

Artikel Mosharafa

by Similarity Check

Submission date: 04-Apr-2024 01:57AM (UTC-0400)

Submission ID: 2339598013

File name: C.1.c.4.b.3._Artikel_mosharafa_2_CEK_PLAG.docx (404.53K)

Word count: 4980

Character count: 28631

3 Students' Higher Order Thinking Process in Solving Math Problems by Gender

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Article received: 2022-08-18, revision: 2023-01-15, published: 2023-04-30

Abstrak

³⁷Keterampilan proses berpikir tingkat tinggi dalam menyelesaikan masalah matematika diperlukan siswa dalam pembelajaran. Tujuan penelitian mendeskripsikan proses berpikir tingkat tinggi siswa laki-laki dan perempuan level menganalisis (C4), mengevaluasi (C5), dan mencipta (C6) dalam menyelesaikan masalah. Subjek penelitian 1 siswa laki-laki dan 1 siswa perempuan. Instrumen utama peneliti sendiri, instrumen pendukung tes berpikir tingkat tinggi dan pedoman wawancara. Teknik pengumpulan data menggunakan tes dan wawancara. Keabsahan data menggunakan triangulasi waktu. Teknik analisis data melalui reduksi, penyajian data, dan menarik kesimpulan. Hasil penelitian subjek laki-laki (C4), mengenali, menyebutkan hal penting, dan membuat rencana solusi. (C5), memeriksa kebenaran pekerjaan, membuktikan kesamaan luas lahan dan memberikan penilaian. (C6), membuat dua gambar berbeda dari solusi jawaban yang pertama serta membuktikan kesamaan luas. Subjek perempuan (C4), mengenali hal penting dan tidak penting, membuat rencana solusi dengan menggambar lahan, membuktikan kesamaan luas dengan menghubungkan materi sumbu simetri dan rumus luas bangun trapesium. (C5), memeriksa kebenaran hasil pekerjaan dengan menghitung luas lahan serta memberikan penilaian, dan menghubungkan konsep materi sumbu simetri. (C6), membuat satu gambar yang berbeda, tidak membuktikan kebenaran kesamaan luas, dan menghitung panjang pagar.

Kata Kunci: Berpikir tingkat tinggi; Permasalahan Matematis; Jenis Kelamin.

Abstract

Higher-order thinking process skills in solving mathematical problems are necessary in the learning process. The purpose of the study was to describe the high-order thinking process of male and female students at analyzing (C4), evaluating (C5), and creating (C6) in problem solving. The participants were 1 male student and 1 female student. The main instrument was the researcher himself, and the supporting instrument were higher order thinking tests and interview guidelines to collect the data. To validate the data, this study utilized time triangulation. The data analysis was processed through data reduction, presentation, and conclusion. The findings of the study revealed that the male subject could (C4), identify the problem, mention important things, and plan the solutions, (C5) evaluate the work, prove the similarity of the land area and provide an assessment, (C6) make two different pictures of the first answer's solution and prove the broad similarity. The female subject could (C4), recognize important and unimportant things, make a solution plan by drawing the land, prove the similarity of areas by connecting the material axes of symmetry and the formula of a trapezoid area, (C5) evaluate the answer by calculating the land area and providing an assessment, and connecting the material concept of the axial symmetry, (C6) make a different picture, not prove the truth of the area similarity, and calculate the length of the fence.

Keywords: Higher Order Thinking; Mathematical Problems; Gender.

I. INTRODUCTION

The law on the National Education System in Indonesia act no. 20 of 2003, article 1 section 1, stated that education is an intelligible and directed action to create a learning atmosphere and experience supporting the students to develop their capabilities to build spiritual competence, self-control, character, information, noble moral, and other necessary abilities for themselves, society, nation, and state (Dirman, 2014). The 21st human resources are encouraged to think critically and creatively, and solve problems (Pratiwi dkk., 2019). Such abilities refer to higher-order thinking skills, or HOTS. According to Sani (2019), it is essential to teach children to think critically, purpose new ideas, determine some solution to problems. Faridah & Artono (2019) further stated that creative thinking and problem solving skills are demanded in the 21st century. The rapid development of science and technology has shaped challenges and problems encouraging critical and creative thinking to solve them (Faridah & Artono, 2019). Higher-order thinking skills depend on how students absorb information and how they approach different mathematical problems as each individual has distinctive characters that influence skill development. Regarding the issue, Pratiwi et al. (2019) argued that teachers' quality has important roles to promote HOTS-based question items at school. The cognitive processes, including higher-order thinking skills (HOTS) and lower-order thinking skills (LOTS), are necessary to understand by teachers. In addition, Widana (2017) stated that teachers contributed to the improvement of HOTS assessment through daily

exercises, end-of-semester exams, and other school exams. The aim is to educate students on different categories of higher-order thinking skills.

Higher-order thinking skills are defined as a thinking ability to apply and manipulate new data or information in search of answers or solutions to problems encountered (Rosita dkk., 2021). Anderson, L. W., & Krathwohl (2001) concluded that higher-order thinking skills consist of analyzing, evaluating, and creating. Analyzing is indicated by three aspects, namely distinguishing relevant and irrelevant information, organizing information through data collection and selection, connecting the smaller pieces of ideas or problems. Evaluating is indicated by two indicators, namely examining facts and justifying information against appropriate criteria. Creating is an ability to generate hypotheses or consideration through certain criteria, compiling critical thinking steps, and creating new products (Anderson, L. W. & Krathwohl, 2010). In other words, higher-order thinking is a process requiring students to analyse, evaluate, and formulate an answer or solution to a problem, going beyond memorizing a concept. The basis of the use of Anderson and Krathwohl's framework in this study was that the framework judged students' answer from the thinking process.

Problem solving is an important process in the learning process (Disparilla & Afriansyah, 2022). According to Anderson, L. W., and Krathwohl (2010), it is a fundamental ability that includes analyzing, breaking down information, thinking, predicting, assessing, and reflecting

(Septyaningrum dkk., 2022). Polya defined HOTS as an effort to find a way out from difficulties to achieve certain goals (Asfar, A.M.I. dan Nur, 2018). Factors that influence mathematical problem solving are experience, emotional and cognition. According to Anderson, problem solving indicators involved seven steps: 1) presenting and defining a problem 2) determining alternative solutions, 3) determining criteria to evaluate the alternative solutions, 4) evaluating the alternative solutions, 5) selecting the alternative solutions, 6) implementing the selected solution, 7) evaluating the results (Basyaib, 2004; Sadiyah & Afriansyah, 2023). In conclusion, mathematical problem solving is the ability of applying information and knowledge to solve mathematical problems. It can be applied not only in numeracy experience, but also in everyday life. This study used Anderson's problem-solving framework as it is appropriate with higher-order thinking skills and the learning topic of flat shapes. Rectangular flat shape is one of mathematics learning lessons that requires students to plan the thinking process, as it is related to the real-life context (contextualization).

Male and female students exist in every level of formal education that, in some way, invited the educators to probe the difference of their thinking process. Critical thinking might be influence by some factors, including 1) experience on problem solving exercises, the more students expose to certain problems; the better they analyze them, 2) motivation encouraging critical thinking, 3) well-being; 4) autonomy; students try to solve problems

without depending on others, 5) gender; there were differences of male and female's higher-order thinking, especially in analyzing (Setyawati et al., 2020). With respect to the issue, gender is one of the factors that influences the capacity in higher-order thinking process.

Some studies on higher-order thinking resulted a variety of findings. Previous studies pointed out that female students tend to make mistakes in analyzing and creating of the question items with the amount of 70% and 66% respectively. On the other hand, 60% male students tend to make mistakes in evaluating question items (Afifah et al., 2019). Other studies using Anderson's framework on higher-order thinking of junior high school students concluded that the value of students' higher-order thinking on multiplication topic depended on the third category which was "adequate". The average score of analyzing was 81, 67; evaluating 56,38; and the lowest score was 28,53 for creating (Mariani et al., 2021).

Van de Walle (Mahanal, 2019; Auliya' & Widjajanti, 2023) stated five reasons of geometry learning to observe, 1) to assist students think about the world, 2) to develop problem solving skill, 3) to take over some roles in the mathematics subject study in general, 4) to contribute to the society, 5) to perplex students and gain their interest. Both abstract and concrete concepts are included in geometry. For this reason, the researcher chose flat shape topic to assess secondary school students' higher-order thining processes in solving problems.

II. METHOD

According to Sugiyono, research is basically a scientific way to obtain information for specific reasons and uses (Sugiyono, 2011). The approach of this study was qualitative that generated descriptive data both in written and spoken from the parties concerned. The rationale of the qualitative method was that the study described the state of the participants by using theoretical framework that was appropriate with the topic and the setting. This study was conducted in SMP Unggulan NU Mojoagung, Jombang involving the 7th graders in the academic year of 2022/2023. Anderson and Krathwohl's framework of higher-order thinking was utilized to analyze male and female students' higher-order thinking processes in problem solving.

The indicators of the study: 1) analyzing (C4): students recognize important and unimportant parts of the problem given, plan alternative solution, link the alternative solution and the problem, 2) evaluating (C5): students examine and assess the process and the results of the problem solving, 3) creating (C6) students formulate hypotheses of other alternative solutions, arrange problem-solving procedures of another alternative solution, create new solution.

The data of the study was collected through test and interview. The first step of the data collection was to determine the participants consisting of one male student and one female student of SMP Unggulan NU Mojoagung with excellent mathematical problem-solving ability. It was determined from *Penilaian Akhir Semester* (PAS) scores. Based on the score,

the study selected one male student and one female student with the highest mathematics score. Besides, the communication skill of the students also influenced the participant selection. There were two instruments in this study, namely main instrument and supporting instrument. The main instrument was the researcher, whereas the supporting instruments were higher-order thinking tests and interview. To get accurate data, the instrument was validated by an expert validator and resulted sufficient validity score. The aim of the test was to explore the participants' higher-order thinking skills in solving problems. After analyzing the results of the test, the researcher conducted interview to get more detail information regarding the participants' higher-order thinking skills in solving mathematical problems. The question items asked the participants to give their opinion, feeling facts and experience. The researcher later concluded the participants' higher-order thinking skills by gender.

The validity of the data in this study was processed through time triangulation. It was conducted by comparing the higher-order thinking test results and the interview results to obtain reliable data to be analysed. The data analysis was conducted by using Miles and Huberman model, including: collecting the data study through tests and interviews, reducing the data of interview results by selecting significant and relevant information to the indicators, presenting the data narratively from the reduced data, drawing conclusions, and verifying (Nuryani et al., 2022).

III. RESULT AND DISCUSSION

Based on the results of the study of the students' higher-order thinking skills in solving mathematical problems, the findings are as follows:

A. Higher-order thinking skills at analysis stage (C4)

The exposure of the test and interview of the male participant regarding higher-order thinking skills at analysis stage (C4).

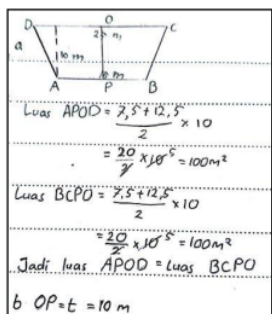


Figure 1. The student's answer performing analyzing skill (C4)

Based on Figure 1, the discussion of this section was based on the analysis results justified by the theoretical framework and previous studies. The male participant (S1) at the analyzing level (C4) was able to identify relevant and irrelevant information from the problem. While reading, he selected numbers to solve the problem, which were 25m, 15m, and 10m. S1, later, wrote and placed number 25m and 15m as the length of parallel sides and number 10m as the height. In addition, S1 recognized irrelevant information from the problems, which were 50 chili seed and 40 tomato seeds. When interviewed, S1 identified another relevant information beside length. S1 made a solution plan by describing the shape of the land and the

position of the fence with their sizes and giving a name, ABCD, to the picture he drew, and add (II) mark which was a sign of equivalent length. S1 linked the alternative solution by inputting the number of the known size of the land into the trapezoid area formula.

The exposure of the test and interview of S2 while solving the higher-order thinking test items at analysis stage (C4).

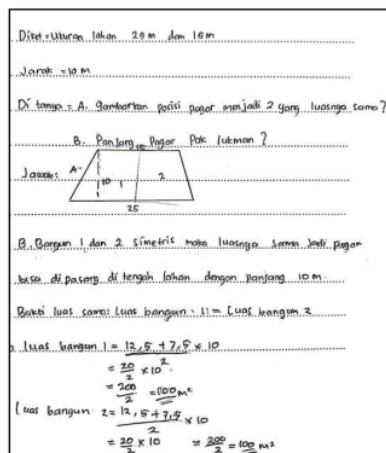


Figure 2. The student's answer performing analyzing skill (C4)

Based on Figure 2, the female subject (S2) at analyzing stage was able to identify relevant and irrelevant information from the problem by circling the numbers on the BTT test sheet, namely number 25m, 15m, and 10m, and crossing number 50 and 40. Later, S2 wrote the detail of the length size and the detail questions of the test item. Furthermore, she recognized unimportant information by crossing the number on the answer sheet. S2 planned the solution by drawing the shape of the land with its size and the fence. In addition, S2 also wrote number 1 and 2 on the drawings to mark the size of the areas that would be proven.

S2 linked the alternative solution by connecting the axis of symmetry and the trapezoid area formula.

B. Higher-order thinking skills at evaluation stage (C5)

The exposure of the test and interview data S1 while solving the questions of higher-order thinking skills at evaluation stage (C5).

$$\begin{aligned} \text{Luas } APOD &= \frac{7,5 + 12,5}{2} \times 10 \\ &= \frac{20}{2} \times 10^5 = 100 \text{ m}^2 \\ \text{Luas } BCPO &= \frac{7,5 + 12,5}{2} \times 10 \\ &= \frac{20}{2} \times 10^5 = 100 \text{ m}^2 \\ \text{Jadi, Luas } APOD &= \text{Luas } BCPO \end{aligned}$$

Figure 3. S1's answer performing evaluating skill (C5)

Based on Figure 3, evaluating stage (C5), S1 examined the results of his work by proving the similarity of the land area with guessing technique or simplifying the numbers and calculating the length of the fence both in the first solution and the second solution. The second solution was related to pythagoras formula. After calculating each area, S1 wrote that the area of APOD = the area of BCPO. He concluded that the fence position in the center of the area was already correct.

The exposure of the test and interview of S2 while solving the question item of evaluation stage (C5).

Bukti luas sama: Luas bangun 1 = Luas bangun 2

$$\begin{aligned} \text{Luas bangun 1} &= \frac{12,5 + 7,5}{2} \times 10 \\ &= \frac{20}{2} \times 10^2 \\ &= \frac{200}{2} = 100 \text{ m}^2 \\ \text{Luas bangun 2} &= \frac{12,5 + 7,5}{2} \times 10 \\ &= \frac{20}{2} \times 10 = \frac{200}{2} = 100 \text{ m}^2 \end{aligned}$$

Figure 4. S2's answer performing evaluating skill (C5)

Based on Figure 4, at the evaluation stage (C5), S2 examined the results of her work by calculating each area, namely area 1 and area 2. She summed the parallel sides first and later divided the result by two and multiplied by 10. After calculating each area, S2 concluded that the fence position in the centre of the area was already correct and connected the concept of the axis of symmetry stating that symmetrical shapes were congruent.

C. Higher-order thinking at creation stage (C6)

The exposure of the test and interview data of S1 solving question items of higher order thinking ability at creation level (C6).

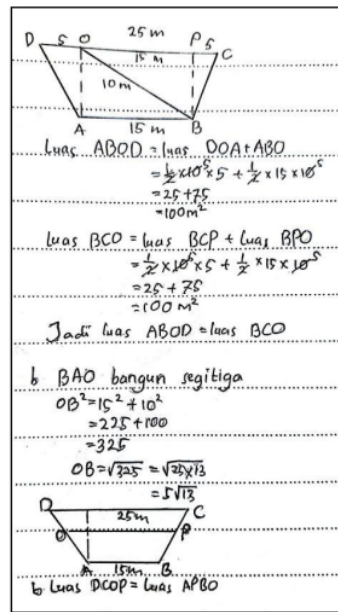


Figure 5. S1's answer performing creating skill (C6)

Based on Figure 5, at creation stage (C6), S1 drew more than one area with different position of the fence. S1 drew trapezoid shape and it appeared that S1 placed 25m and 12m as the size of the

parallel sides and 10m as the height. He also named the shape as ABCD, drew a dotted line to show the height of the trapezoid, namely AO and BP. Later S1 drew the fence by connecting O and B to form a line. From the picture, there were 4 different triangular shapes namely triangles AOD, ABO, BCO, and BCP. From the buildings made, S1 also wrote the numbers 5, 15 and 5 on the upper side. S1 had arranged a procedure of another alternative solution by calculating and naming the area. Thus, it appeared that the shape formed 4 areas which later S1 calculated the areas by applying the trapezoid area formula. ABOD area was formed from triangles of DAO and ABO. Meanwhile, the area of triangle BCO was formed from the area of BCP and BPO. S1, later, calculated each triangle and resulted 100 m². However, S1 was not able to prove the equivalent area of the second picture. Besides calculating the areas, S1 also calculated the length of the fence by applying pythagorean formula. The participant substituted the number into the formula, which was 15 for the base side and 10 for the height. From the calculation, S1 understood that the length of the fence was $5\sqrt{3}$. From the second picture, S1 was able to prove the equivalency of the areas and calculate the length of the fence correctly. However, S1 did not prove the equivalency. However, if S1 had linked the problem to the comparison concept, S1 would have been able to prove the equivalency of the area and the length of the fence.

The exposure of the test and interview data of S2 solving question items on higher order thinking skills at creation level (C6).

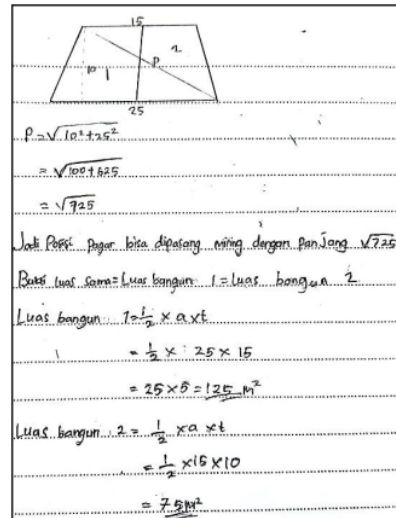


Figure 6. S2's answer performing creating skill (C6)

Based on Figure 6, at creation stage (C6), S2 made a different drawing from the first answer but could not prove the equivalency of the area nor calculate the length of the fence correctly. S2 drew the land position incorrectly so that she could not develop a solution procedure from other alternatives. In this indicator, S2 seems to first calculate the length of the fence by connecting it to the Pythagorean formula. However, while entering the numbers in the Pythagorean formula, S2 input the wrong number $\sqrt{10^2 + 25^2}$ so that the length of the fence obtained was $\sqrt{725}$. Number 25 was not supposed to be written on the bottom side because the bottom side had been separated or cut by the height line, so the size was not 25 but 20, $\sqrt{10^2 + 20^2}$. To prove the equivalency of the area of shape 1 and shape 2, S2

applied the trapezoid area formula. While calculating the area of the shapes, S2 seemed unable to prove the similarity of the areas with the position of the fence made. S2 did not create a new solution because she did not describe the position of the land correctly, so S2 could not prove the equivalency of the areas with the position of the fence placed on the diagonal plane.

The findings of this study were in line with the previous studies stating that the participants were able to demonstrate higher-order thinking skills at analyzing skill, by which students identify relevant information, organize the information and link the pieces of information within an idea. The participant was able to demonstrate higher-order thinking skills at evaluating skill, by which the participant was able to examine the data and criticize the information. The participant was able to demonstrate higher-order thinking skills at creating skill, by which the participant was able to arrange and plan the solving problem steps and generate new ideas (Rahmawati, 2016; Syahri & Ahyana, 2021; Rahayu, Liddini, & Maarif, 2022). The results of other studies also stated that female students solved geometry problem by emphasizing algebra lesson such as using substitution technique and calculate the number. Meanwhile, male students solved problem by using a simpler and easier technique to get the fastest method in problem solving (Nafi'an, 2021; Firdaus & Shodikin, 2022).

The students in general provided the known and questioned information to described mathematical model, but they failed to get the correct analysis results as

they usually made mistakes at the identification and drawing process.

Regarding evaluation skill, students were able to analyse problem by chunking down bigger patterns into pieces to identify the significant parts and then selecting a solution among the parts. Regarding creation skill, the students arranged another design to provide alternative solution to the problem. However, they did not make a correct decision due to in accurate identification. However, there was a prominent ability, especially using various techniques to solve the problem (Nst & Rahmi, 2017; Rahman dkk., 2020; Nursyahidah dkk., 2018; Apiati, Heryani, & Muslim, 2019; Rosita dkk., 2021; Hartono & Putra, 2022). The findings were different from the previous studies stating that mathematics problem-solving skills of female students were slightly better than male students'. at each stage, female students demonstrated a better problem-solving skill compared to male students. Unlike male students, female students arranged the answer carefully. In contrast, male students were not as careful as female and they did not get the expected outcome (Afifah dkk, 2019; Firnanda & Pratama, 2020; Nurcholis dkk, 2021; Annisa dkk, 2021; Ulfa, Roza, & Maimunah, 2022; Lisnani & Inharjanto, 2023)

IV. CONCLUSION

Based on the analysis results and discussion, the conclusions regarding students' higher-thinking processes in solving mathematical problems by gender were as follows:

Higher-order thinking process of male students at analysis (C4), evaluation (C5),

and creation stage (C6) described as follows: At analysing stage, the participant recognized relevant and irrelevant information while reading the problems by marking the number. The participant arranged a plan to find solutions by drawing the shape and the fence position with its number, and substituting the trapezoid area formula. At evaluating stage, the participant examined the results by proving the equivalency of the areas and the participants wrote a conclusion that the fence position in the centre of the area was already correct. At creating stage, the participant made two different pictures and proved the equivalency of the area and calculated the length of the fence correctly. However, the participant did not provide any proof of the area equivalency, nor calculate the length of the fence in the third solution.

The higher-order thinking process of female students at the level of analysing (C4), evaluating (C5), and creating (C6) in solving problems can be described as follows: At analysing stage (C4), the participant identified relevant and irrelevant information by selecting numbers from the text. The participant arranged solutions by drawing the area with its size and the fence position. To prove the equivalency, the participant linked the answer to the alternative solution by applying the axis of symmetry lesson into the trapezoid area formula. At evaluating stage (C5), the participant examined her work by calculating the areas, assessing the accuracy of the fence position, associating the result with the axis of symmetry concept stating that

symmetrical shapes were congruent. At creating stage (C6), the participant made a different picture from the first answer, but she was not able to prove the equivalency of the area and calculate the length of the fence correctly.

The findings of the study were the students usually identified the known and asked information during analysing processes. They, later, wrote the mathematical models and described them as the solution to the problem. However, due to inaccurate identification and description of mathematical models, the participants were not able to get the correct result. The students' analysing skills included describing an object to determine the significance and sorting out the possible answers. At creating stage, the participants made an alternative design to get other possible answers. However, due to inaccurate problem identification, they were not able to draw a correct conclusion. However, there was a prominent skill within male student's higher-order thinking process when they were exploring new possible answers.

According to the results of the study, there were some suggestions to students, teachers and researchers. Students were encouraged to practice on higher-order thinking question items, especially at creating level (C6) and in term of contextual items or items that promoted everyday problems. Such items could assist students to easily recognize a variety of mathematical problems. It was expected that students were able to solve the problem systematically, arrange some solutions, execute the plan, and evaluate

the result. Teachers were encouraged to understand higher-order thinking process to plan and conduct the learning process that promoted students' higher-order thinking skills. Besides, they were encouraged to prove HOTS-based items in the classroom. Students were guided to learn HOTS-based mathematical problems coherently by teachers, starting from understanding the problem, planning the solution, executing the plan, and evaluate the solution. Thus, students were able to solve the mathematical problem correctly. To other researchers, the results of the study were expected to be a reference and basis to conduct further studies regarding higher-order thinking process.

ACKNOWLEDGEMENT

Thanks to SMP Unggulan NU Mojoagung, one of the first private school established in Jombang, for the opportunity given to the researcher to make this study possible to conduct.

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