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Junior high school students' abilities in solving the open-ended mathematical problems with the context of *Songket* motif

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Abstract

Many researchers stated that most students struggle to solve higher mathematical problems, including open-ended problems. One of many solutions is to apply a realistic context close to students. Hence, this research aimed to analyze students' abilities in solving an open-ended mathematical problem using *the Songket* context, particularly *the Kembang Tengah* motif. The subjects were 24 seventh graders. The instruments for this descriptive research were an open-ended problem and an interview sheet. The results show that in solving the open-ended problem, 88.33% of students understood the problem, 59.72% were able to construct, and 72.22% applied the plan, while 52.78% wrote the conclusion. No students evaluated their solution to the problem. In implementing open-ended problems in the traditional context, students have different solutions based on their various experiences with the context, problem-solving schema, and mean-putting on the problem. They also applied multiple problem-solving strategies in working the problem. The similarity was the use of assumptions in solving the problem. However, some assumptions were inconsistent, neither their prior work nor other mathematical concepts. Therefore, teachers and researchers need to emphasize students' written self-evaluation to check and improve their solutions. Another suggestion is to see the metacognitive process in solving the open-ended mathematical problem using a specific tradition. Furthermore, teachers should engage more in using open-ended problems and scaffold students when facing obstacles in solving them.

Keywords: open-ended; mathematical problem; problem solving; *Songket* motif

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Introduction

One of many abilities that students must have is problem-solving (Annizar et al., 2020; Siagian et al., 2019). This ability is beneficial for their school lives and their daily lives (Porgow, 2005; Saragih & Napitupulu, 2015). It allows students to connect various abstract concepts and make sense of the real-world problem (Lester & Cai, 2016; Stohlmann & Albarracín, 2016). Solving mathematical problems also benefit students by enhancing their thinking abilities, such as reasoning, critical, creative, and even metacognitive thinking (Amir et al., 2018; Basri et al., 2019; Maskur et al., 2020; Pratama et al., 2018). More importantly, solving mathematical problems can improve students' confidence and motivation to learn mathematics and think mathematically (Hendriana et al., 2018; Peranginangin et al., 2019).

Despite those benefits, students in Indonesia are still considered to have poor problem-solving abilities compared to other countries (OECD, 2019; Tanudjaya & Doorman, 2020). Based on the Program for International Student Assessment (PISA) ranking in 2018, Indonesia ranks 75 out of 80 countries (OECD, 2019). It also means that the ability of Indonesian students to solve problems that demand the ability to examine, give reasons, communicate effectively, solve problems and interpret problems in various situations is still very weak (Hewi, La; Shaleh, 2020; Tanudjaya & Doorman, 2020). Some studies suggest that students experienced difficulties answering test questions that measured analytical ability, problem-solving, and interpretation of mathematical questions (Hadi et al., 2018; Rudi et al., 2020; Tambychik & Meerah, 2010).

Many factors could cause this phenomenon. One contributing factor is that teachers rarely implement problem-solving activities (McCormick, 2022; Russo et al., 28 C.E.; Tanujaya et al., 2017). Often, mathematics tasks in the classroom solely demand lower thinking ability to solve them (Boesen et al., 2014; Hiebert, 2003; Lithner, 2004). Furthermore, many textbooks in school do not allow students to generate mathematical ideas, and the exercises tend to support procedural skills rather than solving challenging problems (Jäder et al., 2020; Putri, 2017; Walle et al., 2010). On the other hand, students also rarely practice solving high-level questions on their own (Hafidzah et al., 2021; Nasution & Pasaribu, 2021).

One way to help students improve their problem-solving skills is to implement problem-solving-based instruction, where the primary treatment is to give students higher-order thinking skills (HOTS) mathematical problems (Hasyim, Maylita; Andreina, 2019; Mustapha et al., 2019). One form of these HOTS problems is the open-ended problem (Hamimah et al., 2020; Ulinnuha et al., 2021). Open problems can be grouped into three types: (1) the process is open, (2) the results are open, and (3) the way of further development is open (Becker & Shimada, 1997). By applying open-ended problems at school, students will get used to thinking creatively and critically (Damayanti & Sumardi, 2018; Sapta et al., 2019; Yee, 2000). The nature of open-ended problems is that by solving them, students are invited to achieve extended ideas and challenge their broader perspectives and understanding (Lock, 1990; Swenson, Beranger, et al., 2021). They allow students to recognize their capability and work at their speed (Olewnik et al., 2020). The focus is not restricted to a specific solution.

Students with different abilities will be able to experience both challenges and successes on the same problem. Furthermore, when students can bring various solutions, there will be potential to discover something new (Becker & Shimada, 1997; Lehman & Stanley, 2008).

Many kinds of research focus on developing open-ended mathematical problems (Kurniawan et al., 2018; Putri, 2017; Surya et al., 2020). However, the formulation of the problems developed in these researches tends to be abstract or not in cultural settings (Imai, 2000; Zulfah et al., 2019). Hence, it is less meaningful for students, especially junior high school students. Other studies applied cultural context, but the aim was to explore a single solution for the students (Simamora et al., 2018; Wulandari et al., 2016). Therefore, in this study, an open-ended problem based on local culture will be developed, which uses the context of the Palembang *Songket* motif. The specific motif used in this study is *Kembang Tengah* motif. *Kembang Tengah* is the core motif of South Sumatra's *Songket* that has 16 regular sides. This motif is used because using cultural contexts that are close to students in learning mathematics has several benefits, including helping students understand the phenomenon of mathematics from the perspective of their own life experiences (Charmila et al., 2016), reducing the abstract nature of learning mathematics (Francois, 2012), and create a positive perception on mathematics (Araiku et al., 2020).

Many kinds of research focus on identifying students' abilities in solving an open-ended problem. However, the use of cultural context in the problem has not been extensively applied, despite the apparent benefits to the students. Hence, this study aimed to describe students' problem-solving abilities toward an open-ended mathematical problem with the employment of *the Songket* motif as the problem's context.

Methods

This descriptive research aimed to analyze students' abilities to solve the open-ended problem using *the Songket* context. The subjects of this research were 24 seventh graders, consisting of 9 male and 15 female students of SMPN 9 Palembang, South Sumatra, Indonesia. The procedure of this research is shown in Figure 1.

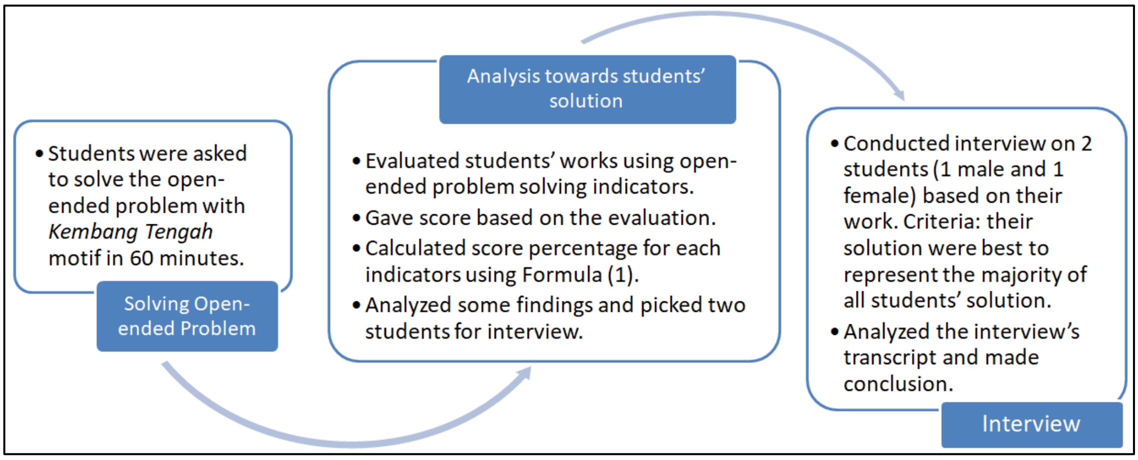


Figure 1. Research procedure

The instruments and the data source in this research are shown in Table 1.

Table 1. Data instruments and data source

Instruments	Data	Data Source
Open-ended problem Students were given one open-ended problem with one of *Songket's* motives, called *Kembang Tengah* (Figure 2). The problem consisted of the motif's description and 3 open ended questions. These questions are designed to allow students determine each motif's area by making sketch based on their perspective towards the motif.	Students solution	Students
Interview sheet The interview sheet was designed semi-structured and used to confirm student's answer.	Interview transcript	Students

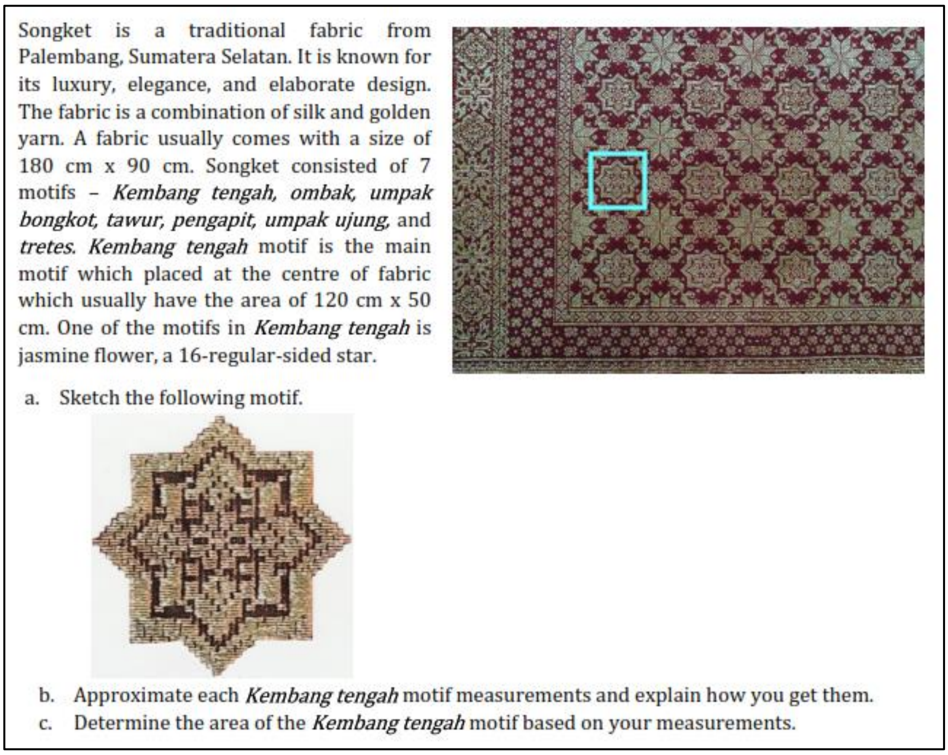


Figure 2. The Open-ended problem with *Kembang Tengah* motif context

The indicators for open-ended problem-solving abilities were synthesized from Polya's problem-solving phase (Polya, 1973), Hong's ill-structured problem-solving process (Hong & Kim, 2016), and Araiku's problem-solving indicators (Araiku et al., 2015), which focused on five abilities, namely understanding the problem, constructing a plan, applying, concluding, and evaluating. The evaluating indicator was implemented due to the nature of the open-ended mathematical problem is an open solution; hence students need to be able to justify their solutions (Douglas et al., 2012). The indicators, sub-indicators, and the maximum score for each indicator are presented in Table 2.

Table 2. Open-ended problem-solving indicator

Problem Solving Indicators	Sub-Indicators	Maximum score per item
Understanding the problem	Interpret information from verbal, nonverbal statements, pictures, or graphics	3
	Identify or formulate questions	2
Constructing plan	Make a consistent problem-solving plan	3
Applying	Applying a problem-solving plan	3
	Applying mathematical concepts	3
Concluding	Provide problem solutions	3
Evaluating	Evaluate the given solution	3

The procedure to calculate students' grade explained as follow:

1. Sum up all students' score in each indicator.
2. Calculate the percentage of the total score in each indicator for all students. The formula used to find the percentage was as follow.

$$TS = \frac{Total\ Score}{Maximum\ Score\ for\ all\ students} \times 100\% \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

3. Make conclusions about student response data. The conclusions were referred to Table 3.

Table 3. Open-ended problem-solving score criteria

Percentage	Criteria
$85\% < TS \leq 100\%$	Excellent
$70\% < TS \leq 85\%$	Good
$50 \leq TS \leq 70\%$	Fair
$TS < 50$	Poor

The works from the students were then cross-examined by interviewing some subjects that represent the most viable solution to the representation of the subjects. The interview transcripts were analyzed to evaluate the results based on open-ended nature, the mathematical concepts, and the context itself.

Results

Classical performance

Some students failed to demonstrate excellence in solving open-ended mathematical problem. Table 4 concludes students' performance in solving the problem.

Table 4. Students problem-solving performance

Indicators	Total Score	Maximum Score	Percentage	Criteria
understanding the problem	106	120	88.33%	Excellent
constructing plan	43	72	59.72%	Fair
applying	104	144	72.22%	Good
concluding	38	72	52.78%	Fair
evaluating	0	72	0%	Poor

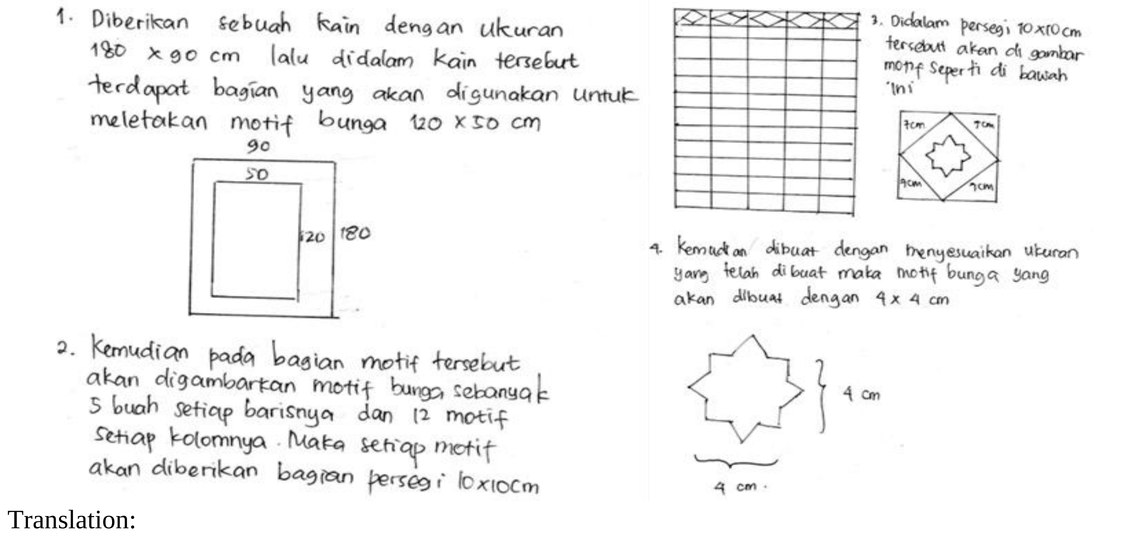
Table 4 shows that the highest score percentage understood the problem with 88.33% (excellent), and the lowest was evaluated with 0%. Most of the students' understanding came from how they interpreted the situation based on their personal experience in the *Songket* context. The context stimulated students to make assumptions about the size of each *Kembang Tengah* motif. Hence, they worked on the problem based on these assumptions and finalized the solution. However, although some students could solve the problem based on their assumptions, they did not evaluate their final solution toward any mathematics concepts. The lack of evaluation caused some errors in the problem-solving process. There were inconsistencies in the work of each line of the solution. Furthermore, some contradiction in students' solutions was found related to other mathematical concepts. Hence, interviews with some students were held to confirm this result.

In addition, it can be seen that the percentage of the applying stage (72.22%) was higher than the constructing plan stage (59.72%). The students did not explicitly write a plan but went straight to applying what they had in mind. Some plans were clearly shown in students' solutions and easily identified by the researchers. These "clear plans" were derived from how students navigated step-by-step work until they achieved the desired solution. Otherwise, the students' works were not fulfilling the constructing plan indicator. The same thing happened in writing conclusions. Many students did not write down the conclusion after completing the calculations.

There were two students, AO (a male representative) and SP (a female representative), were recruited as correspondences for interviews for this research. These subjects were chosen because their performances were representative enough for the rest of the class.

Subject AO

Figure 3 shows Subject AO's solution on problem a.



Translation:

1. Given a fabric with size 180×90 cm. The inside the fabric, there is an area that will be used to put flower motive with size 120×50 cm.
2. Then, at the motive will be drawn 5 flower motive in each raw and 12 motive in each column. Then each motive will be given square part 10×10 cm.
3. Inside 10×10 cm square will be drawn the following motive.
4. Then, by adjusting the size, the motive that will be drawn will be 4×4 cm.

Figure 3. Subject AO on problem a

For the first question, subject AO gave quite clear explanation about how he derived the measurements of the motif. The first step was a reinterpretation of the initial problem. This step indicated that the AO understands the problem given, hence satisfied the first problem solving indicator. The second step was an assumption that the place for *Kembang Tengah* could only fit for 60 motifs, which the size was 5 rows × 12 columns. Therefore, each motif would occupy an area of 10 cm × 10 cm at the fabric.

R : *Let us now consider the second step. Why can AO decide that each row can only have 5 motifs and each column can only have 12 motifs?*
AO : *hmm (thinking)… I was just guessing, sir. Just use feeling, sir. The thing is, the size of the cloth in the middle is 120 cm long and 50 cm wide, so I think 12 equals 5 only.*
R : *Is there another size possible?*
AO : *You can, sir. Like 5 cm × 5 cm each motif. So the motive could be more.*
R : *Why not write that down?*
AO : *The problem is that if 5 cm × 5 cm the motif is too small, it doesn't make sense*

Based on the results of the interviews above, it can be concluded several things. First, in the open-ended problem-solving process, AO students apply several problem-solving strategies simultaneously. When AO explained how he determined the area of each motif 10 cm × 10 cm, the strategy he used was intelligent guessing and testing (approximation). This strategy aroused because AO relates the length and width of the inside of the fabric, which was 120 cm × 50 cm. Indirectly, AO was able to see the relationship between the concept of the area of the flat figure and the greatest common factor (GCF). This was a significant feat in solving open-ended problem.

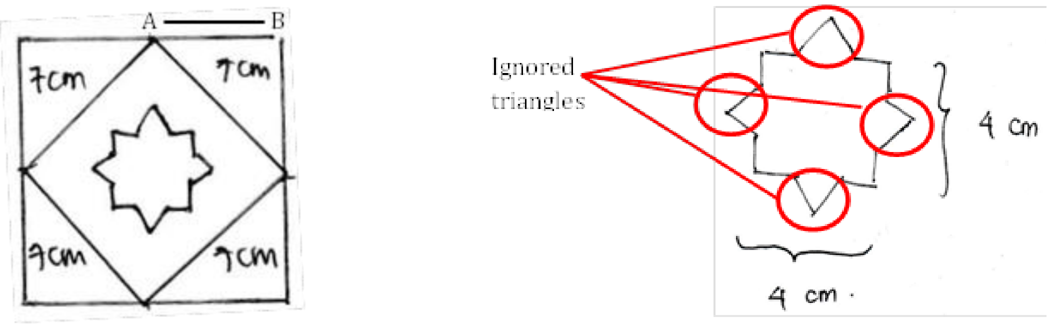
In addition to intelligent guessing and testing strategies, another strategy that emerged from AO in answering question a was logical reasoning. This can be seen when AO asserted that although there were other possible solutions, for example the area of each motif is 5 cm × 5 cm, and this did not make sense because it was too small. This was also the basis for the second conclusion, which is the process of making sense of the results of problem solving by AO. AO was able to argue that certain sizes did not make sense to be a solution to the problem because AO was well acquainted with the *Songket* fabric which is his culture. Hence, it can be concluded that one of the advantages of using real contexts in everyday life, especially regional culture, in designing open-ended mathematical problems is that there is a good sense of students as a basis for solving mathematical problems, so that even offered can vary, but does not contradict their understanding of real life.

The area of 10 cm × 10 cm, however, was not fully filled with the particular *Kembang Tengah* motif. The subject made another assumption that the motif will only take place at the center of each area, which illustrated in statement 3. AO determined that the *Kembang Tengah* motif will be placed inside 7 cm × 7 cm square. This decision was really interesting, hence the researcher asked AO.

R : *AO can explain why this is 7 cm (while showing Figure 4(a))?*
AO : *Because this box has a side size of 10 cm, it will be 7 cm.*
R : *How do I get it?*

AO : This is a square, sir, so this point (pointing point A, see Figure 4(a)) is in the middle. If it is in the middle, it means that the size from here to here (pointing point A and point B, see Figure 4(a)) is 5 cm. After that, use Pythagoras, sir. 5 squared plus 5 squared equals 50. So the root of 50 is close to the root of 49, so the root of 49 is 7.

Based on the results of the interview, AO was able to integrate the concept of the Pythagorean Theorem with solving the problem. In addition, AO also provides an approximation technique as a strong reason to do rounding.



(a) (b)

Figure 4. AO's error solution

After an adjustment, AO concluded that the *Kembang Tengah* motifs have the size of $4\,cm \times 4\,cm$. However, this measurement iwas only for the square shape which completely ignoring the triangle shape (see Figure 4(b)). And after an interview, subject AO stated that he put $4\,cm \times 4\,cm$ as the size only because it was less than 7 cm and no mathematical reasoning behind this decision. Hence, it can be seen that for the first question, subject AO made 3 assumptions in order to solve problem a.

Based on the solution of problem a, subject AO continued to solve problem b, which was determining the size of the motif (Figure 5). This answer met inconsistency with statement 4 in solution a. Comparing both models, ΔABC must be a isosceles triangle with $AB = AC = 1\,cm$ and $BC = 2\,cm$, which was impossible to create a triangle with such measurements, because $AB + AC = BC$.

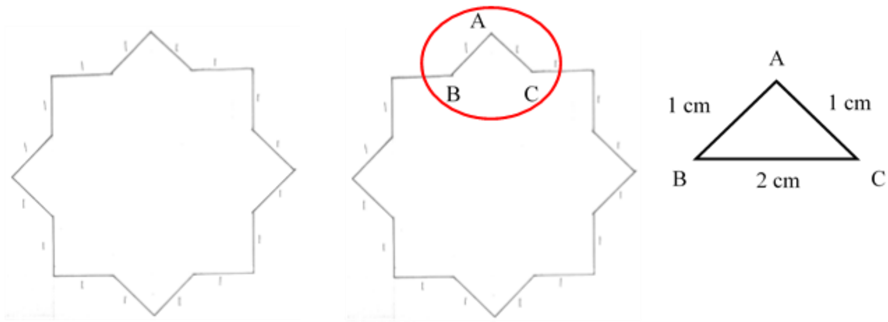


Figure 5. Subject AO on problem b

The error of solution b caused further mistake in solving question c, which was finding the area of the motif. Subject AO solved the problem by dividing the picture into two main parts, a square and 4 congruence triangle. Subject AO didn't find any problem in determining the area of the square. However, in determining the area of a triangle, AO made an error. In

Figure 6, the subject miss calculating $\sqrt{1+1} = \sqrt{1}$ as the height of the triangle, which was supposed to be $\sqrt{1+1} = \sqrt{2}$.

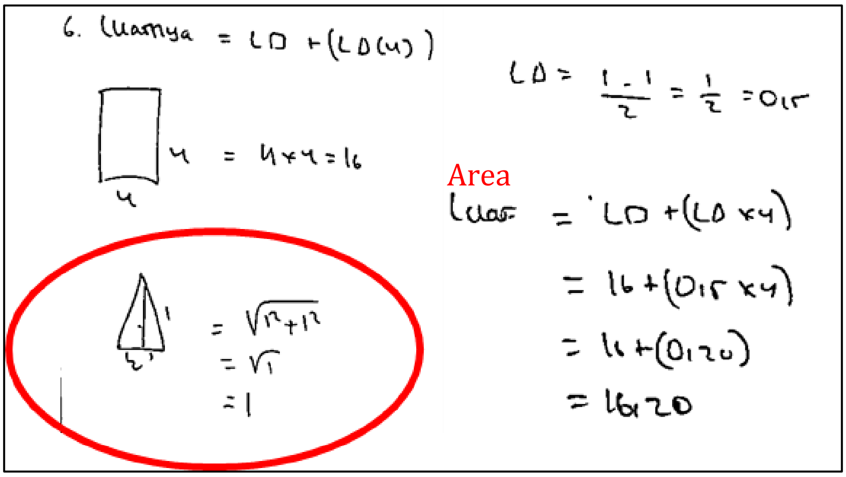


Figure 6. Subject AO on problem *c*

In this particular answer, the researcher conducted an interview to see how the subject arrived to such conclusion.

R : *Are there any inaccurate calculations in this section?*

AO : *Wait a minute sir, I'll take a look first (pay attention to the answer for a moment)...*

R : *Oh yes sir, something is wrong. Should be root 2.*

AO : *That means the next calculation is also wrong, sir. The area of the triangle is* $\frac{2\times\sqrt{2}}{2} = \sqrt{2}$. *So, the total area is also wrong, sir. Should've been* $6 + 4\sqrt{2}$.

From this interview, it can be concluded that subject AO did not consider evaluating his work. However, during the interview, this evaluation process appeared verbally. AO realized his mistakes and eventually was able to improve the solution. It highlights the importance of scaffolding in solving HOTS problems, like open-ended problems. Furthermore, it also can be concluded that evaluating indicators could appear both written and verbally.

Subject SP

In solving problem a, subject SP put similar reasoning. The difference with subject AO was she derived on the conclusion that the space occupied for each motif was 6 cm × 6 cm, including the shape of four triangles. She used different technique to find 16-sided plane $ABCDEFGHIJKLMNOP$. First, she found the area of $PQRS$ and then subtracted by exceeding area (8 equal trapezoids).

Overall, there was no problem with the strategy to find the solution. However, some procedures met some unexplained decisions and causing mistakes (Figure 7). For instance, SP stated that $AB = \frac{1}{2}PC$ based on her assumption. And then in order to find the distance between line PC and line AB or the height of trapezoid BCP (t), there was no mathematical reason why $t = \frac{1}{2}AB$. Therefore, the researchers conducted an interview.

R	:	*SP, can you explain why* $AB = \frac{1}{2}\ PC$*?*
SP	:	*The thing is, this is an isosceles trapezoid, so the shape is symmetrical. It means that the hypotenuse is the same as left and right, so the right triangle is the same. So it is divided into two sir.*
R	:	*If, for example, we draw a line here (make a line that goes through B to the right PC) and here (make a line through A perpendicular to PC), what is the approximate height and base?*
SP	:	*(working in silence) Different, Sir*

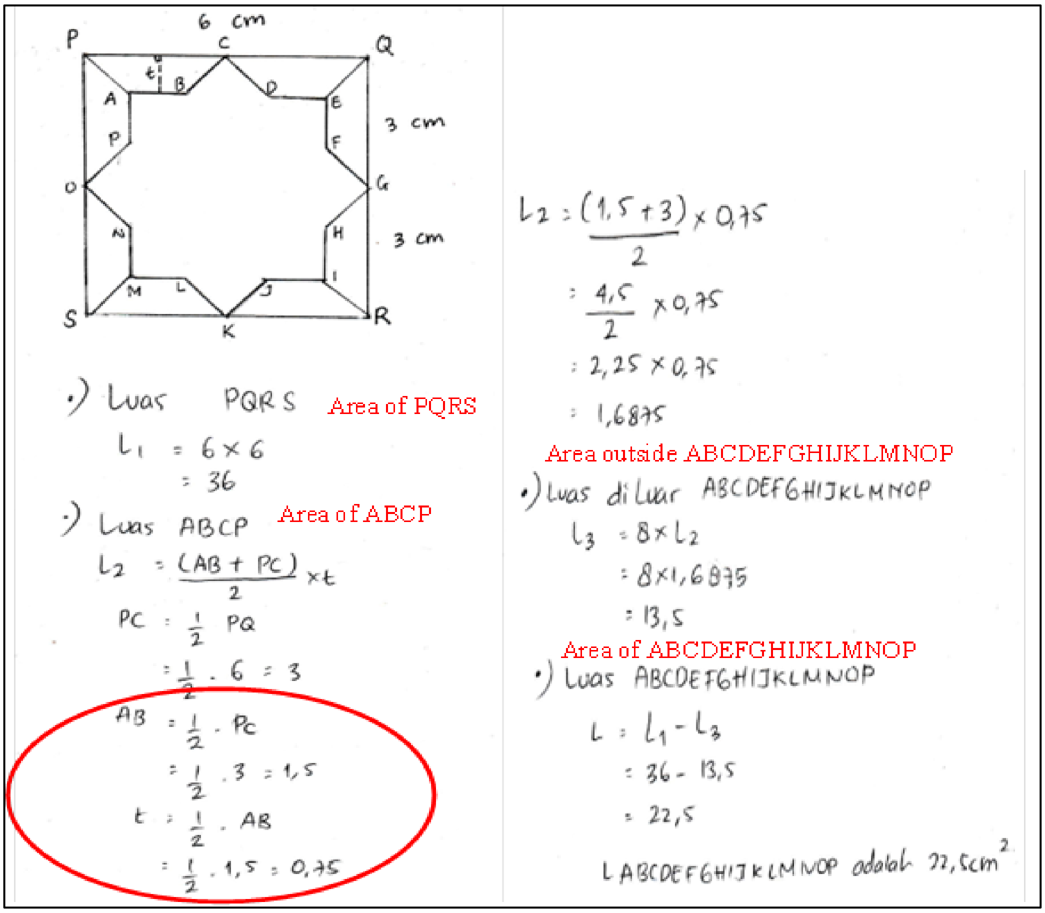


Figure 7. subject SP on problem *b* and *c*

Based on this interview, it can be seen that subject SP failed to improve her solution. It was because SP made assumptions that were not used properly. For example, based on SP's solution, if $t = 0.75\ cm$ and the distance between line EF and GQ is also $0.75\ cm$, then by Pythagorean theorem, BC equals to:

$$BC = \sqrt{0.75^2 + 0.75^2}$$
$$BC = \sqrt{0.5625 + 0.5625}$$
$$BC = \sqrt{1.125}$$
$$BC = 1.06.$$

Since $AB = 1.5\ cm$ and $BC = 1.06\ cm$, which means $AB \neq BC$, then this conclusion contradicted with the stated fact that all sides are equals. This means that the evaluating indicators did not appear from SP both written and verbally.

Discussion

When solving open-ended mathematical problem, majority of students work didn't fit to the problem-solving scheme. Many students didn't explicitly write down the plan to solve the problem and the final conclusion. Instead, they jumped to applying some formulas to the final solution. This was in line with previous research that stated in the problem-solving process, students tend not to write down the steps of understanding and making a problem-solving plan, but went straight to the application stage (Saputri & Mampouw, 2018; Yuwono et al., 2018). This implied that in order to achieve clear and complete data, the design of the problem must accommodate all the indicators needed.

In the application stage, students apply various problem-solving strategies. Moreover, in solving mathematical problems, especially open-ended problems, the ability to relate various concepts in mathematics is crucial (Bahar & Maker, 2015; Douglas et al., 2012). They must explore the initial problem by connecting all their understanding of mathematical concepts (Chong et al., 2018). For example, AO students apply the intelligent guessing and testing and logical reasoning strategies, while SP students apply the partitioning strategy (Dym et al., 2005; Intaros et al., 2014). Both strategies were appropriate for their solution(Chong et al., 2018; Yunita et al., 2019). This difference in strategy arises for two main reasons: different problem-solving plans and different problem-solving schemes. These are based on students' experiences in solving similar problems (Araiku et al., 2020; Mairing, 2017). In addition, students' experiences in everyday life also affect problem-solving (Harding, 2021; Hasbi et al., 2019). As is well known, this research implements the *Kembang Tengah* motif as the context in which the problem is developed. The existence of students' knowledge of this context is beneficial for students to interpret what the questions want. The existence of meaning in the context of this problem helps students make problem-solving plans. Differences in putting the meaning of open-ended problems lead to different problem-solving plans (Chong et al., 2018). It confirms several research results that learning mathematics, associated with students' local culture, will make it easier for students to interpret and understand mathematics (Abiam et al., 2015; Harding, 2021; Nursyahidah et al., 2018). It will also be easier for students to understand because their abstract knowledge can be accommodated and assimilated by their knowledge in everyday life (Hasbi et al., 2019).

Although there were differences in meaning, problem-solving plans, and strategies used, open-ended mathematical problem solving has the same basis, which was the use of assumptions (Diefes-Dux et al., 2010; Mourtos et al., 2004). The assumptions given by students in solving problems are mainly at the stage of applying the plan. Most of the application process goes according to the designed plan, but when faced with obstacles, students will use assumptions as a bridge to reach the desired conclusion. The analysis results showed that some of the students' assumptions were not based on proper reasoning. For example, in the case of AO, it is not explained why the size of *Kembang Tengah* is only 4cm × 4 cm, ignoring the triangular shape. In the case of AO, there is no logical explanation for the assumption that $AB = \frac{1}{2}PC$ and $t = \frac{1}{2}AB$.

The use of assumptions, of course, is not a mistake because in solving high-level problems, logical assumptions are needed (Widana et al., 2018). However, assumptions that are not accompanied by logical reasoning will lead to inconsistent solutions and conclusions (Kumar et al., 2018). Several relevant studies have shown that in solving open-ended problems, inconsistent solutions often occur (Biber et al., 2013; Haryanto & Pujiastuti, 2020). This inconsistency then causes errors in the problem-solving process. Some of the errors identified in this study include the transformation and process skill errors (Shinariko et al., 2020). One example of a transformation error is when subject AO fails to compare the sizes AB, AC, and BC with the intended triangle ABC model. According to several relevant studies, the transformation error made by high school students in solving high-level problems is quite large (Hadi et al., 2018; Shinariko et al., 2020). Furthermore, errors in process skills also often occur in this study. Students fail to explain the procedures or steps used to solve problems, such as calculation errors and failure to provide logical reasoning, so the conclusions are inaccurate.

These two errors should be resolved if students independently carry out the evaluation process (Andrade & Du, 2007; Andrade & Valtcheva, 2009). This evaluation process is intended so that students can check for errors that may be made and see internal consistency (relationships at each stage of completion) and externally (related to other mathematical concepts) in the process of solving mathematical problems (Araiku et al., 2015; Douglas et al., 2012). The subject AO only saw this evaluation process verbally during the interview. It highlights the importance of scaffolding in solving HOTS problems, like open-ended problems (Edson, 2017; Swenson, Rola, et al., 2021). However, this evaluation process failed to occur from SP. Some factors may cause this finding. First, SP was not used to evaluate the given solution (Araiku et al., 2015). Second, SP's ability to connect various geometric concepts is still lacking (Jupri et al., 2022). Third, the SP problem-solving schema is inappropriate (Mairing, 2017). Therefore, for further research, improvements can be made in affirming questions to students to carry out written self-evaluations. In more depth, an independent evaluation process in solving open-ended problems is closely related to students' metacognitive processes (Earl, 2006). In the metacognitive process, the first step that must be done is to make students aware of their process (Mowling & Sims, 2021). So that in further research, it may be possible to see students' metacognitive processes in solving open-ended problems with the use of specific contexts.

Furthermore, the teacher's role is significant in solving open-ended mathematical problems using a cultural context. Students do not make mistakes, especially because students' answers can vary according to their understanding of the problem or their culture. Therefore, teachers need to guide students through scaffolding actively. Future research can analyze how appropriate scaffolding techniques help students solve open-ended problems using specific contexts.

Conclusion

The results showed that students' abilities in solving the open-ended problem with *the Kembang Tengah* motif context, 88.33% of students understood the problem, 59.72% of students were able to construct, and 72.22% applied the plan. In comparison, 52.78% wrote consistent conclusions about their solution. However, no student evaluated their solutions with other criteria or mathematics concepts. In solving open-ended mathematics problems with *the Kembang Tengah* motif context, students came up with different solutions. These differences are caused by various meanings and understanding of the problem, problem-solving schemes, and personal experiences. On the other hand, the similarity of the open-ended mathematical problem-solving process is based on assumption.

The finding of this study is limited to verbal self-evaluation. Therefore, researchers can focus on emphasizing students' written self-evaluation to check and improve their solutions for the following research. The researchers can also see the metacognitive process in solving the open-ended mathematical problem using a particular tradition. Furthermore, it is suggested that teachers should be more engaged in using open-ended with the daily context in their classroom and actively scaffold students for when they face obstacles in solving them.

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Conflicts of Interest

We would like to state that there is no conflict of interest in this research process and article writing in term of ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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