CRITICAL THINKING OF PROSPECTIVE MATHEMATICS TEACHERS: WHAT ARE THE ERRORS IN ARGUMENTATION?

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A B S T R A C T

Critical thinking is one of the important aspects and must be owned by prospective teachers. But the fact is that many prospective teachers do not think critically, especially in the argumentation aspect. This study aims to find out the mistakes of prospective teachers in making arguments after solving the given problem. The research design used is qualitative with an exploratory descriptive approach. The number of participants is 80 teacher candidates, then three subjects are taken who have errors in making arguments. The instruments used are tests and interviews. The data that has been collected is analyzed using data reduction, data presentation, and concluding. The results of this study state that there are two mistakes teacher candidates make in arguing, namely errors in conveying arguments and the ideas used are illogical. Suggestions for further research are that a question and answer session is needed to train prospective teachers' arguments and develop their critical thinking skills.

1. INTRODUCTION

Critical thinking is one of the mindsets that prospective teachers must have (Simsek & Yazar, 2019; Tohir et al., 2020). By thinking critically, it is hoped that prospective teachers can think of appropriate problem solving (As'ari et al., 2017; Murtafiah et al., 2018). Critical thinking is an important aspect needed in facing the 21st century (Arisoy & Aybek, 2021; Cheng & Wan, 2017; Kavenuke et al., 2020; Smith et al., 2018). By thinking critically, prospective teachers can make good decisions (Özelçi & Çalışkan, 2019; Zandvakili et al., 2019). In addition, by thinking critically, prospective teachers can prepare the 21st century generation that can be competitive and solve various challenges in the future (Dwi Susandi et al., 2019; Jose M Ocampo, 2018). This shows that critical thinking is an important mindset that prospective teachers must have in solving problems.

One way to apply critical thinking is to always use it in solving problems (Dwyer & Walsh, 2020). Solving problems with critical thinking has been done by prospective teachers by considering the components that exist in critical thinking. Furthermore, critical thinking has become one aspect of the world's learning curriculum (Dwi Susandi et al., 2019; Hariyani et al., 2016). Various efforts have also been made to maximize the critical thinking

of prospective teachers, including training, preparation of learning tools, and evaluations characterized by critical thinking (Kavenuke et al., 2020). This shows that critical thinking is closely related to the learning process carried out by prospective teachers.

Critical thinking consists of finding out the main problem, guessing, generalizing, arguing, and evaluating (Ennis, 2015; Facione, 2016). After the problem is given, someone can find out the core of the problem, then make assumptions based on the knowledge they have. Next is to bring the general form according to the existing theory and then argue according to the ideas you have. The last step is to evaluate all the activities that have been carried out. All aspects of critical thinking are needed in solving problems (Erdoğan, 2020; Poce et al., 2022)

Critical thinking is one part of thinking that can be trained and developed through the learning process (Ellerton, 2022). The critical thinking process is reflective thinking that makes sense and focuses on deciding what to believe or do (Gomez Marchant et al., 2021). There are six critical thinking processes of a person known as FRISCO (Focus, Reason, Inference, Situation, Clarity, Overview) (Kozikoğlu, 2019). Based on the results of the researcher's preliminary study based on the Ennis and Facione theory, five aspects of critical thinking were obtained, namely identifying, connecting, applying, argumentation, and clarifying.

One aspect of critical thinking is argumentation. Argumentation is the process of explaining thoughts about what has been done (Liu & Roehrig, 2019; Mukuka et al., 2020). By arguing, prospective teachers can convey their ideas (Sönmez et al., 2021). But in fact, many teacher candidates are still unable to make an argument after solving the problem (Liu & Roehrig, 2019; Mukuka et al., 2020). In the aspect of argumentation, prospective teachers still have not conveyed their ideas optimally (Mikeska & Howell, 2020). This shows that research is needed to examine the argumentation aspects of prospective teachers.

Several studies have examined the arguments of prospective teachers. The results of research Liu & Roehrig (2019) state that arguments are needed by prospective teachers to teach and prepare prospective teachers to make decisions in the future. Research by Mukuka et al (2020) stated that learning must raise critical problems so that it raises arguments for prospective teachers. This shows the importance of the argumentation process for prospective teachers.

Errors in making arguments are also still found in prospective teachers. Errors in the argumentation of prospective teachers in solving problems include conceptual and procedural (Demiray et al., 2022; Marchant et al., 2021). Conceptual errors arise when delivering the material while procedural when solving problems (Meral et al., 2021), If prospective teachers experience errors in making arguments, this results in errors in the concepts presented. These errors have an impact on the invalidity of the information received by students.

Invalid information to students has long-term effects. The concept received by students is wrong so they have difficulty solving problems. This shows that action is needed to overcome this problem. Research on the errors of prospective teachers in arguing has been done but there has been no research that examines the errors of argumentation of prospective teachers in expressing opinions after completing the questions. The purpose of this study was to describe the mistakes of prospective teachers in making arguments after solving the problems given.

2. LITERATURE REVIEW

2.1 Critical Thinking Process

The critical thinking process developed in this study refers to Ennis, Facione and the results of the preliminary study. The following is a table of the results of the researcher's study on critical thinking.

Table 1. Critical Thinking Process

Ennis (1996)	Facione (2016)	Preliminary studies
F *(Focus)* find out the initial problem to be solved	*Interpretation* the ability to give meaning and expression to a given problem	*Identifying* Determine the subject matter by analyzing what is known and asked
R *(Reason)*	*Analysis*	*Connecting*

Provide an appropriate or inappropriate explanation of the problem given. S *(Situation)* Can understand the conditions of the problem given, then clarify the information provided and know the keywords.	Ability to make connections between relationships, materials, and concepts in solving problems.	Relates the relationship between the subject matter at hand and the knowledge already possessed.
I *(Inference)* State the conclusion from the selected steps.	*Inference* The process of classifying a given problem so that conclusions can be determined.	*Applying* Ability to determine the steps used to solve problems
C *(Clarity)* Ability to determine the steps used to solve problems O *(Overview)* Do a re-check of all the steps taken.	*Evaluation* Ability to evaluate the results of thinking *Explanation* Do a re-check of all the steps taken. *Self-regulation* ability to do self-evaluation	*Argumentation and Clarifying* Explain the results of thinking based on evidence and methods Re-check the work that has been done

This study focuses on the error aspect of argumentation. The indicators of the argumentation aspect are as follows.

Table 2. Indicators of the argumentation aspect

Aspect	Stages	Indicator	Error
Argumentation	a. Explain the results of thinking based on logical evidence	a. Write down and mention the thoughts that have been selected	a. Unable to write and mention the thoughts that have been selected
		b. Shows that the results of the thinking mentioned are logical	b. Unable to show logical thinking results
	Explain the result of thinking based on the appropriate method	a. State the results of thoughts in writing and orally	a. Unable to mention the results of appropriate thoughts both verbally and non-verbally
		b. The results of the ideas presented are adjusted to the method that has been chosen.	b. Have not been able to convey the results of thoughts in by following per under with the chosen method.

3. METHODOLOGY

3.1. Research Design

This research is qualitative research with an exploratory descriptive approach. This study aims to explore the results of teacher candidates' answers after solving problems. This descriptive qualitative research aims to obtain information about the argumentation aspect from the results of interviews and written tests. According to Creswell (2012), a qualitative approach is used to understand the function of a study on the problem in question. The problem in this study is the weakness of the argumentation aspect of prospective teachers in solving problems.

3.2.   Sample and Data Collection

All participants are students majoring in Mathematics Education in semesters 6 and 8 from private universities in Indonesia. The selection of participants used a purposive sampling technique because not all participants were selected. The number of selected participants is 80 prospective teachers who have taken Euclid's geometry course. After the prospective teacher is given a problem in the form of a test that is done within 20 minutes, then it is classified and research subjects that meet the criteria of critical thinking are taken. After that, prospective teachers were interviewed to find out the argumentation aspect. In this study, prospective teachers were taken who experienced errors in making arguments.

3.3.   Instruments

The research instruments used were tests and interviews. The test consists of one mathematics problem which aims to explore the arguments of the prospective teacher. The test is used to determine the critical thinking process of prospective teachers. Meanwhile, the interview used was unstructured. Interviews were conducted with prospective teachers who met the criteria for critical thinking. The purpose of the interview is to explore information about the argumentation in depth. This study uses 3 research subjects who are considered to represent 80 students.

The following is a test given to prospective teachers to explore their arguments

Look at the following picture

Figure 1   Figure 2   Figure 3   Figure 4
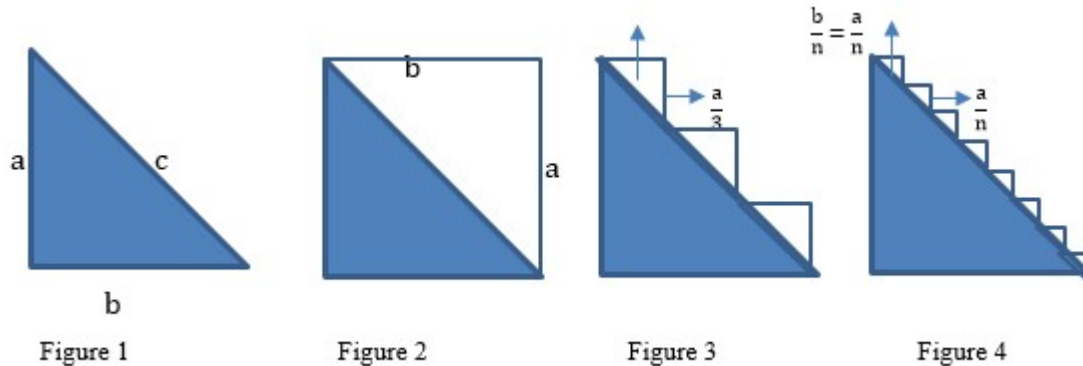
It is known that Figure 1 is an isosceles right triangle with the length of the hypotenuse c and the length of the right side being $b = a$. Based on the Pythagorean Theorem, the equation $a^2 + b^2 = c^2$ is obtained. Since $b = a$, we get $a^2 + a^2 = 2a^2 = c^2$. So that $c = \sqrt{2}a$.

Consider Figure 2, the ladder is made on a sloping side, where the height is a and the width is b. More and more stairs are made with the height and width of each rung being the same, it can be seen in Figures 3 and 4. Pay attention to Figure 4, it can be seen that the length of the hypotenuse c is formed from the rungs whose height and width are respectively $\frac{a}{n}$ and $\frac{b}{n}, n \in \mathbb{N}$.   So the length of the hypotenuse c is $\left(n \times \frac{a}{n}\right) + \left(n \times \frac{b}{n}\right)$.

Because it is known that $a = b$, then the length of the hypotenuse c is $\left(n \times \frac{a}{n}\right) + \left(n \times \frac{a}{n}\right) = \frac{an}{n} + \frac{an}{n} = \frac{2an}{n} = 2a$. It means that the value of $c = 2a$.

Question: Does the above result contradict the result $c = \sqrt{2}a$ obtained from the Pythagorean theorem? Explain your answer!

The interview in this study aims to obtain additional information from the written test. The format used in this study is an unstructured interview. By conducting interviews, it is hoped that prospective teachers can express their opinions freely without coercion from anyone. The questions submitted are based on the answers from prospective teachers. By conducting interviews, it can be seen the mistakes of prospective teachers in making arguments.

3.4 Analyzing of Data

The data obtained were analyzed covering three activities, namely data reduction, data presentation, and conclusion. The first is data reduction, namely the process of selecting, classifying, and organizing test and interview data so that conclusions can be drawn. The second is data presentation, which is a narrative compilation of a collection of information and the results of data reduction so that conclusions can be drawn and further action is taken. The data presented in this study are the results of teacher candidates' answers which indicate aspects of critical thinking. In addition, the results of interviews are also presented the third is drawing conclusions or verification, the process of giving meaning to the data presented to conclude. Conclusions were verified during the study. The activity carried out is to test the truth and suitability of the meanings that arise from the data found.

4. RESULTS

In this study, the results of the argumentation of prospective teachers after solving the problem were seen from the results of answers and interviews. The following is a problem given to prospective teachers and worked on for 20 minutes.

From the answers in Figure 1, subject 1 (S1) redraws the questions given. S1 explains each part of the picture. From the answer, S1 obtained information that the results of the answers have not conveyed the idea based on the Pythagorean concept that has been selected. Furthermore, S1 has not stated that the chosen idea is logical. From the answers, S1 also still has not answered the questions given. Furthermore, to find out how S1's argument was, an interview was conducted. Interviews were conducted after S1 had solved the problem. R code for researcher and S1 code for subject 1

R : "What is your idea to solve the given problem?"

S1: "I think using the Pythagorean theorem"

R: "Why? Please explain!"

S1 : "Since it is a right triangle, it must use the Pythagorean theorem."

From the interviews, information was also obtained that the ideas conveyed were illogical. S1 states that every problem with a right triangle is always solved by the Pythagorean theorem.

Figure. 1. Participant 1's Answer
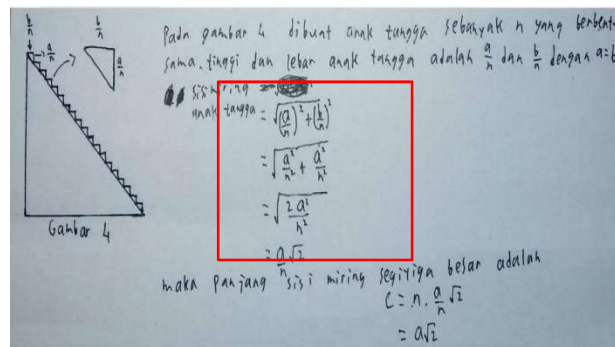
Answer S2 states that the results of the two are contradictory. From the results of interviews obtained information that is called contradictory because the values are not the same.

R : "Why do you say the contrary?"

S2: "Because the values are not the same, so I think they are contradictory"

R: "How do you solve the problem?"

S2: "I'll solve it with the Pythagorean theorem first, then I call it contradictory"

From the answers and interviews, information was obtained that S2 had not been able to answer the questions using the selected Pythagorean theorem. Furthermore, the idea conveyed by S2 that if the values are not the same then contradicts is illogical.

Figure. 2. Participant 2's Answer

S3's answer shows that there is no work process, he only conveys how to solve the problem. In the results of the answers, S3 stated that the results of the calculations presented in the questions were incorrect. According to S3, the error is because the procedure performed is not appropriate, it should determine the value of one of the triangles and then multiply by n. The concept used by S3 is the Pythagorean theorem. To find out in-depth information about the S3 argument, the researcher conducted interviews. Here is a snippet of his interview.

R : "What do you think is the appropriate step?"

S3: "I think the method is wrong. The truth is that one triangle is calculated first and then multiplied by some n

R: "Why is that?"

S3: "So far what I know is using that method"

From the interview, excerpts obtained information that S3 criticizes the working process. But in his answer, he did not give examples and the correct process. In addition, S3 also has not answered the questions given. Another mistake that S3 made was saying that if the method was not by the examples he knew so far, then it was wrong.

Figure 3. Participant 3's Answer

Based on the results of the teacher candidates' answers, shows that the purpose of argumentation is to strengthen answers. Answers that are not correct can be corrected by using logical arguments. Furthermore, correct answers can be strengthened by valid arguments. The argumentation errors of prospective teachers are obtained from previous knowledge. To identify the argumentation errors of prospective teachers, the researchers used argumentation criteria. Criteria for argumentation aspects in critical thinking include: conveying ideas based on selected concepts and mentioning that the chosen ideas are logical.

5. DISCUSSION

The argumentation stage is to explain the results of thinking based on evidence and methods (Meral et al., 2021). In this section, prospective teachers convey the ideas that are in their minds based on the results of the analysis

that has been carried out in the previous stage. At this stage, the prospective teacher determines the beliefs of what has been decided and clarifies the results of his work (Mikeska & Howell, 2020). Prospective teachers mention and rewrite whether the solution is correct and recalculate the results of the completion (Trempler & Hartmann, 2020).

The argumentation stages are according to the results of S1 thinking in solving problems, namely understanding the image in the problem and using the Pythagorean theorem to solve it. While the argumentation stage is according to the results of the S2 thinking in solving problems, namely reading and understanding the problem and using the Pythagorean theorem. From the results of the S3 answers and the interview process, information was obtained that S3 could explain the completion steps used. S3 at the time of the interview said that there was nothing wrong with the two methods presented in the problem. At the time of writing the answer, S3 said that there was a conflict between the two, but during the interview, S3 said that there was no conflict. This shows that S3 is controversial and after being given time to argue, S3 can explain the results of his thoughts.

During the argumentation stage, prospective teachers carry out the Polya stage in solving problems, namely understanding the problem and relating it to other relevant problems (Polya, 2019). According to Polya (1973) the stages of solving the problem consist of four steps, namely a) understanding the problem or problem given, b) drawing up a plan in solving the problem, c) implementing the plan in solving the problem, and d) re-examining the results of the settlement that has been done.

Argument errors in conveying ideas according to the specified concept appear to prospective teachers after solving problems (Sa'dijah, Rahayuningsih, et al., 2021). The idea used in solving the problem is to use the Pythagorean theorem. But the knowledge previously acquired affects the ideas conveyed (Chantarasombat, 2021). For example, showing a contradiction but not by the concept, blaming the calculation because it does not match the information obtained and a different way is considered wrong. This shows that personal knowledge cannot be used as a reference to convey logical arguments (Liu & Roehrig, 2019)

The ideas used to argue by prospective teachers vary according to the information previously obtained (Mikeska & Howell, 2020). The idea used by prospective teachers is to always use the Pythagorean theorem when it is known that a right triangle is not true. This is because it is often found that the Pythagorean theorem and a right triangle are one part, but they are not. This contradiction is also encountered by someone when expressing his opinion (Meral et al., 2021; Trempler & Hartmann, 2020). The existence of contradictions can be one aspect of someone's error in arguing.

Prospective teachers' mistakes in expressing their opinions can arise when they are given a problem that includes aspects of critical thinking (Brečka et al., 2022; Paulsen & Kolstø, 2022). The mistakes of prospective teachers when solving problems can be discussed in the learning process in class (Subanji, Rosyadi, AAP, & Emanuel, 2021). The keyword is not to blame but to find the interesting side (Sa'Dijah et al., 2020; Sa'dijah, Rahayuningsih, et al., 2021). If the error is known, it will not be repeated when solving the next problem (Tohir et al., 2020).

During the process of solving problems, there are also activities in which there is the drafting of concepts (Sa'dijah, Kholid, et al., 2021). The preparation of these concepts can encourage someone to carry out cognitive activities to make connections between concepts in building new knowledge (Barrera-Mora & Reyes-Rodríguez, 2013). In this study, the subject solved the problem by relating it to the Pythagorean theorem that had been obtained previously. This is what triggers a link between the old concept and the new concept to be completed (Sa'dijah, Rahayuningsih, et al., 2021).

About Polya's steps, S1 and S2 in the argumentation aspect take steps to understand the problem. S1 understands the existing picture of a given problem. After understanding the problem, S1 draws up a plan to solve the problem by choosing the Pythagorean theorem. While S3 on the argumentation aspect there is a process of checking back on the results of the answer.

During the re-checking process carried out by S3, there was a cognitive conflict, this was reinforced from the results of the interview, namely as follows:

R: "Please explain how you used the appropriate steps to solve the problem?"

S3 :"After understanding the problem in the problem above, namely the difference in the results of c, whether they are contradictory or not, then use the Pythagorean theorem to find the length of the hypotenuse and get a result that corresponds to c=√2a"

R: "Do you think it is contradictory or not?"

S3: "I think yes because the answer is different. But the method used in my opinion is not wrong."

R: "So how?"

S3: "I don't think it's contradictory, ma'am, just a different point of view"

R: "What kind of different points of view?"

S3: "The first method uses Pythagoras, then the second method uses the concept of distance"

R: "Both of them are right, right?"

S3: "Yes ma'am"

The occurrence of the cognitive conflict itself is caused by three things, namely: a) cognitive conflict occurs because of differences in the existing conceptions in the cognitive structure of the environment, b) cognitive conflict occurs because of differences in existing conceptions with protected conceptions and c) cognitive conflict occurs because of differences in conceptions that exist (Devine et al., 2018). The term cognitive conflict itself was presented by Piaget as one of the psychological developments and the most important thing in cognitive change (Sopamena et al., 2016).

Based on the theory of cognitive conflict, what S3 experienced was due to differences in the existing conceptions of the cognitive structure and the environment (Devine et al., 2018; Van Luit & Toll, 2018). This is because there was a conflict during the interview, the results of the initial answers from S3 changed after the interview was conducted by the researcher.

The finding of this study is that when prospective teachers make an argument there is a cognitive conflict. Cognitive conflict occurs when there is a conflict between what is encountered with previously acquired knowledge (Devine et al., 2018; Van Luit & Toll, 2018). With a cognitive conflict, prospective teachers can conduct arguments so that they can improve another aspect of critical thinking, namely evaluation (Ellerton, 2022). Evaluation is one aspect of critical thinking that rarely appears when solving problems (Sadijah et al., 2021).. Most prospective teachers do not consider the evaluation process, only concerned with the results of the answers (Brečka et al., 2022).

The results of this study state that lecturers should provide problems that can bring up aspects of critical thinking, especially aspects of argumentation. This is because, during the learning process, argumentation is needed to know ideas and explore them (Demiray et al., 2022; Sönmez et al., 2021). In addition, the mistakes of prospective teachers when making arguments can also be used as references for lecturers to make learning improvements.

6. CONCLUSION

The results of this study state that one of the indicators of critical thinking is that prospective teachers do not have argumentation. The mistakes of prospective teachers in making arguments include a) prospective teachers have not been able to convey ideas to answer the given problem and b) the ideas used to solve problems are not logical. The ideas conveyed by prospective teachers in solving problems are not following the concept of the material provided. In addition, the ideas presented are still not logical, so improvements are needed in the discussion process

7. RECOMMENDATIONS

Recommendations for future research are to determine the relevance and not a given problem requires in-depth exploration. For example, by giving questions and answers to prospective teachers on the problems given and

providing other equivalent problems which are then discussed together. In addition, a learning process is needed in which there are arguments between prospective teachers. This is done to develop the ability to argue and criticize the problems given.

8. LIMITATIONS

The limitation of this research is the critical thinking aspect that dies is the error in the argumentation of the prospective teacher after solving the problem. For further research, errors can be seen in other aspects of critical thinking. Questions can be adapted to the critical thinking aspect that will be observed

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