The Emergence and Form of Metacognitive Regulation: Case Study of More and Less Successful Outcome Groups in Solving Geometry Problems Collaboratively

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Abstract: The current research trend of metacognitive regulation has shifted from an individual to a social context. One such social context is collaborative problem-solving. Interaction between group members is an essential factor in completing collaborative problems. Metacognitive regulation is divided into four forms based on the interaction in collaborative problem-solving. This study aims to analyze the emergence and form of metacognitive regulation in groups that are more and less successful at solving geometric problems collaboratively. Each group consists of two undergraduate students who have taken geometry courses. The group tries to solve geometry problems in the form of proof problems. This study examines how metacognitive regulation emerges in group discussion activities. The emergence of metacognitive regulations was identified through student utterances when discussing in groups. In addition, interview data support researchers in exploring metacognitive regulation carried out by groups. This study also identifies forms of metacognitive regulation that occur when groups interact. The study results showed differences in the metacognitive regulation activity in four aspects: orientation, planning, monitoring, and evaluation. The more successful group has a form of co-constructed social metacognitive regulation. In contrast, the less successful group has a form of ignored social metacognitive regulation.

Keywords: Metacognitive Regulation, Collaborative, Problem-Solving

INTRODUCTION

Current curriculum and teaching reforms have focused more on the teaching and assessment of 21st-century skills. Four skills are demanded in the 21st century, namely 4C critical thinking and problem-solving, collaboration, communication, and creativity. Problem-solving is essential to learning (Purnomo et al., 2022). The National Association of College and Employees (NACE) is an American non-profit professional association for college career services, recruiting practitioners, and hiring college graduates. NACE states that there are five primary skills in workforce recruitment: teamwork skills, leadership, communication skills, problem-solving skills, and a strong work ethic. Therefore, collaboration and problem-solving are central skills in the 21st century.

Metacognition is a predictor of problem-solving. Research shows that someone with good metacognitive abilities is associated with good problem-solving (Roick & Ringeisen, 2018; Zan, 2000). Metacognition was introduced by (Flavell, 1979), who mentions "thinking about thinking." Metacognition is divided into metacognitive knowledge and regulation (An & Cao, 2014; Brown, 1987; Schraw & Moshman, 1995). Metacognitive knowledge is individual awareness of their cognitive processes. In comparison, metacognitive regulation describes individual monitoring and control of their cognitive processes.

Metacognitive regulation is considered a more critical aspect than metacognitive knowledge. Awareness of cognitive processes needs to be improved to explain cognitive processing results. It requires examining strategies for monitoring and controlling cognitive processes, which are metacognitive regulations. (Stephanou & Mpiontini, 2017). Thus, this study focuses on the study of metacognitive regulation. In its development, metacognitive regulation has been studied in individuals and groups. Research shows that metacognitive regulation can emerge in group activities, not just individuals (Jin & Kim, 2018; Kim et al., 2013; Magiera & Zawojewski, 2011).

Interaction is essential in student group activities, especially in solving collaborative problems. With successful interaction, it is possible to build a space of shared understanding to solve common problems (Roschelle & Teasley, 1995). However, some interactions were influential in the group activities, and some could have been more effective. Research shows that there are group members who ignore each other's contributions and focus only on their thoughts. Based on the differences in interactions in the collaborative group, Molenaar et al. (2014) create a framework that divides metacognitive activity into four forms that align with the framework of Iiskala et al. (2021). By adopting these two frameworks, this study divides the form of metacognitive regulation into four: ignored social metacognitive regulation, accepted social metacognitive regulation, co-constructed metacognitive regulation, and shared social metacognitive regulation. During the problem-solving process, of course, not all groups can solve it successfully. Some groups are both more successful and less successful.

It would be interesting to study the form of metacognitive regulation in these two groups with different criteria. The research findings are expected to provide information such as the emergence of metacognitive regulation in collaborative problem-solving. Besides, the finding is forms of metacognitive regulation in groups that are more and less successful in solving problems. These findings can be followed up by looking at the differences in metacognitive regulation in collaborative problem-solving in groups with more and less successful results.

Previous research analyzed the form of metacognitive regulation in each aspect based on the coding scheme of Molenaar et al. (2014). However, this research focuses on using collaborative scripts to improve students' metacognitive regulation in task-oriented reading (Kielstra et al., 2022). In this study, we want to see the emergence and dominance of forms of metacognitive regulation in groups that are more successful or less successful in solving geometric problems. Forms of metacognitive regulation are obtained from utterances or conversations when students discuss solving problems. The utterances produced can be classified as verbalized metacognitive regulation and are supported by interview data.

THEORETICAL FRAMEWORK

Metacognitive Regulation in Social Context

In the traditional view, metacognition was studied by individuals. How to see a person's awareness of his cognition is called metacognitive knowledge. How to see someone monitoring and controlling their cognitive process is called metacognitive regulation (Flavell, 1979; Scheiner & Pinto, 2016; Sternberg & Sternberg, 2012). However, metacognition has been studied in a social context in its development. It is because individual learning outcomes cannot be separated from the role of others. Social-based contexts are situations where students interpret multiple perspectives, engage in explanations, and seek mathematical consensus (Magiera & Zawojewski, 2011). It also applies to metacognitive regulation, which is part of metacognition. Jin & Kim (2018) found that elementary school students were metacognitively engaged in collaborative problem-solving activities. Besides that, research by Jin & Kim (2018) challenges the traditional view of metacognitive regulation studied. Metacognitive regulation can emerge at both individual and group levels.

Metacognitive regulation is indicated by orientation, planning, monitoring, and evaluation (Brown, 1987; Veenman et al., 2006). Orientation refers to self-orientation by analyzing the task, realizing the perception of the task by way of task content orientation, generating hypotheses about the task content, and activating prior knowledge. Planning involves selecting and sequencing strategies, allocating resources, and formulating action plans (Jacobs & Paris, 1987; Nelson, 1990; Schraw, 1998). Monitor self-progress by checking the adequacy of solving problems/task solutions and understanding by identifying inconsistencies and modifying problem-solving, including monitoring (Brown, 1987; Veenman et al., 2006).

At the same time, evaluation refers to assessing learning outcomes and learning processes (Brown, 1987; Jacobs & Paris, 1987; Schraw, 1998; Veenman et al., 2006). The indicators of metacognitive regulation above are indicators in a particular context. The meaning of collaborative work must be clearly defined to determine indicators of metacognitive regulation in collaborative problem-solving. Damon & Phelps (1989) distinguish group interaction activities into peer tutoring, cooperative, and collaborative. Peer tutoring occurs in interactions where people with different skills are brought together so that one can instruct the other. In cooperatives, some arrangements allow groups to share tasks and master their separate parts. In collaboration, interaction occurs when students with the same competency level share their ideas to solve challenging problems together (Damon & Phelps, 1989). Collaboration is a mutual process of exploring each other's reasoning and viewpoints to build a shared understanding of the task, generating methods and interpretations of mutually acceptable solutions. Therefore, mutual interaction requires one to propose and defend their ideas and ask their colleagues to clarify and justify ideas they do not understand (Goos et al., 2002). Collaboration is characterized by "togetherness" between group members from the beginning to the end of the problem-solving process. This togetherness occurs in terms of sharing ideas, clarifying each other, and gaining a common understanding in solving problems.

By paying attention to collaborative work, this study offers indicators of metacognitive regulation in solving collaborative problems, presented in Table 1.

Metacognitive Regulation Indicator in Collaborative Problem-Solving	code
Orientation	
1. Self-orientation by analyzing tasks aims to prepare the problem-solving process in groups.	Orientation-1
2. Recognizing shared perceptions of the problem to be solved by generating hypotheses about task content and activating previous knowledge	Orientation-2
Planning	
1. Selecting the right strategy from the results of collaborative thinking before and during the problem-solving process	Planning-1
2. Optimizing self and or group resources in solving problems	Planning-2
3. Formulating action plans resulting from collaborative activities	Planning-3
Monitoring	
1. Be aware of self or each other's understanding and cognitive performance	Monitoring-1
2. Monitoring self- or collaborative thinking and actions (participation, interaction, and group cohesion)	Monitoring-2
3. Identifying self or other's cognitive conflicts and inconsistencies and modifying problem-solving if necessary	Monitoring-3
Evaluation	
1. Assessing the quality of self-performance or collaborative performance in problem-solving	Evaluation-1
2. Assessing self or group learning outcomes	Evaluation-2

Table 1: Metacognitive Regulation Indicator in Collaborative Problem-Solving

Form of Metacognitive Regulation in Collaborative Problem-Solving

Interaction is necessary for the process of solving collaborative problems. With successful interaction, it is almost possible to build a space of shared understanding to solve common problems (Roschelle & Teasley, 1995). In collaborative groups, interaction can occur differently (Volet et al., 2009). Interaction in collaborative learning is divided into two: shared interaction and co-constructed interaction (Van Boxtel, 2004). Shared interaction occurs when group members share existing knowledge and mutually acknowledge each other's contributions (mostly without disputes/demands for justification).

Meanwhile, co-constructed interaction occurs when students build their activities to explain and question each other's thoughts and provide feedback. The characteristics of co-constructed are students formulating actions and knowledge that individual group members cannot produce alone. However, not all collaborative activities occur effectively. Studies show that students ignore each other's contributions and concentrate on their thinking (Molenaar et al., 2014).

Following the differences in these interactions, Molenaar et al. (2014) divide four types of interactions into metacognitive activities: ignored social metacognitive activities, accepted social metacognitive activities, co-constructed metacognitive activities, and shared social metacognitive activities. In line with Molenaar et al. (2014), the framework proposed by Iiskala et al. (2021) divides metacognitive regulation into four forms: verbalized metacognitive self-regulation, ignored metacognitive regulation, metacognitive other regulation, and socially shared metacognitive regulation. The forms of metacognitive regulation in this study are defined as four types of interactions in metacognitive regulatory activities in collaborative problem-solving. Metacognitive regulations are manifested verbally. In this study, four forms of metacognitive regulation in collaborative problem-solving are:

1. Ignored Social Metacognitive Regulation
   It occurs when a group member tries to control or monitor group learning activities, but others ignore these efforts. Example: A student evaluating the answers produced by the group commented that the answer was wrong. Other group members did not respond to his comments.
2. Accepted Social Metacognitive Regulation
   It occurs when other group members agree with one group member's metacognitive comments by implementing them in their cognitive activities. Example: A student evaluating the answers produced by the group commented that the answer was wrong. The other group members started rechecking their answers. It shows that evaluation activities are considered and followed up in re-examination. So, group members engage with these metacognitive comments through cognitive contributions.

3. Co-constructed Social Metacognitive Regulation
   Group members build on each other's ideas by collaboratively constructing metacognitive activities to organize collaborative learning. Group members exchange metacognitive comments that generate new ideas. This new idea emerges when students propose metacognitive comments to one another. Example: a student gives an idea in the form of several strategies that can be used to solve a problem. Another group member commented that he believed one of them was the best. The first student agreed and explained why this strategy was also the best according to him.
4. Shared Social Metacognitive Regulations
   Group members share their metacognitive ideas and respond to each other's contributions, but they do not build each other's ideas toward new ideas. Example: a student evaluating the answers produced by the group comments that the answer is wrong. Another group member commented that he believed his different answers might be wrong too.

METHOD

This research uses a qualitative approach with a multiple-case study. The two cases used in this study have different criteria that the two groups represent. The criteria of one group were more successful in solving geometry problems in collaboration, and the other could have been more successful. The group that has a more successful outcome is the group that can use a logical proof strategy even though the writing has yet to use the proper proof steps. In contrast, the less successful group was the group that failed to prove the questions given. Each group consists of two people. Working in pairs can increase the possibility of group members negotiating, interacting, reaching agreements, and evaluating their assignments (Córdoba Zúñiga et al., 2021). Thus, collaborative work is expected to occur well.

The participants of this study were undergraduate students at the University of Muhammadiyah Malang, Indonesia, who had taken geometry courses. The number of participants is 26 students divided into 13 groups. Three groups are included in the more successful outcome groups, and ten groups are included in the less successful outcome groups. The researcher selected one of the three and ten groups, respectively. The two chosen groups are more interactive than the others enabling researchers to obtain more complete data on metacognitive regulation. Thus, in the result section, two groups are the focus of the study. Henceforth, we will refer to the members of the first group as S1 and S2. While the members of the second group as S3 and S4. Table 2 shows the characteristics of S1, S2, S3, and S4—student characteristics in the form of gender and learning outcomes. Learning outcomes are obtained from the midterm exam score and divided into three criteria: high, medium, and low.

Subjects	Gender	Learning Outcomes
S1	Female	High
S2	Female	Medium
S3	Female	Medium
S4	Female	Low

Table 2: The Characteristic of the Subjects

The instruments used were group assignment sheets and interview guidelines. *Group assignments* are problem-solving tasks that trigger students' metacognitive regulations in conversations or speech. Researchers analyzed the emergence and form of metacognitive regulation based on group student discussions. The interview data were used to examine the students' metacognitive regulation. The interviews were conducted in groups. There are four aspects.

The group was given a geometric problem task with the type of problem to prove. Figure 1 shows the task assigned to the groups. Groups complete tasks collaboratively. While the group discussed completing its task, the recording was done using a video-audio recorder. After completion, the researcher interviewed the group using a task-based interview guide developed based on indicators of metacognitive regulation in collaborative problem-solving. Student conversation and interview transcripts were analyzed to identify the emergence and forms of metacognitive regulation. Four aspects asked during the interview correspond to the four aspects of metacognitive regulation. In the first aspect, orientation, we ask about the nature of the task and what prior knowledge students must have to complete the task. In the second aspect, planning, we ask how many strategies have been discussed to solve the problem. In the third aspect, monitoring, we asked about students' awareness of their understanding and how they understood their colleagues' understanding. In addition, we asked about students' need for more understanding in completing assignments. In the last aspect, evaluation, we asked how they assessed their learning outcomes and their assessments of group solutions and collaboration.

Do the following problems in pairs with your friends!

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. Prove that $RSTV$ is an isosceles trapezoid.

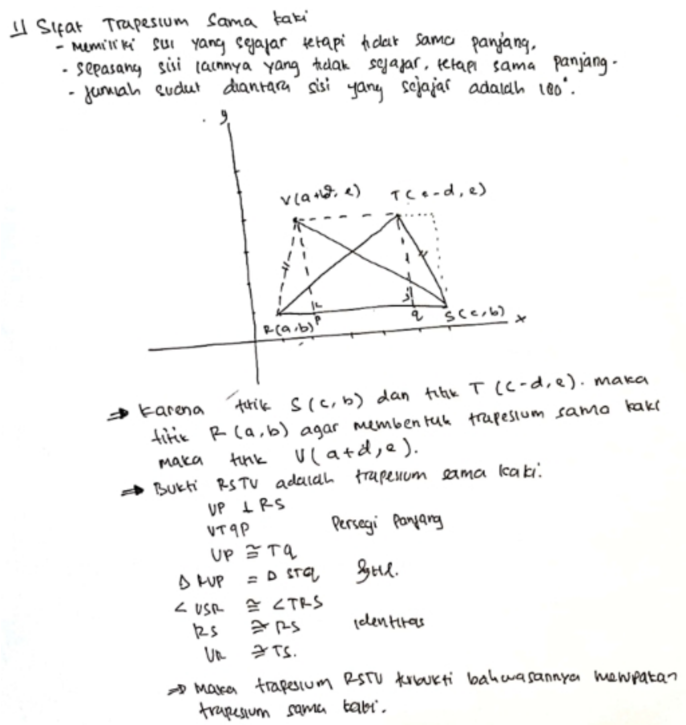
Figure 1: Tasks given to student groups

There are three stages in analyzing data, namely, (1) data condensation, (2) data display, and (3) inclusion drawing/ verification (Miles et al., 2014). The data from group conversations and interview transcripts are coded in the data condensation activity. The coding scheme for metacognitive regulation refers to Table 1 (Iiskala et al., 2021; Molenaar et al., 2014). Then the data is displayed in conversations or interview excerpts that contain examples of the occurrence and form of metacognitive regulation. In addition, the results of data analysis are displayed in a matrix that compares the occurrence of metacognitive regulation in the two groups of subjects. The last stage is drawing conclusions and verification.

RESULT

Metacognitive regulation of more successful outcome groups

Figure 2 is the result of group work that is more successful in solving the given problem. The results of the group's work are still in Indonesian, but we have added a translation in English.



Isosceles Trapezoid Properties:
- Having parallel sides but not the same length
- The other pair of sides are the same length but not parallel
- The sum of angles measured between the parallel sides is 180°

- Since $S(c,b)$ and $T(c-d,e)$ thus $R(a,b)$. To form an isosceles trapezoid then $V(a+d,e)$
- Proof of $RSTV$ is isosceles trapezoid
  $VP \perp RS$
  $VTQP$ is rectangle
  $VP \cong TQ$
  $\Delta RUP \cong \Delta STQ$
  $\angle VSR \cong \angle TRS$
  $RS \cong RS$ (identity)
  $VR \cong TS$
- Thus, proved that $RSTV$ is the isosceles trapezoid

Figure 2: Group work that is more successful at solving problems

In Figure 2, it can be seen that students start their answers by writing down the properties of an isosceles trapezoid. Based on the results of interviews with the student group, they agreed that the first step was to know the properties of an isosceles trapezoid. They drew the known points from the problem, determined the coordinates of the point in question, and drew an isosceles trapezoid. The following is an excerpt from the group interview transcript. Assume that the first group consists of S1 and S2. At the same time, the researcher is written as R. The text in bold, and italics is a code for indicators of metacognitive regulation in collaborative problem-solving.
R: "How did the group agree on a strategy to solve the problem?"

S1: "We first thought that we must first know the properties of an isosceles trapezoid. After that, draw an isosceles trapezoid at Cartesian coordinates" ***(Orientation-2)***
S2:" Then we determine the point. The point is obtained by making the line the same length as the line. Because then" ***(Orientation-2)***
In the interview excerpts, students recognized a shared perception of the problem to be solved by generating hypotheses about task content and activating previous knowledge. It shows one indicator of metacognitive regulation on the orientation aspect. The utterances that appeared when the first student had a discussion showed self-orientation by analyzing tasks. The following is an excerpt of students speech during the discussion.
(After they finish reading the questions)
S1: "do it represents coordinates?" (pointing to the known dot symbol in the problem) ***(Orientation-1)***
S2: "correct. It coordinates."
S1: "means we draw the coordinates first" ***(Orientation-1)***
S2: "Yes, we draw the point first at any initial position."

In the conversation it can be seen that students analyze assignments that aim to prepare for solving group problems. The analysis they did about the coordinates of the points they would later draw to create an isosceles trapezoid shape. From the results of collaborative work, students agreed to prove by showing that RSTV fulfils the properties of an isosceles trapezoid. They mentioned the three properties of an isosceles trapezoid, as shown in Figure 2, although, in the end, they proved it in another way. Another way is that the group proves that an isosceles trapezoid can be constructed from two congruent right triangles and a rectangle ***(planning-3)***. This group is a more successful outcome group, not because of their perfectly correct answers but because of the logic they put into completing the proof. The steps students take in choosing and determining more accessible, appropriate strategies for solving problems are included in the planning aspect of metacognitive regulation.

R: “Why, in the end, did the proof not use the trapezoidal property as written?”
S1: “Initially, we wanted to prove one of the properties, that is, two non-parallel sides are the same length, by using the Pythagorean theorem. However, we cannot continue. Finally, we use the second method. If we can determine that this figure consists of a rectangle and two congruent right triangles, then we can prove an isosceles trapezoid” ***(Planning-1)***
R: “Why is that?”
S2: “in our opinion, the proof will be easier” ***(Planning-1)***
Monitoring activities occur during the problem-solving process. It was also found when researchers conducted interviews with groups. The excerpt of the conversation transcript shows that S1 can identify the lack of understanding of S2. S2's incomprehension is a cognitive conflict that he faces. “Hmmm” was said by S2 and immediately identified by S1 that S2 did not understand, so S1 continued his explanation. Therefore, S1 can identify cognitive conflicts from their group mates, an aspect of monitoring. The following conversation transcript shows the emergence of the monitoring aspect.

S2: "How do we prove an isosceles trapezoid?"
S1: "First, we prove that the non-parallel sides are equal in length" ***(Monitoring-3)***
S2: "Hmmm?"
S1: "means we show the length of the side TS the same as VR. Let us try using the Pythagorean theorem" ***(Monitoring-3)***

The evaluation aspect was not seen when the group discussed it. However, the interview transcripts show that the group evaluated the group's performance and learning outcomes. The following interview transcripts show evaluation aspects of metacognitive regulation.
R: "What do you think about group work?"
S1: "I find it more helpful to work with a group because we can exchange opinions and understandings" ***(Evaluation-1)***
S2: "I agree because we can choose a better way by sharing ideas."
R: "Are you sure about the evidence you have produced?"
S2: "Not sure, we think our strategy is right, but we are not sure about the writing." ***(Evaluation-2)***

Metacognitive regulation of less successful outcome groups

Figure 3 is the result of the group's work which could have been more successful in solving the problem of proving geometric material. As shown in Figure 2, student work is still Indonesian, and we have translated it into English.

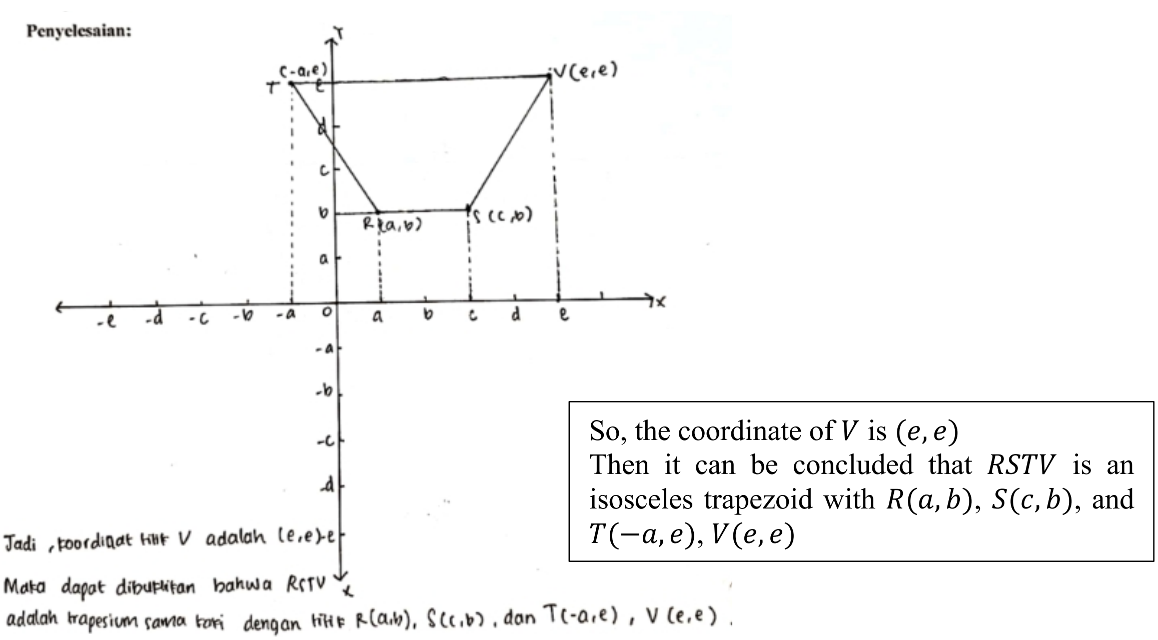


Figure 3: Group work which could have been more successful in solving problems

The group writes down the answers starting with drawing an isosceles trapezoid at Cartesian coordinates. The group needed to write down how to get the point coordinates. There is no basis for providing conclusions on the evidence carried out. The text provided only shows that after the group determined the point coordinates, they concluded that $RSTV$ was an isosceles trapezoid.

We identified that this group could have been more successful in proving an isosceles trapezoid. It is because mathematics conceptual knowledge was not used. Conceptual knowledge is essential to understand the basic concepts in solving mathematical problems (Ho, 2020). Polya (1945) divides problems into "problems to find" and "problems to prove," in which this study used problems to prove mathematics. Students need to be corrected in interpreting symbols a, b, c, d and e, which is known in the problem. They assume that the symbols a, b, c, d and e represent numbers 1,2,3,4 and 5, respectively, on the x-axis and y-axis. At the same time, it should be the symbol a, b, c, d and e and is any number on the x-axis and y-axis. This misrepresentation causes the group to need clarification in drawing points that have coordinates $(c - d, e)$. They change the coordinate of point T to $(-a, e)$, whereas $(c - d, e)$ and $(-a, e)$ are different coordinates.

In group discussions, students orient themselves by analyzing tasks to prepare for problem-solving. However, this orientation indicates that they are unsure of their coordinate knowledge. The following is an excerpt of the group's utterances during the discussion. Assume the group members are S3 and S4 while the researcher is R. The text in bold and italics is a coding scheme for indicators of metacognitive regulation in collaborative problem-solving.

(After they have finished reading the questions)
S3: "Shall we use the coordinates?" ***(Orientation-1)***
S4: "Yes, it is true."
S3: "At $T(c - d, e)$, what point do the coordinates have a minus sign?" ***(Orientation-1)***
"At $T(c - d, e)$, what point do the coordinates have a minus sign?" His sentence shows that S3 has no understanding of point coordinates. S4 also needed help understanding the meaning of the symbol, but in the end, they agreed that the symbol a, b, c, d and e represent the number $1, 2, 3, 4,$ and 5 on the x-axis and y-axis, respectively. The group has a shared perception of the coordinates of the points ***(Orientation-2)***, but the hypothesis about the task content they make needs to be corrected.

There was no choice of strategy discussed by the group in proving an isosceles trapezoid. The group only planned the proof by drawing isosceles trapezoids without using concepts, principles, theorems, properties, corollary, and lemma. It can be seen from the excerpts of the conversation.

S3: "How to prove isosceles trapezoid? You can prove it through pictures alone" ***(Planning-3)***
S4: "I think so" ***(Planning-3)***

Based on the results of interviews with the group, we obtained that the group knew that the steps were incorrect, but they could not find another way to prove that the shape is an isosceles trapezoid.
R: “Do you think the answers that have been written are correct?”
S3: “I do not think it is right, but we have no other way to prove it” ***(Monitoring-1, Evaluation-2)***
S4: “not yet right because we were just guessing” ***(Monitoring-1, Evaluation-2)***
From the results of the interviews above, the group assessed their learning outcomes. They judge their work as not optimal. However, they do not try to improve their work.

Metacognitive regulation form of more successful outcome group in solving geometry problem collaboratively

Based on group conversations in discussing solving problems, two excerpts of conversations are used to identify the dominance of forms of metacognitive regulation.

Conversation Excerpt (1)

S1: “Let us start by drawing the coordinates, shall we?”
S2: “I think so.”
S1: “Do point R drawn here?”
S2: “Point R can be drawn in any position.”
S1: “True, but we must note that the symbol $a, c, c-d$ are on the x-axis and b, e are on the y-axis.”

Conversation Excerpt (2)
S1: “How do we start proving isosceles trapezoids?”
S2: “We should first know the properties of an isosceles trapezoid.”
S1: “Okay. It has one pair of parallel sides that are not the same length and another pair of sides that are the same length but not parallel. The sum of the interior angles between parallel sides is 180°.”
S2: “So, what next.”
S1: “First, we show the side lengths of TS and VR and the same length. Let us just use the Pythagorean theorem” (after trying for a while, they found a problem)
S2: “It seems difficult. How do you prove the other two parallel sides? What if we show that this isosceles trapezoid can be constructed from a rectangle and two congruent right-angled triangles?”
S1: “Okay, let us try. We make an auxiliary line first.”

Based on the excerpts of group conversations above, it can be identified that the form of metacognitive regulation is Co-Constructed Social Metacognitive Regulation (CSMR). S1 and S2 share ideas. In excerpt (1), S1 gives the idea that the first step is to draw coordinates, and S2 justifies and emphasizes that points on coordinates can be drawn at any position. S1 agrees and reminds the meaning of the symbols in the problem. In excerpt (1), the group builds on each other's ideas to devise a strategy to solve the problem. A similar explanation can also be identified in excerpt (2).

S2 offers a strategy to prove an isosceles trapezoid. The strategy is to use the properties of an isosceles trapezoid. S1 justifies this method and gives an idea to show one of the isosceles trapezoidal properties by using the Pythagorean theorem. However, after they tried, they ran into problems. Therefore, S2 offers another strategy by giving reasons. S1 supports and continues the strategy by trying to make an auxiliary line. The group exchanges thoughts and generates new ideas to solve problems. Therefore, the dominant form of metacognitive regulation in this group is CMSR. The group exchanges thoughts and generates new ideas to solve problems. Therefore, the dominant form of metacognitive regulation in this group is CMSR. The group exchanges thoughts and generates new ideas to solve problems. Therefore, the dominant form of metacognitive regulation in this group is CMSR.

Metacognitive regulation form of less successful outcome group in solving geometry problems collaboratively

Some excerpts of group conversations are used to identify forms of metacognitive regulation in collaborative problem-solving. The following shows two examples of excerpts of student group conversations.

Conversation Excerpt (1)
S4: "$c - d$ can be interpreted between points c and d on the x-axis. I think it can be easy."
S3: "That time?"

Conversation Excerpt (2)
S3: "I know the point V will be $(\ldots, e)$ or it could even be$(-a + d, e)$"
S4: "That is not true. We calculate from the coordinates, then the point $V\ (e, e)$."

The results of group conversations show that metacognitive regulations that occur in solving dominant collaborative problems in the form of Ignored Social Metacognitive Regulation (ISMR) can be identified. The ISMR form is found in the examples of the two excerpts above conversation, where S4 rejects or ignores S3's ideas and, conversely, S3 doubts S4's opinion. In the collaborative problem-solving process, S4 dominates in providing solutions and often ignores S3's ideas to defend his ideas in finding a solution. The solution provided by S4 was the wrong solution, but S3 seemed forced to accept it despite doubts about the answers they wrote. S4 ignored S3's ideas and concentrated on his thoughts.

DISCUSSION

Metacognitive regulation can emerge well in group activities, not only in individual contexts. This research proves that student metacognitive regulation can emerge in collaboration with other students in problem-solving activities. Shared knowledge construction and joint information problem-solving challenge students to discuss and regulate their and each other's cognitive activities, providing an opportunity to practice with and refine one's metacognition (Raes et al., 2016; Thalemann & Strube, 2004). Iiskala et al. (2011) concluded that metacognitive experience and regulation emerged in collaborative processes. It was not reducible only to the individual level, which he termed Socially Shared Metacognition.

Table 3 compares the metacognitive regulation that emerged in the groups with more and fewer results. The comparison is presented on every aspect of metacognitive regulation. The comparison results showed that every aspect of metacognitive regulation emerged in the more successful and less successful groups. However, not all indicators can be identified during the problem-solving process. The difference in metacognitive regulation in the two groups is the quality of their metacognitive activities. The ability of students to manage their learning is considered necessary for the quality of collaborative learning (Ucan & Webb, 2015). In addition, there are findings that conceptual knowledge has a role in solving mathematical proof problems. The more successful group had better mathematics conceptual knowledge than the less successful group.

Metacognitive Regulation Aspect	More Successful Group	Less Successful Group
Orientation	The group agrees on the task content hypothesis, which shows that their prior knowledge is good enough.	Self-orientation for groups that are less successful shows disbelief in the knowledge they have.
Planning	The group has several settlement strategies planned together. They choose one strategy that they think is easier to solve the problem.	The group has only one agreed strategy. However, the strategy they agreed on could have been more precise.
Monitoring	Students are aware of their understanding of themselves and their group mates. They provide further explanation as a form of their awareness of their partner's cognitive conflict.	The group realizes that their understanding and knowledge could be improved. Nevertheless, they continued to solve the problem approximately.

Evaluation	Evaluation does not appear in speech when the group is discussing. However, the interview data analysis found that the groups reviewed the quality of group performance and learning outcomes.	Evaluation does not appear in speech when the group is discussing. The group realized that the strategy they used needed to be more appropriate. However, there has yet to be an attempt to improve the answer.

Table 3: Comparison of the emergence of metacognitive regulation in the group with more and less results

Based on the results of the conversation analysis that occurred when students discussed solving problems, the researcher found that the more successful group's dominant form of metacognitive regulation was co-constructed social metacognitive regulation. The less successful group has a dominant form of ignored social metacognitive regulation. The results of this analysis are empirical evidence of a form of metacognitive regulation in solving collaborative problems initiated by Molenaar et al. (2014). It also shows that interactions that build ideas between group members give better results than groups that ignore the ideas of other group members.

The difficulty in implementation is that researchers must carefully determine which utterances are included in metacognitive or cognitive activities. Researchers must be directly involved when observing group activities, not just relying on video results. Video is used to reconfirm the researcher's understanding of the activities carried out by students and how their metacognitive regulation appears. This study was limited to only two groups which were case representatives. In future studies, the representative group can be expanded. In addition, we limit the type of problem to prove where problems with that type are complex for students. Further research can develop tasks with the type of problem to find.

CONCLUSIONS

The more successful and the less successful groups demonstrated metacognitive regulatory activity that appeared in verbal form. Both groups carried out every aspect of metacognitive regulation, but the quality differed. The difference in the quality of this metacognitive regulation indicates a level of metacognitive regulation. De Backer et al. (2016) gave the term level of metacognitive regulation, which describes the different qualities of metacognitive regulation called low and deep-level metacognitive regulation. Furthermore, the results of this study indicate that differences in interactions that occur in collaborative groups will provide different forms of metacognitive regulation. In this study, the more successful group had the CSMR form, while the less successful group had the ISMR form. Further research would be exciting to identify other forms of metacognitive regulation in collaborative problem-solving.

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