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Secondary students' spatial thinking in solving the minimum competency assessment (MCA) on geometry

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Abstract

Reflecting on PISA and TIMSS, international mathematical, reading, and science literacy assessments, the Indonesian government began implementing the Minimum Competency Assessment (MCA) for primary, secondary, and high school students. MCA demands the ability to solve daily life problems, one of which is geometry problems that require spatial ability. This research focused on describing spatial thinking ability used in numeracy competencies on geometry content. This research is descriptive with a qualitative approach. Thirty junior high school students in Malang, East Java, Indonesia, took the MCA preparation test and assessed their spatial thinking skills. The research was conducted in three stages: preparation, implementation, and analysis, and showed that three aspects of spatial ability, namely visualization, orientation, and relations, had not yet fully emerged. Some students cannot arrange the expected pattern. There are even students who ignore the geometric shapes requested. Students simplify drawing a hexagon with a quadrilateral, which are two different geometric objects, which leads to fatal errors. This study suggests that teachers emphasize learning mathematics that can train students' spatial thinking skills because it can lead to better mathematical understanding and performance.

Keywords: geometry; minimum competencies assessment; spatial thinking

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Introduction

To produce a generation with a higher level of thinking, the Indonesian Ministry of Education, Culture, Research, and Technology made an innovation by implementing the Minimum Competency Assessment (MCA). Reflecting on PISA and TIMSS, international assessments in mathematics, reading, and science literacy, the Indonesian government has started implementing MCA for elementary, middle, and high school students. MCA is one of the national assessments to photograph the process and quality of student learning outcomes in Indonesia. MCA focuses on measuring students' literacy and numeracy competencies (Mendikbud, 2020). Although it has not yet been implemented, the Ministry of Education, Culture, Research, and Technology has conducted socialization and training for schools regarding the technicalities and variety of MCA questions. However, many education practitioners (teachers and students) do not understand this MCA. It can be seen from the research result of Rokhim et al. (2021), which is based on a survey of 116 students in East Java regarding the understanding of MCA. The study stated that 53.2% of students did not understand and recognize the minimum competency assessment (MCA).

Two essential competencies assessed using this MCA are literacy and numeracy. Literacy is the ability to understand, use, evaluate and reflect on various texts (Mendikbud, 2020). Montoya (2018) define literacy as the ability to identify, understand, interpret, create, communicate and compute using printed and written materials associated with varying contexts. Moreover, OECD (2000) stated that literacy is the ability to understand and employ printed information in daily activities, at home, at work, and in the community – to achieve one's goals and develop one's knowledge and potential. On the other hand, numeracy is the ability to use mathematical concepts, facts, and procedures to solve real-life problems relevant to students' lives (Mendikbud, 2020). Numeracy skills include counting, knowing the relationship between numbers, and compiling and decomposing numbers (Hornburg et al., 2018).

Students' daily lives are closely related to mathematical material, especially geometry (Baeti & Murtalib, 2019; Hidayati, 2019; Jamil & Dintarini, 2021). Geometry is an essential material in mathematics. Geometry is considered a difficult material compared to other materials in mathematics (Nur'aini et al., 2017; T.R., 2017; Ubi & Odiong, 2018). By studying geometry, students will also practice spatial abilities (Fiantika et al., 2018; Gilligan et al., 2020). Spatial ability is a set of skills that people use every day, including recognizing shapes and sizes; identifying and remembering the location of objects; reconstructing patterns; reading maps, diagrams, and directions; rotating and manipulating shapes and objects (Pruden et al., 2020).

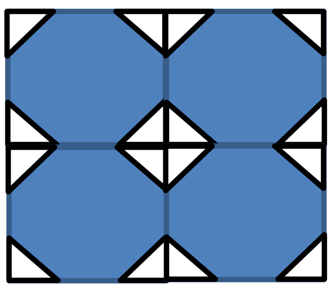
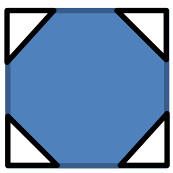
Spatial ability has been a topic of research for centuries. Previous researchers have made various attempts to improve spatial abilities. Moss et al. (2015) adapted lesson study in Japan to improve students' spatial reasoning ability. The result found that the model effectively supported teachers' spatial knowledge and reasoning and reduced their awareness of geometry and spatial reasoning. On the other hand, Safhalter et al. (2016) conducted 3D Modeling training using SketchUp software, viewed by gender and age. The research found that the 3D model effectively improves students' spatial ability, especially object manipulation indicators. Other research also reveals that students' spatial abilities affect students' performance in solving math problems (Lowrie et al., 2016; Novak & Tassell, 2017). At the same time, several studies on spatial thinking in Indonesia that have been investigated include the differences in spatial thinking between men and women (Fiantika et al., 2018; Immanudin & Isnaniah, 2017), spatial thinking skills viewed by intelligence (Bintoro & Sumaji, 2021) and the effect of applying learning models on students' spatial thinking (Pujawan, 2020; Usman et al., 2020). There is still no research that analyzes students' spatial ability in solving MCA problems, and there is still no research, especially in geometry. Therefore, the researcher is interested in analyzing the students' spatial thinking ability in solving geometry MCA problems?

Methods

This research was descriptive with a qualitative approach. The purpose of the study was to describe students' spatial abilities in solving MCA-based questions on geometry material. Research with qualitative methods was chosen to explore the results of student work in the form of steps or student processes in solving MCA-based geometry problems. Thirty students of SMP Muhammadiyah 4 Malang did the MCA preparation test, and four students were selected to be the described spatial thinking indicator. The selection of these students was based on the uniqueness of their answers and represented all of the answers of thirty students.

The preparation stage is conducted by conducting a literature study, namely looking for references from journal articles, books, and interviews with the school regarding the Minimum Competency Assessment (MCA) and students' spatial abilities in geometry material. The instrument used for data collection is a test sheet. The test sheet was developed based on MCA and based on indicators of spatial ability with geometry material. The test instrument has been validated by the Expert, a lecturer in Mathematics Education at the University of Muhammadiyah Malang, with minor revisions related to sentences. Therefore, the data collection technique is the provision of MCA-based geometry tests. Table 1 is suggestions from the validator and the results of the revision.

Table 1. Result of revision of test after validation

Geometry Test (Initial)	Geometry Test (After Validation)
 Siti's bathroom floor, which is square in shape, is tiled with 4 tiles like the motif above. Siti's bathroom area 4 m^2. a. Determine the width and length of each tile.	Siti wants to renovate her bathroom, which is 2 meters long and 2 meters wide. Bathroom floor will be fitted with square tiles with a pattern like a picture below.  It turned out that the surface of the bathroom floor only needed four tiles. • What is the size of each tile?

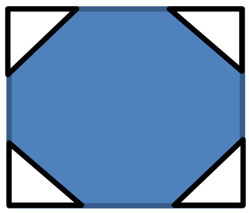
Geometry Test (Initial)	Geometry Test (After Validation)
b. If the small square in the center of the floor has an area of 0.08 m^2. Determine the area of the hexagon contained in one tile motif.	• Draw the arrangement of tiles that might be installed on the floor. • Again, look at the arrangement of the tiles. In the middle, there is a rectangle with 0.08 m^2. Determine the area of the hexagon contained in one tile motif! (*Validator's comment: to facilitate the aspect of spatial orientation regarding the arrangement of elements into a geometric pattern, it is enough to give only one tile motif*)

The data analysis technique used in the interactive analysis (Miles et al., 2014) is 1) data reduction (condensation), 2) data presentation (display) and 3) drawing conclusions and verification. Data reduction was carried out to summarize and select data that matched the research focus, namely the students' spatial abilities obtained from thirty students' work on the MCA-based geometry test. For the result of data reduction, four students' work will be described in this paper according to the indicator of spatial thinking. The presentation of the data simplifies the process of analyzing the data, where the data are grouped based on indicators of spatial ability. Data presented in this paper has been described in the classification of spatial indicator thinking. The last step of this study was making data conclusions and verification.

Results

A test was given to 30 students that consisted of 13 males and 17 females in SMP Muhammadiyah 4 Malang. The test given is an MCA problem for geometric materials that require students' numeracy literacy and spatial thinking skills. The test questions are arranged through team discussions to get questions that can be used to see students' numeracy literacy skills and bring up aspects of spatial thinking. The following figure 1 shows MCA test questions given to students.

Siti wants to renovate her bathroom, which is 2 meters long and 2 meters wide. Bathroom floor will be fitted with square tiles with a pattern like a picture below.



It turned out that the surface of the bathroom floor only needed four tiles.

- What is the size of each tile?
- Draw the arrangement of tiles that might be installed on the floor.
- Again, look at the arrangement of the tiles. In the middle, there is a rectangle with 0.08 m^2. Determine the area of the hexagon contained in one tile motif!

Figure 1. MCA test questions

Five students were selected from 30 students who took the test to describe their spatial thinking skills based on aspects of students' spatial thinking skills, namely visualization, orientation, and spatial relations. The description of students' spatial thinking skills will be explained by researchers based on these three aspects.

Spatial visual aspect

The aspect of spatial visualization is characterized by students being able to manipulate, rotate or flip a geometric object. The students' ability to manipulate geometric objects can be seen in the students' answers to question b. In question b, students are asked to draw a possible arrangement of tiles for the bathroom. The following figure 2 shows some of the results of student work.

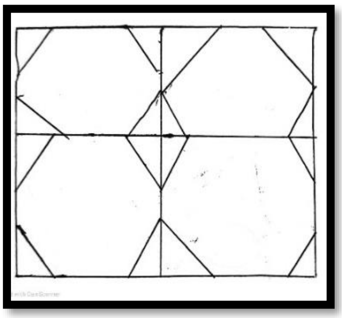


Figure 2. AR students' answer to question b

In figure 2, AR students correctly described the arrangement of tiles that might be installed in a bathroom. AR's ability to manipulate geometric objects in his mind is closely related to his answer to question a. In answering question a (what is the size of each tile), AR first writes down information that may be useful in solving the given problem. Then write down the solution plan. Figure 3 is AR's answer to question a, converted into English.

Known:
The length of bathroom= 2 meters
The width of bathroom= 2 meters
Tiles reguired is 4

Asked: what is the measure of the tiles?
Answer:
The area of bathroom = the numbers of tiles that needed
4 meters = 4 tiles
1 meter = 1 tile
Thus, the measure of the tile is 1 m for the length and 1 meter for the width.

Figure 3. AR students' answers to questions a

AR solves the tile size problem by dividing the bathroom area by the number of tiles needed. To solve this problem, AR starts by imagining a possible arrangement of tiles according to the size of the bathroom. It means that AR manipulates and rotates geometric objects (tiles). Manipulation occurs when AR imagines four tiles arranged like picture a, then adjust the image to the conditions given in the problem. AR might also imagine other possible forms of placing tiles in the bathroom. However, he did not get another form that satisfied the conditions given in the problem.

In contrast to AR, student B described the arrangement of bathroom tiles with only two tiles, as shown in Figure 4.

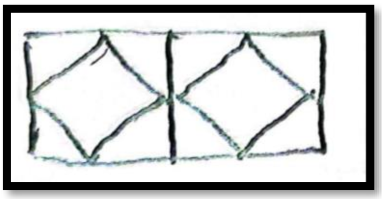


Figure 4. B Students' answer to question b

Students describe the arrangement of tiles like the picture above because they do not understand the problem. It was indicated by the following figure 5 student B's answers to problem a.

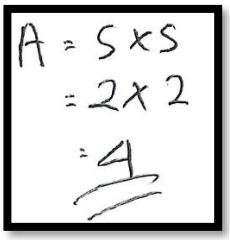


Figure 5. B Students' answer to question a

In answering the problem a, student B writes down $A = s \times s = 2 \times 2 = 4$. This is the formula for the area of a square. Actually, B has started the initial step in solving problem a. However, B did not continue it by adding further information needed, namely information on the number of tiles that can be installed in the bathroom. Therefore, the spatial visualization aspect has not been seen in work B. Most subjects describe the arrangement of tiles as student B, indicating that students still lack mastery of the spatial visualization aspect. This is supported by research x

Aspects of spatial orientation

The second aspect of spatial ability is spatial orientation. The indicator of the aspect of spatial orientation is that students can arrange elements into a geometric pattern. Based on the second aspect of this spatial ability, it is hoped that students can arrange the tiles given in the problem to be like the following figure 6.

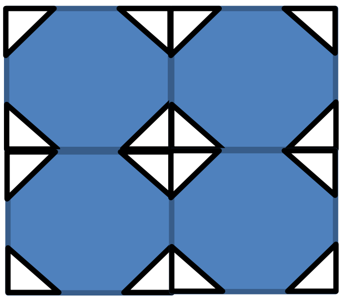


Figure 6. The right arrangement of the tiles

Based on the data obtained from the students' work, there were AR and SW students who managed to arrange the tiles correctly. Even though the images were not precise, the students managed to arrange them into a geometric pattern. Below figure 7 is an image produced by AR and SW students.

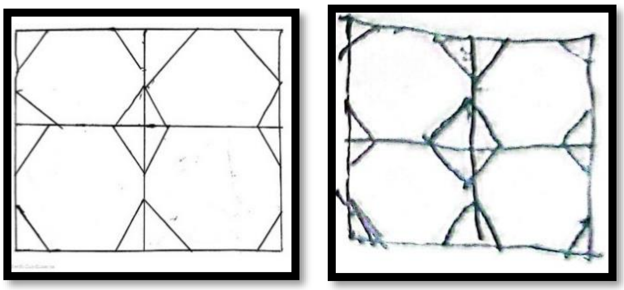


Figure 7. The left is a picture of AR work, and the right is a picture of SW work.

Some students drew the wrong arrangement of tiles to be installed on the floor as requested by the question. Student B only arranged two tiles in the picture, while in the question, it was clearly written that the bathroom floor needed four tiles. In addition, student B was also seen drawing tiles with different motifs; the blue motif in the question should be a hexagon, but what student B drew was a quadrilateral. The picture of the arrangement of tiles produced by student B can be seen in Figure 4.

The arrangement of tiles made by other students is mostly the same as the arrangement made by student B. This shows that students have not been able to distinguish between rectangular and hexagonal shapes in the tile square. In addition, students are also less careful in seeing flat shapes that build tile motifs and are less careful in reading questions related to the number of tiles needed to be arranged on the bathroom floor.

In addition to the arrangement like figure 4, student Y draws the arrangement of tiles incorrectly. The following figure 8 is a picture made by student Y.

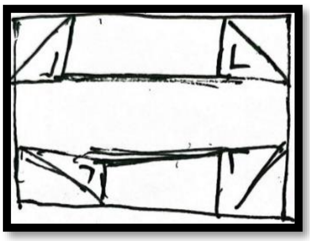


Figure 8. Arrangement of tiles made by student Y.

Student Y is seen drawing one tile motif by adding two horizontal lines so that four isosceles and triangles are formed on the tile. From Figure 4, it can be seen that student Y cannot make the arrangement of tiles correctly and does not understand the meaning of the question. Student Y was fooled by the next question that asked for the area of the hexagon, so he tried to divide the picture to get the size of the hexagon from one tile motif.

Based on the results of students' work on the aspect of spatial orientation in solving geometric problems, class VII students of SMP Muhammadiyah 4 Malang do not master this aspect. Spatial ability in arranging elements into a geometric pattern is still minimal.

Aspects of spatial relations

Aspects of spatial relations are characterized by students' ability to understand, correlate, and imagine verbal descriptions into a form of the geometric object. The problem given by the researcher is in the form of story questions, where students are required to imagine and manipulate geometric shapes according to the sentence by sentence displayed in the problem. Of the 30 students who took the MCA test, only two students, namely AR and SW, understood the given problem and changed it in the appropriate arrangement of geometric objects. Although in solving problem c, AR and SW have not been able to solve it correctly. The following is the answer to AR students' question c. Figure 9 is AR's answer to question c, which has been converted into English.

c. The area of rectangle tile = the area hexagon tile = 0.08 m^2

Figure 9. AR's answers to question c

In answering question c, it is seen that AR writes that the area of the rectangular tile formed is the same as the area of the hexagon tile. Not much can be extracted from this AR article. Apart from that, AR still relies on its vision and intuition for geometric objects. In the end, AR falls into the belief that the area of a rectangular tile is equal to the area of a hexagon tile. So, in AR's work, the spatial relation aspect has started to emerge, as can be seen from how AR solves problems a and b but fails at c because of its belief. Therefore, teacher assistance is needed so that AR can better master aspects of spatial relations. In addition to AR, other students briefly wrote down their answers, such as 0.04 and 0.16. Other students' answers (figure 10) have not shown the emergence of spatial relations aspects, which is supported by their answers to questions a and b.

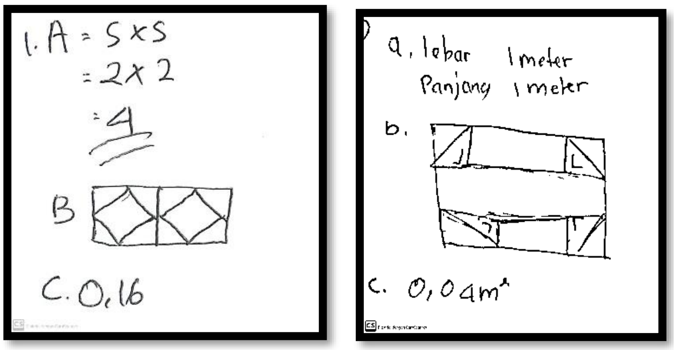
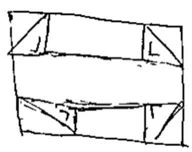


Figure 10. Answers of student B and student Y Respectively

Student Y’s answer that has been converted in English is in the Figure 11.

a. Width = 1 meter
   Length = 1 meter

b.



c. 0.04 m^2

Figure 11. Student Y’s answer that has been converted in English

Discussion

A case study conducted on SMP Muhammadiyah 4 Malang students showed that the spatial visualization aspect of junior high school students was still lacking. It is supported by research by Rahman et al. (2017), which states that the visualization error of the diagnostic test performed is greater than the other errors. It shows that students still have difficulties visualizing geometric objects in solving MCA problems. It is also found in Tias & Wutsqa (2015), which state that students have difficulty understanding visual-spatial 3.54%, difficulty applying visual-spatial 3.10%, and difficulty analyzing visual-spatial 2.65%. A student with spatial visualization skills can manipulate, rotate, or reverse a geometric object. This study illustrates that the role of students' previous understanding of geometry transformation material must be mastered well. Geometry transformation, which consists of the concept of manipulating objects by moving the points on the object, rotating, reflecting, and dilating, will help students master aspects of spatial visualization. Teachers can also assist in manipulative media so that students can practice object manipulation directly.

The aspect of spatial orientation requires students to be able to arrange elements into a geometric pattern. In the task given to students, namely arranging tiles, some students arranged correctly but only a minority. Most of the students cannot arrange it correctly. It is known that students have not been able to draw carefully to distinguish the shape of a square, pentagon, or hexagon. One of the studies on the ability of junior high school students conducted in Mojokerto showed the results that only 16% of students were at a high level of spatial ability, 69% of a low level of spatial ability, and 15% were at a moderate level of ability (Putri & Imanah, 2018). Study Putri and Imanah (2018) reveal that spatial ability, a cognitive activity that changes the point of view when looking at a visual object owned by junior high school students, is still at a moderate level. Students' ability to manipulate, imagine, and arrange elements to form geometric patterns has not shown promising results. The lack of students' spatial ability impacts their understanding of geometric concepts, and this is because the spatial ability is correlated with understanding geometric concepts (Battista et al., 2018; Hasanah et al., 2018; Hwang et al., 2019). Especially for this aspect of spatial orientation, the ability to understand geometric concepts is needed as initial knowledge that students must have. This knowledge includes being able to mention the characteristics of each plane figure, distinguish plane figures, and determine the area and circumference of a plane figure. Thus, this information can provide knowledge for teachers to develop learning strategies so that the basic concepts needed by students to understand other concepts can be achieved. It is the essence of the hierarchy that exists in mathematics.

Regarding spatial relations, SMP 4 Muhammadiyah students need teacher assistance, either in the form of scaffolding Dintarini and Zukhrufurrohmah (2021) or specific learning strategies (Fajri et al., 2017; Jamil & Dintarini, 2021). Students with spatial relation skills can understand, correlate, and imagine verbal descriptions into geometric objects. This ability is closely related to geometric problems presented in the form of the word problem. Therefore, the ability of spatial relations has to do with problem-solving. Students must understand the questions given and know the strategies for solving them, namely turning verbal problems into geometric objects, implementing strategies, and evaluating solutions.

Conclusion

Case studies on junior high school students show three aspects of students' spatial abilities: spatial visualization, spatial orientation, and spatial relations, that students have not entirely mastered. Based on the given task, there are findings that each aspect of spatial ability is related to certain geometric materials. The aspect of spatial visualization is related to geometric transformation. The aspect of spatial orientation is related to the concept of plane figures. In contrast, spatial relations are related to solving mathematical problems in the form of word problems. Guidance from the teacher is needed so that students' spatial abilities can be mastered, one of which is by providing scaffolding. This study suggests that teachers emphasize learning mathematics to increase spatial thinking ability because it can lead to better mathematical understanding and performance.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and falsification, double publication and submission, and redundancies, have been completed by the authors.

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