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A COMMOGNITIVE STANDPOINT: THE PROCESS OF PROBLEM-SOLVING IN POLYHEDRON

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Abstract

This study aims to describe students' commognitive in the process of solving the problem in polyhedron, based on the four stages of Polya. This study uses an approach with a descriptive type of research. The instruments used in this study were in the form of problem-solving test questions and interview guidelines. The subjects of this study were students of class VIII in one of the schools in the Nganjuk district. The result of this research is that at each stage of problem-solving students use cognitive components. Narrative components that affect students' success in solving problems, as seen in the results of subject answers. This shows that narrative has an important role in the problem-solving process. The narrative component is related to understanding mathematical concepts, so it is hoped that in learning students can understand concepts. The results of this study indicate that students are still more focused on the final solution and attention to an important component in the problem-solving process, in this case, the commognitive component.

Keywords: *Commognitive, Problem Solving, Polyhedron*

INTRODUCTION

One of the main goals of learning mathematics according to the Ministry of National Education is to improve problem-solving skills (Pramono, 2017). Problem-solving in NCTM (2000) is not only the goal of learning mathematics but also the basis for achieving other goals of learning mathematics. Based on the regulation of the Minister of Education and Culture number 36 of 2018 in the 2013 curriculum (revised 2018), it is emphasized that problem-solving is the goal of every learning (Untarti & Kusuma, 2018; Rahmmatiya & Miatun, 2020).

Wulan & Rosidah (2020) argued that an important part of learning mathematics is problem-solving ability. Problem-solving skills are also important in dealing with problems in everyday life, so problem-solving skills are very important for students to have. It is similar to the opinion of Ruseffendi (in Islamiah et al., 2018)

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that problem-solving skills are very important both in learning mathematics and in everyday life. It can be concluded that problem-solving has an important role in creating thinking processes, understanding concepts, mathematical communication with students, and helping students in solving problems in everyday life.

According to Polya (in Wulan & Anggraini, 2019), problem-solving is an activity to find a solution or a solution to a problem where a solution cannot be found immediately. Meanwhile, according to Krulik and Rudnick's opinion, problem-solving is an individual effort using previously acquired knowledge, skills, and understanding to find a solution to a problem. (Kusumaningtyas et al., 2017).

Polya's theory of problem-solving steps is the most suitable for the majority of students' problem-solving in mathematics (Carson, 2007; Wulan & Rosidah, 2020). Based on this, the researcher intends to use the Polya model problem-solving indicators in this study. Polya suggests that the steps in problem-solving include (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back (Sunandar et al., 2018).

As an effort to achieve the goals of learning mathematics, one of them is to know the abilities and ways of thinking of students, so that teachers can design learning according to students' abilities. As explained earlier that one of the goals of learning mathematics is problem-solving. Students' problem solving process can be analyzed using commognitive (Presmeg, 2016; Lefrida et al., 2021; Rossydha et al., 2021). Commognitive is a combination of the word communication with the word cognitive which emphasizes more on individual communication with his thoughts. In other words, thinking is part or form of individual communication (Sfard, 2008).

Thinking can be seen as an individual communication activity with himself. The process of interpersonal communication and the process of thinking are two different manifestations of the same phenomenon so the two terms are combined to form a new term, namely commognitive (Ngin, 2018; Setyo et al., 2019). There are four components in cognition according to Sfard (2008) such as word use, visual mediator, narrative dan routine.

Word use is the use of mathematical terms or words (Sfard, 2008) for example line segments, sides, lengths, widths, and others related to the polyhedron. A visual mediator is an object that is used to represent objects in mathematics (Rossydha et al., 2021) such as graphs, sketches, diagrams, and so on. A narrative is an explanation of mathematical facts such as definitions, theorems, axioms, and others (Zayyadi et al., 2019). Routine is the process of rules that describe a pattern in mathematics such as defining, proving, and abstracting (Sfard, 2008). In this study, routines can be in the form of steps used by students in problem-solving.

One of the learning materials in mathematics is the shape of a solid figure with a flat side. In this study, it will describe how the commognitive component of students in solving the problem of polyhedron. The material on polyhedron is used based on the

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possibility of using all commognitive components during the problem-solving process. Several previous studies have examined students' commognitive in the problem-solving IDEAL model (Zayyadi et al., 2019), problem-solving strategy in commognitive point of view (Rossydha et al., 2021), and also students' mathematics discourse from a commognitive point of view (Bistari, 2015; Roberts & Roux, 2018).

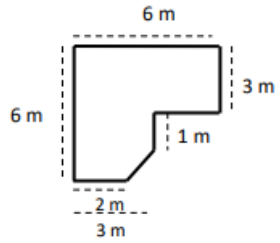
However, there are limitations to the description of the commognitive students studied in other problem-solving theories, one of which is the problem-solving process of the Polya model. Therefore, this study intends to obtain an overview of the commognitive components at each stage of Polya's problem-solving in the polyhedron material.

The commognitive picture can be used to determine the extent to which students think in solving problems so that they can be used as initial capital in developing learning strategies according to the character and abilities of students.

METHODS

This research uses a qualitative research approach with a descriptive type of research. The data collection technique used in this research is by giving a problem solving test of polyhedron and interviewing research subjects. Before the problem solving test questions and interview guidelines were used, the instrument was tested and validated by the experts. The problem solving test instrument is presented in figure 1.

1. Pak Jerome adalah seorang tukang kayu, ia akan membuat peti berbentuk kubus dengan panjang sisi luar peti 60 cm dan tutup peti berbentuk limas dengan tinggi sama dengan panjang sisi luar peti. Pak Jerome berencana akan melapisi peti dan tutupnya tersebut dengan karpet pada seluruh sisinya. Berdasarkan informasi tersebut, tentukan:
   a. Luas karpet minimal yang dibutuhkan pak Jerome!
   b. Jika harga karpet tersebut $RP.15.000/m^2$, berapa biaya minimal yang dibutuhkan pak Jerome?
2. Sebuah kolam renang berbentuk gabungan beberapa bangun ruang sisi datar dengan kedalaman seluruh sisi kolam adalah $2m$. Berikut merupakan ilustrasi kolam renang jika tampak atas.



Ilustrasi kolam renang tampak atas

Dari informasi tersebut, tentukan:
   a. Berapa liter air maksimal yang dapat ditampung kolam renang?
   b. Jika kolam diisi dengan debit $0{,}4\ liter/menit$, berapa lama kolam renang yang semula kosong terisi sampai penuh?

Figure 1. Problem solving test instrument

The results of the problem-solving test were categorized into three for further use in the selection of research subjects. The research subject consisted of one student with high, moderate, and low problem-solving ability categories. The categorization of students' problem-solving abilities is presented in table 1.

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Table 1. Category of problem-solving ability

Interval	Categories
65-100	High
55-64	Moderate
0-54	Low

(Fatmawati & Murtafiah, 2018)

The scoring technique used in this study is to assign a score to each stage of problem solving based on the Polya stages presented in table 2.

Table 2. Problem-solving test scoring guidelines

Problem Solving Step	Score	Description
Underesting the problem	1	Students do not identify elements that are known and asked.
	2	Students identify elements that are known and asked to be incomplete or inaccurate
	3	Students identify all the elements that are known and asked completely and accurately.
Devising a plan	1	Students do not write the problem formulation.
	2	Students design plans that are not in accordance with problem solving
	3	Students design a plan according to the problem that is written correctly
Carrying out the plan	1	Students do not carry out the plan.
	2	Students carry out a complete and appropriate strategic plan but the results are not precise.
	3	Students carry out the entire plan or calculation strategy correctly and with the right results
Looking back	1	Students do not analyze the solutions obtained
	2	Students analyze solutions that do not match the answers or do not follow the procedure and are not appropriate
	3	Students analyze the solutions obtained and draw conclusions appropriately
Maximum Score	**24**	

$$\text{Final Score} = \frac{total\ score}{maximum\ score} \times 100$$

Data analysis techniques are carried out continuously using data reduction techniques, data presentation, conclusions, and verification. In this study to check the validity of the data used triangulation techniques and member checks. Commognitive indicators in problem-solving can be seen in table 3.

Table 3. Commognitive indicators in problem solving

Commognitive	Description
Word use	Students use mathematical terms or words in the form of area, volume, edge, cm, m, etc.
Visual	Students use pictures, graphs and tables that can be used to

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Commognitive	Description
mediator	represent mathematical objects
Routine	Students use clear and precise work patterns or steps in solving problems
Narrative	Students describe mathematical facts such as definitions, theorems, axioms, and the use of commognitive components

RESULTS AND DISCUSSION

This study aims to describe the commognitive component of students in the process of solving the problem of polyhedron based on the four stages of Polya. Based on the results of the problem-solving ability test, it was found that from a total of 21 students, five students had a high problem-solving ability category, six students had a moderate problem-solving ability category, and ten students had a low problem-solving ability category. The research subjects were taken from each category of problem-solving ability and on the recommendation of the class teacher (Table 4).

Table 4. Research subjects

Name	Subject Code	Categories	Final Score
RIA	S1	High	95
AFA	S2	Moderate	62
AIR	S3	Low	33

The following are the results of solving the subject problem based on the Polya stages which were analyzed using the commognitive component.

Understanding the Problem

At the stage of understanding the problem, the subject divides or identifies the problem into several parts, such as writing down information that is known and asked. Zayyadi et al. (2019) states that by dividing the problem into several parts in this case identifying the information obtained in the problem will make it easier for the subject to understand the problem.

At the stage of understanding the subject matter of S1, S2, and S3 using the commognitive word use component by writing down the information obtained in the problem. Such as writing edge = 60 cm, height = 60 cm, and so on the subject's answer sheet. Nardi et al. (2014) explained that visual markers of algebraic expressions are often manifested in verbal form.

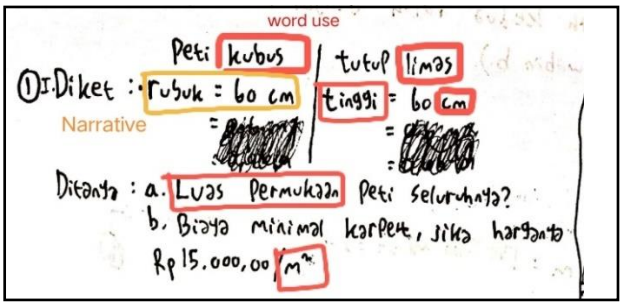

Figure 2. S1 Understanding the problem

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The results of the answers of subject S1 in figure 2 shows that in addition to using the commognitive word use component, the subject of S1 also uses narrative. The narrative is used to define edges. Subject S1 wrote edge = 60 cm indicating that indirectly the subject has been able to define "edge" in the form of polyhedron. Mathematical theories, definitions, proofs, and theorems are narratives in mathematical discourse (Zayyadi et al., 2019).

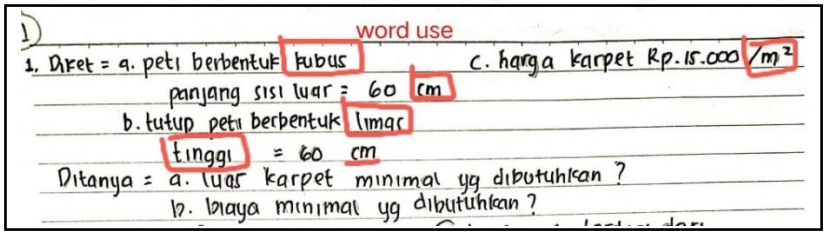

Figure 3. S2 Understanding the problems

Based on the results of the answer sheet in figure 3, the S2 subject did not write down special symbols related to the polyhedron such as the edge (*r*) or side (*s*). S2 subjects only write down information according to the questions given. This shows that the master's subject is less able to connect the mathematical concepts in the problem with symbols related to the material. Mudaly & Mpofu (2019) states that students' understanding of concepts can be described by students' ability to relate mathematical concepts to the symbols associated with them.

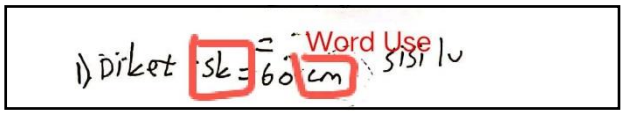

Figure 4. S3 Understanding the problem

The results of the S3 subject's answers in figure 4 show that the word use used represents the information in the problem, although the information identified by the S3 subject is still incomplete. In the results of the interview, the doctoral subject was also unable to explain in detail the information obtained from the questions.

P *What do you understand from the question?*
S3 *I can figure out how to calculate the area of the carpet and I can calculate the price of the carpet per meter*
P *Alright, what information do you know and ask from question 1?*
S3 *It is known that the length of the outer side is 60 cm and the lid of the crate is in the shape of a pyramid with a height equal to the length of the outer side of the crate*

Mudaly & Mpofu (2019) categorize students at level 1 (low) when students cannot understand the problem or identify problems with statements that are not mathematically acceptable.

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Devising a Plan

At the stage of planning the strategy of the subject of S1 using components of commognitive word use, visual mediator, and narrative. While the subject of S2 uses commognitive components in the form of word use and narrative. Mudaly & Mpofu (2019) explained that the differences in mathematical objects used in solving problems were influenced by the conceptual understanding possessed by students. In line with the results of research by Rossydha et al. (2021) that the use of the commognitive component by students is based on students' understanding of mathematical concepts.

S1 and S2 subjects use commognitive word use components in this stage in the form of terms and symbols in mathematics, namely the terms cube, pyramid, and so on. Sfard (2008) explains that certain terms or symbols are considered mathematical if they display mathematical words such as those related to quantity and form. The use of the word refers to mathematical vocabulary and ordinary words that have special meanings in mathematics (Setyo et al., 2019).

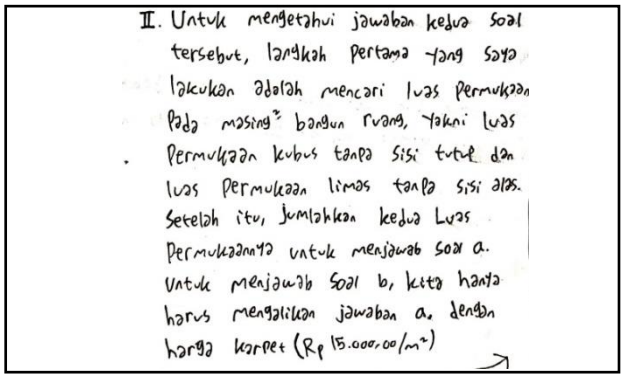
II. Untuk mengetahui jawaban kedua soal tersebut, langkah pertama yang saya lakukan adalah mencari luas permukaan pada masing² bangun ruang, yakni luas permukaan kubus tanpa sisi tutup dan luas permukaan limas tanpa sisi alas. Setelah itu, jumlahkan kedua Luas permukaannya untuk menjawab soal a. Untuk menjawab soal b, kita hanya harus mengalikan jawaban a. dengan harga karpet (Rp 15.000,00/m²)

Figure 5. S1 planning strategy 1

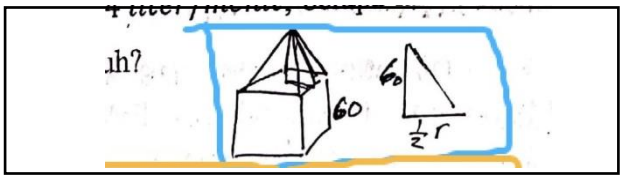

Figure 6. S1 planning strategy 2

While the visual mediator component used by the S1 subject in the form of a combination of flat figure sides is shown in figure 6. The S1 subject uses a visual mediator to facilitate the problem-solving process as described in the previous chapter. Sfard (2008) suggests that visual mediators are used as a means to convey or express thoughts. S2 and S3 subjects did not use visual mediators in solving problems, thus affecting the results obtained. This is in line with the research of Setyo et al. (2019) if the selection of visual mediators is wrong then students will have difficulty in continuing to the next solution.

The use of the cognitive narrative component by the undergraduate subject at the stage of planning a

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strategy in the form of the subject's argument against the use of a visual mediator. At this stage the subject of S1 can explain in detail what strategic plan will be used in solving the problem, this is shown in the results of the researcher's interview with the subject of S1.

P *after you understand problem 1, what strategy or plan of steps will you use to solve problem 1?*

S1 *The first step I took was to find the surface area for each of the shapes, namely the surface area of a cube without a lid and the surface area of a pyramid without a base.*

P *Why did you choose to use that method?*

S1 *Because in the question he said he would coat the crate and the lid with a carpet on all sides, so the surface side was looking for.*

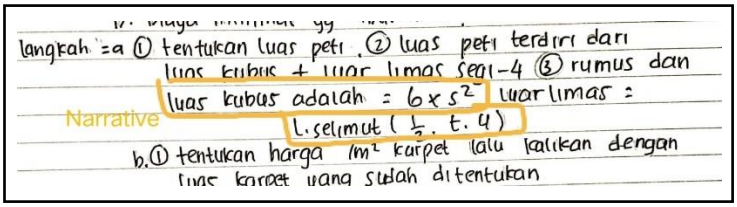

Figure 7. S2 degree planning a strategy

While the narrative is used by the subject of S2 to define the surface area of the cube and pyramid as shown in figure 7. According to Thoma & Nardi (2016), a Narrative is a description of a mathematical object in the form of writing or verbal. Sfard (2008) argues that the use of mathematical objects by students is influenced by the narrative used to find alternative answers to problem-solving. The results of the S2 subject's answer in figure 6 show that the subject can define the surface area of the cube and pyramid but it is not following the given problem.

Carrying-out The Plan

At the stage of implementing the strategy, the subject carries out the previously planned strategy. At this stage the subject uses commognitive components in the form of word use, visual mediator, routine, and narrative.

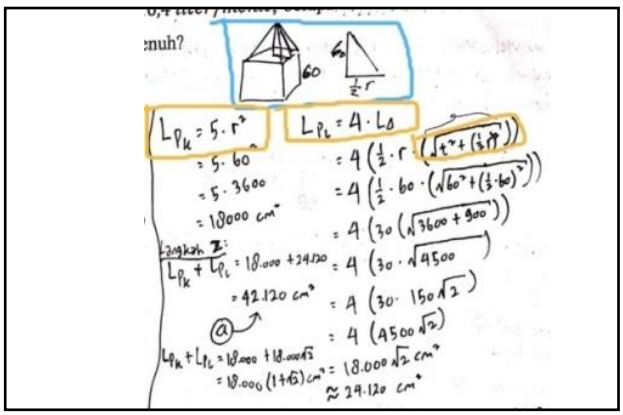

Figure 8. S1 implementing strategy

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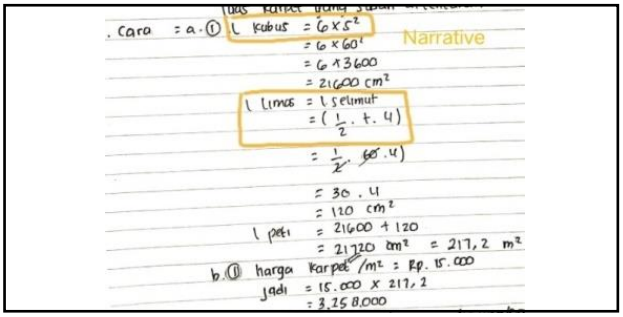

Figure 9. S2 implementing strategy

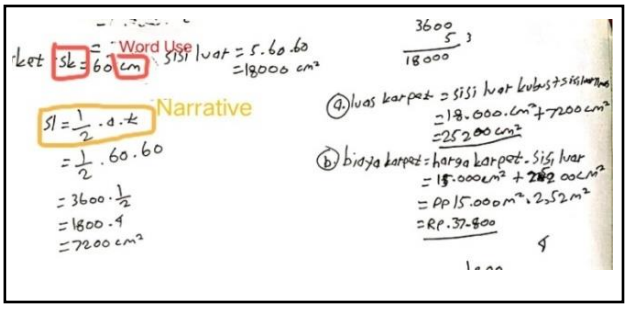

Figure 10. S3 implementing strategy

At the stage of implementing the S1 subject strategy using a commognitive visual mediator component, the S1 subject can solve problems with the right process and results. Setyo et al. (2019) stated that the visual mediator plays an important role as a communication tool. While the S2 and S3 subjects did not use the commognitive visual mediator component at this stage in solving problems, so there was a misunderstanding that caused the results obtained to be inaccurate.

Based on the answers obtained by the subject, it shows that the importance of visual mediators in problem solving. Thoma & Nardi (2018) explained the importance of using visual mediators in accordance with certain discourses. In line with research that visual mediator can be regarded as students' interpretation in solving mathematical problems (Setyo et al., 2019). If the visual mediator selection is wrong, students will have difficulty in continuing the next solution.

At this stage, the S1 subject can describe each commognitive component that is used appropriately according to mathematical concepts. This shows that the S1 subject is able to understand and solve problems in accordance with mathematical concepts accompanied by appropriate supporting arguments. Roberts & Roux (2019) stated that mathematical discourse is characterized by narratives about mathematical objects that can be supported by precise or correct mathematical axioms, definitions, or theorems.

While the S2 and S3 subjects are still unable to properly describe the use of each commognitive component during the problem solving process. This can be seen from the results of the researcher's interview with the subject.

P Can you explain how the process you went through to get the results below?

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S2 The first way I determine the area of the cube the formula is 6×s^2, after that the second I determine the area of the pyramid, the area of the pyramid is 1/2×h×4
P Why did you choose to use this formula (the formula for the area of a cube)?
S2 Because yesterday I thought about using that formula, as far as I know this formula.

Subjects S2 and S3 defined the surface area based on what they remembered. In another sense, the subject cannot explain the basic concept of the definition of the surface area of a flat-figure side. Although on the answer sheet the subject of S2 can write the formulas for the surface area and volume of the polyhedron. Mudaly & Mpofu (2019) said that the majority of students could imitate the solutions they had seen but could not provide appropriate arguments according to concepts in mathematics. In other words, students only imitate what the teacher has learned and taught in class.

Students who find alternative answers using conceptual understanding and procedural fluency are students who can find alternative answers using narratives that can be linked to other mathematical objects. (Mudaly & Mpofu, 2019). Lack of understanding in a concept in mathematics can lead to errors in solving mathematical problems (Berger & Bowie, 2012; Emanuel & Meilantifa, 2022).

Looking Back

The stage of re-examining the answers was carried out by the subject by re-examining the use of the commognitive component in the answer. This can be seen in the results of the researcher's interview with the subject.

P While you were doing this did you also double check your answers?
S1 yes ma'am
P How do you check answers?
S1 I see again I'm over and over again
P Oo you recalculate your answer so?
S1 Yeah right

At the stage of re-examining the subject using commognitive word use and routine components. Students who do the review stage are students who have concerns about alternative answers that have been found, so students need to look back at whether the results of alternative answers are in accordance with the problem (Rossydha et al., 2021).

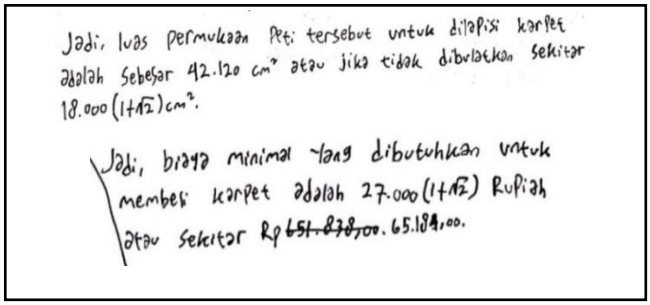

Figure 11. S1 looking back

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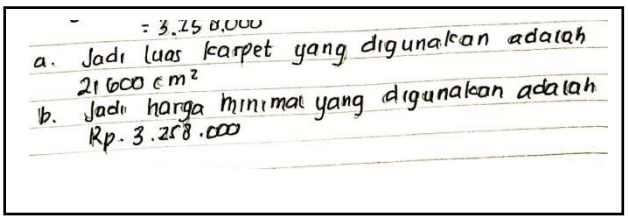

Figure 12. S2 looking back

At this stage, the subject of S1 and S2 analyzes and writes the final conclusion based on the answers obtained. While the S3 subject did not write a conclusion at the end of the answer. Most of the students did not verify their final answer (Zayyadi et al., 2019).

CONCLUSION

The results of this study indicate that students are still more focused on the final result and ignore an important component in the problem-solving process in this case is the commognitive component. The results also show that in every problem-solving process, the use of commognitive word use components, visual mediators, and routines accompanied by supporting narratives is one of the characteristics of students understanding related mathematical concepts. The narrative component affects students' success in solving problems, as shown in the results of the subject's answers. This shows that narrative has an important role in the problem-solving process. The narrative component is related to understanding mathematical concepts, so it is hoped that in learning it can emphasize students' understanding of concepts.

Several learning models that can be used in learning are the PMR approach, Problem-Based Learning (PBL), and reciprocal teaching. This research is expected to provide an overview related to understanding students' thinking in solving mathematical problems. Researchers recommend further research related to how to develop strategies or learning media by paying attention to the commognitive component so that it can improve students' problem-solving abilities. How commognitive students at other levels of education and or other learning materials. And how the commognitive component in the learning stages in the classroom.

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