Students' Critical Thinking Ability in Solving Geometry Problems

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Abstract. One of the discussion trends in the mathematics education curriculum is how to improve critical thinking skills in solving mathematical problems. This research aims to analyze students' critical thinking abilities in solving mathematical problems on geometry topics. The research subjects consisted of 25 students. This research uses a qualitative approach to describe critical thinking skills through written test answers. The results of written answers and in-depth interviews were analyzed qualitatively to describe critical thinking skills using indicators of mathematical critical thinking skills, namely (1) Identification and interpretation of information, (2) analysis of information, and (3) assessing evidence and argumentation. The results of the research show that, on the identification and interpretation of information indicators, 20% of students are at a low level, 56% of students are at a medium level, and 24% of students are at a high level. In the information analysis indicator, 16% of students are at a low level, 60% of students are at a medium level, and 24% of students are at a high level. and in terms of indicators assessing evidence and argumentation, 20% of students are at a low level, 60% of students are at a medium level, and 20% of students are at a high level. The results of this research reveal that the limitations/barriers to critical thinking in solving problems are the lack of student interaction with solving complex problems. Therefore, educators need to develop critical thinking skills by providing more complex problems to students.

Keywords: critical thinking; complex math problems.

1 Introduction

Improving critical thinking skills in mathematics has become a topic of discussion in mathematics education curricula throughout the world (Sachdeva & Eggen, 2021); Butera et al., 2014; Aizikovitsh-Udi & Cheng, 2015; Applebaum, 2015; Caceres, Nussbaum & Ortis, 2020). Learning mathematics is not just learning about counting, but learning about how to think critically in solving problems, analyzing information, reasoning, communicating and making logical conclusions. Thus, critical thinking skills can give students the confidence to explore complex problems. Meanwhile, Firdaus, et al (2015) stated that critical thinking skills will encourage students to think

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more deeply and practice solving problems at school and in the world of everyday life. Chukwuyenum's (2013) research results show the influence of critical thinking skills on mathematical understanding.

Teaching mathematics to students is not only about teaching mathematical concepts, but what is more important is encouraging students to think critically when solving mathematical problems. Critical thinking activities in solving problems are identifying and analyzing problems, finding and evaluating relevant facts and information to make logical conclusions (Paul & Elder, 2016; McPeck, 2017). Therefore, to encourage students to think critically, it is necessary to be facilitated with complex, contextual, open problems that provide stimulus for students to identify various facts, concepts and theorems, then look for connections between one another.

As prospective teachers, PGSD students need to be trained in critical thinking skills to teach students in elementary schools (Aktaş &Ünlü, 2013; As'ari, Mahmudi & Nuerlaelah, 2017; Uslu, 2020). Based on the 2018 PISA survey, it appears that the scores obtained by Indonesian elementary school students in mathematics are very low (OECD, 2019). One of the reasons is that teachers do not place emphasis on solving complex problems in the learning process, resulting in students' low critical thinking abilities in solving problems (Firdaus, et.al. 2015; Afriansyah, et.al, 2021). In general, elementary school teachers only give routine problems that only require low-level thinking skills, namely solving simple and procedural mathematical problems (Widyatiningtyas, et.al. 2015; As'ari, Mahmudi & Nuerlaelah, 2017). So, one effort to increase Indonesian students' scores in PISA is to train elementary school students' critical thinking skills. Therefore, teachers and prospective teachers need to have critical thinking skills as a very important skill for teaching elementary school students to solve complex problems. Based on this reality, students' critical thinking skills in mathematics learning need to be the focus of attention to prepare the intellectual competence of prospective teachers in schools.

Critical thinking skills are very important for prospective teachers to face the challenges of educating and teaching in the millennial century. So PGSD students need to be trained how to deal with solving complex problems that require critical thinking skills. Critical thinking skills can be taught in an integrated manner through various subjects (McPeck, 2017). Several previous studies show that critical thinking skills in solving mathematics problems of students in Indonesia are in the low category (As'ari, Mahmudi and Nuerlaelah, 2017; Safrida, Ambarwati & Adawiyah, 2018; Adinda & Hamka, 2019; Afriansyah, et.al, 2021). Therefore, through solving complex mathematical problems in the learning process, students' abilities and obstacles in developing critical thinking skills can identify the root cause of the problem. Apart from that, we can get very important information to help students how to solve complex problems that require logical reasoning, analysis, synthesis, and looking for alternative problem solving ideas.

Learning mathematics with complex problems can encourage the development of critical mathematical thinking skills. Through the thinking process of analysis and synthesis it can stimulate students' critical thinking abilities (Peter, 2012; Monteleone, White & Geiger, 2018). Complex mathematical problems that are open and contextual will encourage students to think critically in solving mathematical problems

(Aizikovitsh, 2012; Chukwuyenum, 2013). Complex mathematical problems can provide stimulus and encourage critical thinking skills (King, Goodson & Rohani, 2013; Syarifah, Usodo & Riyadi, 2018). Therefore, the activity of solving complex problems will encourage students' thinking abilities in identifying information, looking for connections between various facts, concepts and theorems in making solution steps and making logical conclusions.

Several researchers have developed critical thinking assessment indicators in solving mathematical problems (Firdaus, et.al, 2015; Firdaus, 2016; Nurmayani, 2020). Critical thinking skills can be assessed through the process of solving complex mathematical problems, because when students solve complex mathematical problems, it will encourage students to identify problems, identify important information, make plans to solve problems and make logical conclusions (Aktaş &Ünlü, 2013; Nurmayani, 2020). According to Peter (2012), to encourage critical thinking skills in mathematics, it is necessary to provide assessment techniques that challenge intellectual abilities, not just problems that require memorization and procedural skills. Paul & Elder (2016) and Ennis (2013) stated that research on critical thinking in the problem solving process is very important to be carried out in educational institutions, to encourage students' intellectual development.

2 Methods

This research is descriptive qualitative research. The subjects of this research were 25 fourth semester students of PGSD Makassar State University for the 2019-2020 academic year on the topic of geometry. To obtain data related to the description of critical thinking skills in solving problems, a written test on the topic of geometry was used, taken from the National Elementary School Science Competition questions. The reason for choosing is because the questions have been tested for validity and reliability and are assumed to be able to measure students' critical thinking abilities in solving mathematical problems. Furthermore, this instrument has received content validation by two mathematics education experts. The use of geometric problems to assess prospective teachers' critical thinking abilities has also been used in research by Applebaum (2015) and Chigonga (2017).

Next, to obtain qualitative data on students' critical thinking abilities, 5 students who had scores at a low/medium level were selected to be interviewed using an unstructured interview guide to explore ways of thinking and obstacles experienced when solving complex problems. In general, researchers explore how students think when making problem-solving plans, interpreting information and how to find hidden facts from complex problems. Data from written test results for solving complex problems and interview results were analyzed based on the Miles and Huberman technique, namely data reduction, data presentation and drawing conclusions (Sugiono, 2018). Meanwhile, to obtain valid data, time triangulation has been used (Creswell, 2017).

The written test instrument used to measure critical thinking skills in solving mathematics is a complex problem on geometry topics that requires the ability to

interpret, analyze and synthesize information and facts and evaluate. A total of five complex problems were given to respondents, while the scoring for each answer to a mathematics problem item was based on the scoring indicators of the mathematics critical thinking ability rubric (Firdaus, 2016) in table 1 below:

Table 1. Guidelines for scoring rubrics for critical thinking skills in mathematics

Aspects that are measured	Student responses to problems	score
Identification and Interpretation of information	Cannot find important facts and concepts from the questions	0
	Find some important facts and concepts from the questions given,	1
	Can find facts and concepts but cannot formulate problems	2
	Finding important facts and concepts, can formulate problems but is not perfect	3
	Finds important facts and concepts and can formulate problems perfectly.	4
Information analysis	There is no attempt to analyze information, facts and concepts	0
	Can analyze some information, facts and concepts, but cannot relate them	1
	Can analyze information, facts and concepts, relate them but cannot translate problems into mathematical models	2
	Can analyze information, facts and concepts, relate them but there are errors in translating problems into mathematical models	3
	Can analyze assumptions, facts and concepts, relate and be able to translate problems into mathematical models	4
Assess evidence and arguments	There was no attempt to carry out a procedural settlement	0
	Carrying out settlement procedures or unclear settlement directions	1
	Can carry out procedural solutions with clear directions, but there are incorrect facts or concepts in its use.	2
	Can carry out the solution procedure correctly but there is an error in carrying out the calculation or can carry out the procedural proof of the formula, but there is an error in using the concept	3
	Can carry out settlement procedures correctly, be precise in carrying out calculations or can carry out formula verification procedures correctly	4

Source: Firdaus (2016)

Next, the level of critical thinking ability in mathematics is assessed based on table 2 below.

Table 2. Criteria for Critical Thinking Ability Level in Mathematics

Criteria	Category
$X \geq \underline{X} + 1$. Elementary	Tall
$\underline{X} - 1$. SD $< X < \underline{X} + 1$. Elementary	Currently
$X \leq \underline{X} - 1$. Elementary school	Low

(Source: Modification from Arikunto, 2016)

3 Results and Discussion

3.1. Results

Data on students' critical thinking abilities in solving mathematical problems is presented in two parts, namely data on written test results in solving complex problems and analysis of answers and interview results of 5 students who were unable to solve mathematical problems correctly.
In detail, the research results are presented as follows:

Data from the written test results on critical thinking skills in solving mathematical problems from 25 respondents were obtained based on the indicators in table 1. Next, the written test result data is presented in the form of a frequency and percentage table as in table 3 below:

Table 3. Critical Thinking Assessment Data in Solving Mathematical Problems

Indicators of Mathematical Critical Thinking Ability	Level of Critical Thinking Ability in Mathematics	N	%
Identification and interpretation of information	Tall	6	24%
	Currently	14	56%
	Low	5	20%
Information analysis	Tall	6	24%
	Currently	15	60%
	Low	4	16%
Assess evidence and arguments.	Tall	5	20%
	Currently	15	60%
	Low	5	20%

The problem that arises in this problem is finding the perimeter of a flat shape. The flat shape in this problem is a combination of a rectangular shape and a semicircular shape. In this question, the respondent's analytical skills are required to use the formula for the perimeter of rectangular and circular shapes. R1's answer shows that the respondent has been able to identify the basic concepts needed, using the formula for the perimeter of a rectangle and the perimeter of a semicircle. However, R1 did not look carefully at the picture, and did not understand the concept of perimeter of a flat shape. Lack of critical thinking skills in identifying information and distinguishing important and unimportant facts that will be used in flat area problems is the cause of problem-solving errors. According to R1, the mathematical problem that is often faced is the perimeter of a simple flat shape, and not a combination of flat shapes.

The problem that arises in this problem is finding the area of a flat shape that is in Cartesian coordinates. R2's answer shows that the concept of triangle area used is limited to finding the area of a right triangle, which requires the length of the base and height of the triangle. Based on this answer, it seems that R2 does not understand the characteristics of the area of a triangle whose coordinates are known on the Cartesian diagram. In solving mathematical problems like this, respondents must remember the basic concept of area, which supports the critical thinking process.

The problem that arises in this problem is finding the area of a flat plane. In the picture, you can see a combination of rectangles, triangles and parallelograms. The ability to analyze the facts in the image for the important information needed is very important in solving complex problems. Answer R3 shows that the respondent can identify the facts needed to solve the problem. Apart from that, R3 has also made a logical resolution plan. However, R3 was not careful in using the formula for the area of a parallelogram. R3 failed to determine the height of the parallelogram, so the area of the shaded area produced an incorrect answer. R3 did not re-examine the completion procedure steps that had been carried out which caused the results obtained to be incorrect.

The problem that arises in this problem is finding the side lengths of a square. The image that is the context for this problem is a combination of a triangle shape and a square shape. R4's answer shows that the respondent has not been able to understand the concept of comparison, which is a prerequisite concept for solving this problem. The respondent's lack of ability to find the relationship between two comparison concepts is the beginning of an error in the completion procedure. One of the critical thinking skills is the ability to look for relationships between concepts and find solutions from these relationships. According to R4, complex problems like this had never been taught and tested before, so respondents had difficulty solving complex problems.

The problem that arises in this problem is finding the ratio of the area between a square and a circle without the unit size of the radius and side length of the square. R5's answer shows that the respondent has tried to determine the size of the radius of the circle. However, respondents did not clearly reveal the facts of the problem and were still limited in designing logical resolution procedures. So, you can't complete it and get the correct answer. From the results of the interview analysis, R5 is not used to solving complex problems of unknown size. The mathematical problems that are

often faced are questions where the formula used is clear and there are examples of solution procedures according to those in the textbook.

3.2. Discussion

Based on the results of the written test, it shows that in the identification and interpretation of information indicators, 20% of students are at a low level, 56% of students are at a medium level, and 24% of students are at a high level. In the information analysis indicator, 16% of students are at a low level, 60% of students are at a medium level, and 24% of students are at a high level. and in terms of indicators assessing evidence and argumentation, 20% of students are at a low level, 60% of students are at a medium level, and 20% of students are at a high level. The results of this research reveal students' critical thinking abilities in solving complex problems, mostly due to the inability to identify the complex problems they face. Among these is the inability to distinguish between important and unimportant pacts, as well as finding connections between one concept and another. This resulted in respondents failing to make appropriate problem solving plans, because they considered the important information in the questions to be incomplete. These findings are in line with the results of previous research (Adinda & Hamka, 2019; Afriansyah, et.al, 2021) which also found low critical thinking skills in solving mathematical problems. This fact is in accordance with Ennis (2005) who states that indicators of critical thinking include identifying problems, stating alternative solutions, logical arguments and evaluating conclusions.

The obstacle for respondents in solving complex problems is that they rarely face complex problems in learning. According to R1, the mathematical problem that is often faced is the perimeter of a simple flat shape, and not a combination of flat shapes. So, when faced with complex problems like this, it is difficult to solve them. Therefore, students need to be given complex problems that challenge intellectually, not just simple problems found in textbooks that suit the curriculum (Aiyub et.al, 2021). The limited time for interaction between educators and students in the classroom and the demands of completing the curriculum mean that educators rarely provide complex problems that encourage students' critical thinking. Therefore, this problem needs to get attention from educators from elementary school to university level to develop critical thinking in the learning process.

The next obstacle in solving complex problems is the limited ability of respondents to see problems from various perspectives. From R2's answer, it can be seen that R2 only knows one way to find the area of a triangle, namely L= ½ (base length x height). From R2's argument, it can be seen that the solution provided does not show the logical flow of critical thinking regarding the perpendicularity requirements of a triangular area. In solving mathematical problems like this, respondents must remember the basic concept of area, which supports the critical thinking process. So respondents must find ideas and provide reasons to correctly answer the complex problem given (Sumarmo, 2013; Tee, Leong & Rahim, 2018) .

The resolution of the problem raised by R3 shows that the respondent did not carry out an evaluation/re-examination of the procedural steps that had been carried out

which caused the results obtained to be incorrect. The habit of not re-examining/evaluating when solving complex problems shows the respondent's low critical thinking ability. Dinuta (2015) states that critical thinking in solving problems requires constructive and creative thinking skills, starting from intuitive and logical thinking and the ability to see things from various perspectives. Next, re-examine all the procedures that have been carried out.

R4's critical thinking ability in solving complex problems shows that the respondent does not see the problem as a whole. The ability to identify facts, important information and try to find relationships between various pieces of information is needed in solving complex problems. According to R4, complex problems like this had never been taught and tested before, so respondents had difficulty solving complex problems. This finding is in accordance with various research results (Facione, 2015; Monteleone, White and Geiger, 2018) that low critical thinking abilities are influenced by the respondent's lack of interaction with solving complex problems.

Another form of complex problem that can encourage critical thinking is a problem that is not equipped with measurements/units. Answer R5 shows an attempt to assume a certain size. But not careful in carrying out the problem solving plan. R5 is not used to solving complex problems of unknown size. The mathematical problems that are often faced are questions where the formula used is clear and there are examples of solution procedures according to those in the textbook. Mathematics textbooks greatly influence what is taught in the classroom because teachers use textbooks as a daily guide to organize their learning process, which is related to teaching content and teaching methods (Maričića & Špijunovićb, 2015; Araiku, et. al, 2020) . In general, textbooks only contain simple problems that are in accordance with curriculum demands, so they cannot encourage students' critical thinking.

4 Conclusion

Based on the research results and discussion above, it can be concluded that:

1. Based on the results of the written test, it shows that in the identification and interpretation of information indicators, 20% of students are at a low level, 56% of students are at a medium level, and 24% of students are at a high level. In the information analysis indicator, 16% of students are at a low level, 60% of students are at a medium level, and 24% of students are at a high level. and in terms of indicators assessing evidence and argumentation, 20% of students are at a low level, 60% of students are at a medium level, and 20% of students are at a high level.
2. Based on the analysis of the results of student interviews at low and medium levels, it was found that the causes of limitations in critical thinking in solving complex problems were obtained, namely: lack of interaction between respondents regarding complex mathematical problems. Apart from that, the mathematics problems they have faced since middle school are mathematics

problems that only require certain procedural steps, so that respondents experience difficulties when facing complex mathematics problems.

3. The results of this research have implications for educators, to design mathematics learning that can encourage students' critical thinking abilities in solving mathematical problems.
4. These findings can provide inspiration for other researchers to assess students' critical thinking abilities using different perspectives.

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