similarities between Subjects E-7 and E-25**
Analyze	Differentiate	Subject E-7 has not written the correct answer along with the appropriate reasons for the four statements	Subject E-25 has not written the correct answer along with the appropriate reasons for the four statements	Subjects E-7 and E-25 were not yet able to recognize it distinguish causal factors from the consequences of a problem complicated
	Connect	Subject E-7 has written all the answers correctly	Subject E-25 has not written the answer completely correctly, because it does not fully show the one-to-one correspondence obtained	Subjects E-7 and E-25 were able to express one-to-one correspondence function
Evaluate	Inspect	Subject E-7 has written down how to calculate function values correctly, but has not written down the complete value of x that satisfies g(x) = 6	Subject E-25 has written how to calculate function values correctly, but has not written down the complete value of x that satisfies g(x) = 6	Subjects E-7 and E-25 have not been able to provide an assessment towards a solution or ideas with using elements there to be sure assess its effectiveness
	Criticize	Subject E-7 has not completely written down the answer correctly in determining the minimum or maximum value	Subject E-25 has not completely written the answer correctly in determining the minimum or maximum value	Subjects E-7 and E-25 have not been able to make a hypothesis, criticize and perform a research
Create	Produce	Subject E-7 has completely written the correct answer in making a function graph, but has not explained the	Subject E-25 has not completely written down the answers correctly in making function graphs, and has not explained the	Subjects E-7 and E-25 were able to draw graphs of functions on Cartesian coordinates

		process of creating the graph	process of creating these graphs	

Table 12 Description of Higher Order Thinking Abilities at the Analyzing, Evaluating and Creating Levels for the Poor Category

Levels of Thinking	**Aspect**	**Subject E-11**	**Information**
Analyze	Differentiate	Subject E-11 has not written the correct answer along with the appropriate reasons for the four statements	Subject E-11 has not been able to recognize it as well distinguish causal factors from the consequences of a problem complicated
	Connect	Subject E-11 has not written the answer completely correctly, because it does not fully show the one-to-one correspondence obtained	Subject E-11 was able to express a one-to-one correspondence function.
Evaluate	Inspect	Subject E-11 has written how to calculate function values correctly, but has not written down the complete value of x that satisfies g(x) = 6	Subject E-11 has not been able to provide an assessment towards a solution or ideas with using elements there to be sure value of its effectiveness i
	Criticize	Subject E-11 has not completely written down the answer correctly in determining the minimum or maximum value	Subject E11 has not been able to make a hypothesis, criticize and perform a research
Create	Produce	Subject E-11 has not completely written the answer correctly in making a function graph, because he has not explained the process of creating the graph	Subject E-11 has not been able to form a perspective or an idea for something problem

Apart from that, from interviews with the five main subjects, information was also obtained which can be displayed in Figure 1 below.

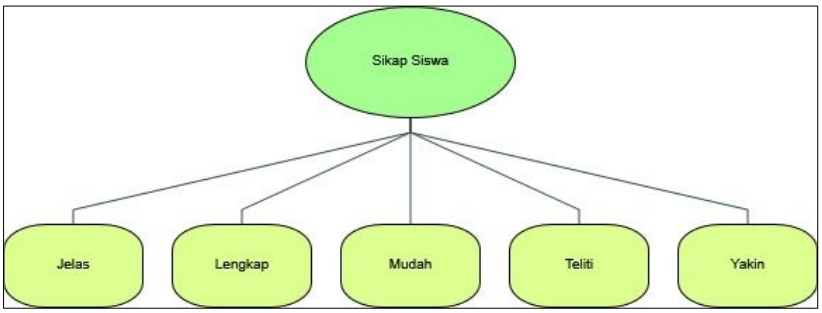


Figure 1 Students' attitudes when answering questions

In Figure 1 above, it can be seen that the attitude shown by students when solving questions, whether analysis, evaluation or creation questions, is the ability to understand the questions clearly, be thorough and complete in

answering, be able to solve questions easily, and be confident. with the answer. This indicates that by implementing the problem-based learning (PBL) model, students are trained in thinking and develop habits in facing challenges, especially in the context of problems that require high-level thinking abilities (HOTS). This is in accordance with the results of research conducted by Ipat Apipah and Novaliyosi with the title "Systematic Literature Review: The Effect of Problem-Based Learning (PBL) on Students' Mathematical High-Order Thinking Skills (HOTS)" (Apipah & Novaliyosi, 2023) and research conducted by Nurhayati and Lia Angraeni with the title "Analysis of Students' Higher-Order Thinking Abilities in Solving Optical Concept Problems through the Problem Based Learning Model" (Nurhayati & Angraeni, 2017).

In addition, through PBL, students' self-confidence levels can increase because they are actively involved in the problem-solving process and become increasingly interested in pursuing further knowledge. PBL has the potential to explore and develop students' potential, as well as create meaningful learning experiences for them because the approach emphasizes the active role of students, with the teacher acting as a facilitator.

4. Conclusion

The research results show that the application of PBL in mathematics learning on relations and functions material has not been able to develop students' high-level thinking processes optimally. Here are some of the key findings from this research tNot all stages of the high-level thinking process appear simultaneously in problem solving carried out by students for each indicator of high-level thinking.

In the problem solving flow, students with good abilities tend to carry out five basic processes in higher level thinking. Students in the good category meet all the indicators of high-level thinking abilities at the analyzing level, while students in the adequate and poor categories do not meet all the indicators of high-level thinking abilities at the analyzing level. Students in the good category meet all the indicators of high-level thinking abilities at the level of evaluating the examining aspect, while students in the adequate and poor categories do not meet all the indicators of high-level thinking abilities at the evaluating level. Meanwhile, students in the good category meet all the indicators of high-level thinking abilities at the creating level, while students in the adequate and poor categories do not meet all the indicators of high-level thinking abilities at the creating level.

Although the application of the PBL model has not been able to develop students' high-level thinking processes optimally, this model has trained students to think critically and develop habits of facing challenges, especially in the context of problems that require HOTS. The application of PBL is also able to create a more meaningful learning experience for students, increase their involvement in the learning process, and make learning more fun and relevant to real life.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest to be disclosed.

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