The potential problem to explore metacognitive regulation in collaborative problem-solving

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Abstract

Metacognitive regulation is an important ability for undergraduate students to have in solving collaborative problems. However, before carrying out research on exploring metacognitive regulation in collaborative problem-solving, the development of suitable instruments must be carried out. The right instrument will produce the correct data. In this study, two instruments were developed, which are tasks containing mathematical problems and task-based interview guidelines. In addition, this study also identified appropriate problem criteria used to explore metacognitive regulation in collaborative problem-solving. The results showed that the problems that can trigger metacognitive regulation in collaborative problem-solving fulfil the following criteria: problems to prove, non-routine problems, open-ended problems, geometric problems, and without DGE. The use of semi-structured interview guidelines can also help deepen students' exploration of metacognitive regulation in collaborative problem-solving. The findings of this study are especially important for researchers who will develop instruments to examine metacognitive regulation, especially in collaborative problem-solving.

La regolazione metacognitiva è un'abilità importante che gli studenti universitari devono avere nella risoluzione di problemi collaborativi. Tuttavia, prima di ricercare l'esplorazione della regolazione metacognitiva nella risoluzione collaborativa dei problemi, deve essere effettuato lo sviluppo di strumenti adeguati. Lo strumento giusto

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produrrà i dati corretti. In questo studio sono stati sviluppati due strumenti, ovvero compiti contenenti problemi matematici e linee guida per colloqui basati su compiti. Inoltre, questo studio ha anche identificato criteri problematici appropriati utilizzati per esplorare la regolazione metacognitiva nella risoluzione collaborativa dei problemi. I risultati hanno mostrato che i problemi che possono innescare la regolazione metacognitiva nella risoluzione collaborativa dei problemi soddisfano i seguenti criteri: problemi da dimostrare, problemi non di routine, problemi aperti, problemi geometrici e senza DGE. L'uso di linee guida per interviste semi-strutturate può anche aiutare ad approfondire l'esplorazione da parte degli studenti della regolazione metacognitiva nella risoluzione collaborativa dei problemi. I risultati di questo studio sono particolarmente importanti per i ricercatori che svilupperanno strumenti per esaminare la regolazione metacognitiva, specialmente nella risoluzione collaborativa dei problemi.

Keywords: collaborative problem-solving; metacognition; metacognitive regulation; research instruments

Parole chiave: problem-solving collaborativo; metacognizione; regolazione metacognitiva; strumenti di ricerca

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1. Introduction

Curriculum reform currently focuses on 21st-century skills known as the 4Cs, which are critical thinking and problem-solving, collaboration, communication, and creativity. The curriculum reform applies to all subjects, including mathematics. One of the 4C skills, namely problem-solving, is a major goal in mathematics curricula in most of the world (Olivares et al., 2021; Stacey, 2005), including Indonesia. Learning mathematics is not only obtained from individual learning outcomes, but there is an influential social role in it. This social role can be realized in the form of collaborative learning between students. Collaboration is one of the social aspects that occur in learning mathematics. Thus, besides problem-solving skills, collaboration skills are also important skills to have. Therefore, both problem-solving and collaboration are central skills in 21st-century in mathematics education.

In fact, solving the problem becomes a difficult thing for undergraduate students. This is shown by the results of research where the problem-solving ability of undergraduate students is still relatively low (Mahanal et al., 2022; Yusuf et al., 2021). Collaborative activities can support the ability to solve mathematical problems, which is often called collaborative problem-solving. As is known, learning outcomes are not entirely the result of individual thinking only, but also there are other people's roles in it. Collaborative problem-solving is a problem-solving activity that is done with two or more people. Problem-solving occurs when a person who encounters a problem has never known the procedure or method for solving it (Salminen-Saari et al., 2021; Schoenfeld, 1985, 2013).

Many studies have been conducted to improve the ability to solve mathematical problems, one of which is by using Metacognition (Izzati & Mahmudi, 2018; Özcan & Eren Gümüş, 2019; Schoenfeld, 2016). Metacognition is a predictor in problem-solving (Zhao et al., 2019). Someone who has good metacognitive abilities, he/she is also a good problem solver. Thus, studying Metacognition more deeply becomes important to support problem-solving.

Metacognition was introduced by Flavell in 1979. Flavell (1979) mentions Metacognition with the term "thinking about thinking". Metacognition refers to a set of processes that individuals use to monitor their cognition so that they can effectively control their own behaviour (Rhodes, 2019). The ability to recognize one's own cognitive processes, such as working memory, is often referred to as Metacognition (Fleming & Lau, 2014). Sternberg & Sternberg (2012) defines Metacognition as our knowledge of and control over our cognition. Based on these opinions, Metacognition is a person's awareness of his/her cognitive processes as well as the monitoring and control of his/her own cognitive processes.

Metacognition is divided into metacognitive knowledge and metacognitive regulation (Brown, 1987; Flavell, 1979; Schraw & Moshman, 1995). Metacognitive knowledge refers to one's awareness of one's cognitive processes, while metacognitive regulation refers to one's monitoring and control of one's cognitive processes. To explain the results of cognitive processing, awareness of cognitive processes is not enough, but it is necessary to examine how a person monitors and controls his cognitive processes. It can be concluded that metacognitive regulation has a more important role than metacognitive knowledge. This statement is in line with Stephanou & Mpiontini (2017), who state that metacognitive regulation is a more important component than metacognitive knowledge. Therefore, it would be very interesting to further research focus on metacognitive regulation.

Metacognitive regulation was initially investigated in the context of the individual, which examines how a person monitors and controls his own thought processes. The traditional view of metacognitive regulation is examined individually on task and learning views. However, at this time, metacognitive regulation has been

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investigated in a social context. Research shows that metacognitive regulation can appear in group learning activities (Iiskala et al., 2021; Jin & Kim, 2018). One of these social activities can occur when groups solve problems.

Similar to research on metacognitive regulation, research on problem-solving has shifted from looking at individual problem-solving processes (Krulik & Rudnick, 1995; Polya, 1945; Schoenfeld, 1985) to examine how the problem-solving process work collaboratively (Artz & Armor-Thomas, 1992; Salminen-Saari et al., 2021). This process can be referred to as a collaborative problem-solving process. As previously explained, to support the success of learning mathematics, collaborative activities between students are needed. Thus, it will be interesting to examine how students' metacognitive regulation can emerge in collaborative problem-solving.

Before carrying out research on metacognitive regulation in collaborative problem-solving, it must be ascertained what research instruments are appropriate to obtain data. Research shows that non-routine problems require metacognitive regulation (Nancarrow, 2004). Furthermore, mathematical problems are divided into "problems to find" and "problems to prove" (Polya, 1945). "Problems to prove" require advanced math skills (Polya, 1945). The participants in this study were undergraduate students; thus, using "problem to prove" is more suitable to be developed into a research instrument. Geometry material about quadrilaterals was chosen to be developed in this study. Therefore, this study aims to develop instruments that can explore students' metacognitive regulation in collaborative problem-solving using geometry problems.

2. Theoretical Framework

2.1 Individual Problem-Solving vs Collaborative Problem-Solving

Group learning activities can be realized when students solve problems collaboratively. Because the exploration of metacognitive regulation in this study focuses on the collaborative problem-solving process, it is necessary to have a theoretical study that discusses the differences between individual problem-solving and collaborative problem-solving. Collaborative problem-solving involves two different constructs that are collaboration and problem-solving. Problem-solving is a cognitive aspect, while collaboration is a social aspect. Therefore, the difference between individual problem-solving and collaborative problem-solving is in the social aspect.

The process of solving individual problems that have existed so far is in the form of a cycle as in the framework created by (Lester Jr., 1994; Mayer, 1989; Polya, 1945; Schoenfeld, 1985). While the collaborative problem-solving process is more unpredictable, where the phases of each stage cannot be determined in a certain timeline sequence (Artz & Armor-Thomas, 1992; Salminen-Saari et al., 2021). Polya (1945) states four heuristic steps in the individual problem-solving process, while Schoenfeld (1985) retains the four steps by changing the second step to choosing a strategy. Mayer (1989), as Polya, states four steps of the problem-solving process in a different term. Then, Lester Jr (1994) develops the individual problem-solving process into six phases. Table 1 shows the steps of the individual problem-solving process according to some experts.

Table 1. Individual Problem-Solving Process

Polya (1945)	Schoenfeld (1985)	Mayer (1989)	Lester (1994)
1. Understanding the problem 2. Devising a plan 3. Carrying out the plan 4. Looking back	1. Understanding the problem 2. Choosing a strategy 3. Implementation 4. Verification	1. Translate the problem 2. Problem integration 3. Plan solution 4. Implement solution	1. Identifying the problem 2. Understanding the problem 3. Analyzing the goal

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	4. Planning strategy 5. Solving strategy 6. Evaluating answer

Whereas the individual problem-solving process can be described as cyclic, collaborative problem-solving is unpredictable. In collaborative problem-solving, the group construct knowledge via interaction. Individuals bring the idea into a collaborative space. Table 2 describes the phases of collaborative problem-solving according to (Artz & Armor-Thomas, 1992; Salminen-Saari et al., 2021).

Table 2. Collaborative Problem-Solving Process

Artz & Armor-Thomas (1992)	Salminen-Saari (2021)
Read	Orienting
Understand	Understanding the problem
Analyze	Planning and Exploring
Explore	Implementing
Plan	Verifying
Implement	Watching and listening
Verify	
Watch and listen	

Furthermore, Goos et al. (2002) and Roschelle & Teasley (1995) distinguish between collaborative work and cooperative work. Collaborative work focuses more on togetherness from the beginning to the end of the problem-solving process, while cooperative work includes a division of tasks between group members in solving problems.

2.2 Metacognitive Regulation in Collaborative Problem-Solving

The study resulted a consensus that metacognitive regulation does not only occur in individual contexts but can also occur in group learning activities or social contexts (Jin & Kim, 2018; Kim et al., 2013; Magiera & Zawojewski, 2011). Research challenges the traditional view of metacognitive regulation studies in the individual context of learning tasks and outcomes. Metacognitive regulation can emerge from group learning activities as well as individual learning (Jin & Kim, 2018). Several factors during students' collaborative work, such as anomalies in task performance, different ideas emerging when solving problems, and uncertainty about these ideas, potentially activate students' metacognitive regulation (Jin & Kim, 2018). Metacognitive regulation emerges in collaborative processes in ways that are not only reducible to an individual level. The interaction process data in (Iiskala et al., 2011) research consisted of a large number of episodes that could be classified as shared Metacognition. In this episode, participating students share experiences triggered by their shared problem-solving process and use metacognitive regulation (Iiskala et al., 2011).

This study offers indicators of metacognitive regulation in collaborative problem-solving derived from (Jin & Kim, 2018), complemented by one other aspect, namely metacognitive orientation from (Brown, 1987; Veenman et al., 2006). Table 3 describes the indicator of metacognitive regulation according to (Brown, 1987; Jin & Kim, 2018; Veenman et al., 2006). Table 8 describes the indicators of metacognitive regulation in collaborative problem-solving in this study.

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Table 3. Metacognitive Regulation Indicator According to Some Expert

Indikator Regulasi Metakognitif (Brown, 1987; Veenman et al., 2006)	Indikator Regulasi Metakognitif (Jin & Kim, 2018; Nelson, 1990)
Orientation: a. Self-orientation by analyzing the task b. Recognizing task perception that generates hypotheses about task content and activating previous knowledge	
Planning: a. Choosing and sequencing a strategy b. Allocating self-resource c. Formulating action plan	*Metacognitive Controlling*: a. Choosing a strategy for solving problems b. Allocating cognitive self-resources
Monitoring: a. Monitoring self-progress by checking the adequacy of solving problems/ task solutions b. Monitoring understanding by identifying inconsistencies and modifying problem-solving if necessary	*Metacognitive Monitoring:* a. Monitoring thoughts and actions during the learning process b. Identifying cognitive connections or conflicts when learning c. Continuous assessment of understanding d. Assessing the quality of task performance
Evaluation: a. Assessing learning outcomes b. Assessing learning process	

3. Research methods

This instrument development research aims to explore metacognitive regulation in collaborative problem-solving. There are two instruments developed that are tasks that contain non-routine mathematical problems in geometry. At the same time, the second instrument was a task-based interview guideline. The participants in this study were two groups of Mathematics Education undergraduate students at the University of Muhammadiyah Malang, Indonesia, who had taken geometry courses. The undergraduate student groups are, respectively, 3^{rd} and 5^{th}-semester students. Each group consists of two students. The steps for developing the instrument are as follows: 1) determining the purpose of instrument development, 2) looking for theory and relevant material coverage, 3) arranging the instrument item grid, 4) creating instrument items, 5) validating the instrument, 6) revising the instrument based on suggestions from the validator, 7) conducting trials on participants, 8) analyzing instrument suitability in exploring metacognitive regulation in collaborative problem-solving.

4. Research result

The instrument development explores students' metacognitive regulation in collaborative problem-solving through eight steps. The following is a detailed explanation of each development step.

1. Determination of Instrument Development Goals

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The purpose of developing instruments in this study is to produce instruments that can trigger students' metacognitive regulation in solving collaborative geometry problems. The developed instrument is a task that contains geometry problems. To solve problems in this task, students must work on it in collaboration with other students. In addition, another goal is to determine whether the task instrument is sufficient or whether there needs to be another instrument for maximizing students' exploration of metacognitive regulations in collaborative problem-solving.

2. Determination of Theory and Relevant Material
In this study, geometry material is used because, based on research conducted by Firmansyah et al., (2022) and Kuzle (2013) explains that geometry problems can explore students' metacognitive regulation. The difference between the two studies is the use of a Dynamic Geometry Environment (DGE), in which DGE is used in Kuzle (2013) but not in Firmansyah et al. (2022). Therefore, in the task instrument that was created, there were two problems to prove on geometry material, one uses DGE, and one does not. This was done to compare which problem could be better to explore metacognitive regulation.
Besides the differences in the use of DGE, there are also differences in the types of problems. Problems that do not use DGE are an open-ended problem, while problems that use DGE are ordinary non-routine problems. Open-ended problems are problems that can take the following forms: 1) problems with many solving strategies, 2) problems with many solutions, or 3) the development of problems from a problem previously given (Ismail et al., 2017). The first problem can use more than one alternative strategy to complete the requested proof. The selection of open-ended problems with many solving strategies is because there is one indicator of metacognitive regulation, especially the aspect of metacognitive controlling, that expects students to choose the right strategy to solve the problem.

3. Arrangement of Instrument Item Grids
The arrangement of the grid for each problem developed in the task follows the determination of the theories that have been carried out in the previous step. Table 4 shows the development of the instrument item grid.

Table 4. Grid of Problem Items on the Task Instrument

Criteria of Problem	Number of Problems	
	1	2
Purpose of problem	Problem to prove	Problem to prove
Material	Isosceles Trapezoid	Rhombus
Procedure of problem	Non-routine	Non-routine
Tool use	Do not use DGE	Use DGE
The number of solving strategies	Open-ended problem	Closed problem

4. Creation of Instrument Items
The instrument contains two problems with geometry material, especially quadrilaterals. At this stage, the problems are arranged based on the item grid that has been made. In addition to the problems, the developed instrument also prepared guidelines for the completion of each problem. The following are two problems made on the task instrument.

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1. Quadrilateral $RSTV$ has the vertices $R(a,b), S(c,b), T(c-d,e)$. Determine the coordinate of V so that it forms an isosceles trapezoid. Show that $RSTV$ is an isosceles trapezoid.
2. Given ABC is an equilateral triangle and a line AD is parallel to BC. D is the intersection point of two circles centred at A and B, respectively, with the radius of the two circles equal to the side length of the equilateral triangle. Show that $ABCD$ is a rhombus.

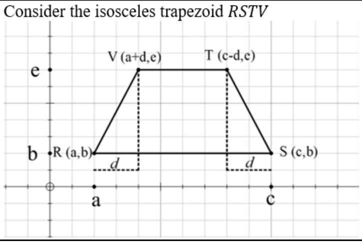
5. Instrument Validation

The instrument was validated by two experts who are lecturers in Mathematics Education at State University of Surabaya. One of the validators is a professor in Mathematics Education, and the second validator is a mathematics lecturer specializing in teaching English for mathematics. The task instrument given to the validator initially contains problems and answer guidelines. However, there are several suggestions from the validator, including 1) giving an imperative sentence for work so that it shows collaborative characteristics, 2) giving the implementation hypothesis of the collaborative problem-solving process in the answer guidelines of each problem, 3) giving the emergence hypothesis of metacognitive regulation and examples of utterance that may occur when solving problems on task. The conclusion given is that the problems that have been made can be used with revisions according to suggestions from the validator.

6. Revision of the Instrument According to the Validator's Suggestion

Based on the suggestions from the validator, Table 5 shows the form of improvement of the task instrument that can be used to explore students' metacognitive regulation in collaborative problem-solving.

Table 5. Repair of Task Instruments Based on Suggestions from the Validator

<table>
<tr><th>Validator Suggestions</th><th>Examples of repairs made</th></tr>
<tr><td>Giving imperative sentences for work so that it shows collaborative characteristics</td><td>For problem number 1,
Do the following problems in pairs with your friends!
For problem number 2,
Do the following problems in pairs with your friends! Use GeoGebra to draw a shape that fits the problem.</td></tr>
<tr><td>Giving the implementation hypothesis of the process of solving collaborative problems in the answer guideline of each problem</td><td rowspan="2"><table><tr><th>Answer</th><th>Implementation Hypothesis of Collaborative Problem-Solving</th><th>Emergence Hypothesis of Metacognitive Regulation</th></tr><tr><td>Consider the isosceles trapezoid RSTV
</td><td>• Orienting
• Understanding the problem
• Planning and exploring
• Watching and listening</td><td>MO
• MO-a
After student reads the problem, student aware/convince that he/she can solve the problem.
e.g: "I convince that I can solve the problem" or "this problem is easy to solve" or "I think it's difficult"</td></tr></table></td></tr>
<tr><td>Giving the emergence hypothesis of metacognitive regulations and examples of utterance that might occur when solving problems on the task</td></tr>
</table>

7. Trial on Participants

Trial of the task was given to two groups of students, each group consisting of two students. The selection of the two groups was random, in which one group was an undergraduate student in 3rd semester and one group of 5th semester. Each group was given a task that contained two problems that had been developed. The two groups were given the task at different times. The first group was given a task a week after the second group was given a task, and these two groups did not know each other. The two groups were chosen

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because they had taken geometry courses in the previous semester. In the process of solving the problems, this group is recorded using a video-audio recorder.

8. Instrument Suitability Analysis
Instrument suitability analysis includes two things that are 1) identifying the suitability of giving tasks to collaborative problem-solving processes, 2) identifying the extent to which metacognitive regulation can be explored in the form of conversations in groups, 3) comparing the results of group work on problems number 1 and 2 to determine the type of problems that are appropriate to explore students' metacognitive regulation in collaborative problem-solving. The process of solving collaborative problems in this study uses the framework of Salminen-Saari et al. (2021), which consists of six stages. The six phases of the collaborative problem-solving process are orientating, understanding the problem, planning and exploring, implementing, verifying, watching and listening seen in conversations and student work. Table 6 shows the phases of the collaborative problem-solving process.

Table 6. Stages of the Collaborative Problem-solving Process.

Phases of Collaborative Problem-solving	Indicator
Orientating	Students recognize problems
Understanding the problem	Students consider the language and schema attributes of the problem using their own words and present the problem in different forms.
Planning and Exploring	Students discuss and produce pictures
Implementing	Students carry out plans and generate possible solutions
Verifying	Student checks to see if the solution satisfies the conditions of the problem/ student explains to group members how he or she came up with the solution.
Watching and listening	Students pay attention to the ideas and work of other people, pay attention to each other in solving problems, and actively try to communicate their thoughts to the group.

The process of solving collaborative problems can be seen from the results of group conversations and the results of group work on the problems given. Table 7 shows the process of solving collaborative problems carried out by groups.

Table 7. The Collaborative Problem-solving Process carried out by the group.

Phases of Collaborative Problem-solving	Explanation of the collaborative problem-solving process
Orientating	When students read the problems, they try to identify the problem
Understanding the problem	Students make another representation of what is known in the problem. The symbols a, b, c, d e in the problem are represented as points both on the abscissa (x-axis) and ordinate (y-axis)
Planning and Exploring	Students and their groups discuss plans for solving problems, which are to draw the points on the Cartesian diagram and produce an

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	isosceles trapezoid along with the identification of points R, S, V, and T, as shown in the figure.
Implementing	After drawing the coordinates of each point, students get a coordinate for point V. In addition, the next problem is to prove that the figure is an isosceles trapezoid, which is solved by students using several strategies. For the first group, they proved it only by using the resulting images. But for the second group, they used the definition of an isosceles trapezoid for the proof.
Verifying	After determining the answers, students verify and explain that the answers obtained are in certain ways. The first group changes the value of symbols a, b, c, d and so on to 1, 2, 3, 4 and so on, respectively. Meanwhile, the second group reaffirmed that the proof based on the definition of an isosceles trapezoid was appropriate.
Watching and listening	This watching and listening activity occurs during the process of collaborative problem-solving. Students convey their ideas to the group; the group listens to the idea and vice versa.

Based on table 7, it can be concluded that the task of developed tasks can trigger a collaborative problem-solving process. Furthermore, the suitability of the instrument is seen from the extent to which this task instrument can explore or bring up student metacognitive regulation. This analytical activity begins with coding the indicators of metacognitive regulation in collaborative problem-solving, as shown in Table 8.

Table 8. Coding of Metacognitive Regulatory Indicators in Collaborative Problem-solving

Indicators of Metacognitive Regulation in Collaborative Problem-solving	Code
Metacognitive Orientation	MO
a. Self-orientation by analyzing tasks that aim at preparing the process of solving problems in groups	MO-a
b. Recognizing shared perceptions of the problem to be solved by generating hypotheses about task content and activating previous knowledge	MO-b
Metacognitive Controlling	MC
a. Choosing the right strategy from the results of collaborative thinking before and during the problem-solving process	MC-a
b. Allocating self-cognitive resources to solving problems collaboratively	MC-b
c. Formulating action plans resulting from collaborative activities	MC-c
Metacognitive Monitoring	MM
a. Recognizing the understanding and cognitive performance of self or others	MM-a
b. Monitor self-action or collaboration (participation, interaction, and group cohesion)	MM-b
c. Identify self or other cognitive conflicts and inconsistencies and modify problem-solving if necessary	MM-c
d. Assess the quality of self-performance or collaborative performance in problem-solving	MM-d

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e. Assessing self or group learning outcomes	MM-e

Based on the results of the analysis, not all indicators of metacognitive regulation appear in students' conversations or verbal when solving collaborative problems. The indicators that do not appear include MO-a, MC-a, MC-b, MM-b, and MM-d. This leads to the conclusion that giving tasks that require a collaborative problem-solving process is not enough to explore students' metacognitive regulations. So, a triangulation method is needed, that is, carrying out interviews with students after they have completed collaborative problems; thus, they can communicate their thoughts. Interviews were conducted with groups, but if it was felt to be lacking, for example, only one member dominated in answering interview questions, individual interviews would be continued. Therefore, group and individual interview guidelines were developed. The questions written in the interview guide correspond to indicators of metacognitive regulation in collaborative problem-solving. The interview guide that was developed was semi-structured and based on the task that students had done. Thus, the problems could be developed according to the conditions during the interview process but still towards the main purpose of conducting the interview.
The purpose of the third analysis is to compare the two problems that have different grids. The results of observations and recordings show that for the second problem that uses DGE, in this case, GeoGebra, students are not accustomed to using GeoGebra even though GeoGebra is not new to them. In addition, the use of DGE makes students focus on how to draw the shapes asked for using the DGE. Seen in both groups, most of their time was spent discussing how to draw shapes using DGE. Within an hour of working on the problems, they took about 30 to 45 minutes to try out drawing using DGE. It can also be seen in the results of the group's work that both groups could not answer the problems well; that is, they could not prove that the resulting shape was a rhombus. This happened because they did not focus on the proof but on how to draw using DGE. Meanwhile, the first problem, in which students draw shapes without using DGE, that is, manually using a ruler and other drawing tools, makes students complete more smoothly and allows them to discuss longer the proofs that are asked for.

5. Discussion

Metacognitive regulation can be investigated at the interpersonal level and occurs in collaborative problem-solving. This is also reinforced by the results of research on metacognitive regulation in collaborative learning, where metacognitive regulation does not only appear at the individual level but also at the social level (De Backer et al., 2014, 2022; Iiskala et al., 2021). In exploring metacognitive regulation in collaborative problem-solving, appropriate instruments are needed to obtain appropriate and in-depth data. There are several criteria that can be used in developing instruments in the form of problems that can trigger a collaborative problem-solving process and trigger the emergence of metacognitive regulation. The criteria for the problem include problems to proof, non-routine problems, geometry problems without DGE, and open-ended problems. Although previous studies have shown geometric problems with DGE can be used to identify patterns of metacognitive behaviour in problem-solving (Kuzle, 2013) but based on the data obtained in this study, the problem without DGE is more able to explore metacognitive regulation. This can lead to the conclusion that the use of DGE in problem-solving can be effective if students are familiar with and experts in using DGE. In addition, the problem to prove is one of the criteria that can trigger the emergence of student metacognitive regulation. This is because the problem to prove requires advanced mathematical abilities in accordance with the participants, that is, undergraduate students.

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The use of instruments in the form of tasks is known to be insufficient to be able to explore student metacognitive regulation, so another supporting instrument is needed, which is the use of task-based interview guidelines. This interview aims to explore more deeply the students' metacognitive regulation, which is not obtained when collaborative problem-solving activities. Previous studies have also used interviews as a technique to collect data on metacognitive regulation (Artzt & Armor-Thomas, 1997; Goos et al., 2002; Jin & Kim, 2018). Research advice given by (De Backer et al., 2016; Iiskala et al., 2011) stated that the triangulation method with interviews would give better results in exploring metacognitive regulation, and it is important for further research to investigate the usefulness of interviews in stimulating metacognitive regulation.

6. Limitations of the present study and suggestions for future research

Despite adding information about tasks and instruments that are suitable for exploring metacognitive regulation in collaborative problem-solving, this present study's limitations should also be acknowledged. First, the number of subjects is only two groups of undergraduate students. It would be much better if the tasks we tried were on a larger number of subjects. Second, a task that has closed-problem criteria must really ensure that it can only be done with one strategy. This can be done by giving an instruction to use a certain strategy on the questions that were made.

7. Conclusion

Based on the results of the analysis above, it can be concluded that giving tasks in the form of problems with criteria, including problems to prove, non-routine problems, geometry problems without DGE, and open-ended problems can be instruments that trigger students' metacognitive regulation in solving a collaborative problem. In addition, the results of the analysis also show that giving tasks is not enough to explore more deeply the metacognitive regulation in solving collaborative problems, so interview guidelines are also needed. This shows that triangulation of methods is needed in research to explore metacognitive regulation in collaborative problem-solving. For further research, the results of this study are useful for ensuring the right instrument in obtaining data on metacognitive regulation, especially in collaborative problem-solving.

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