Visual-spatial intelligence level of junior high school students: what difficulties are experienced by the students

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Abstract. Visual-spatial intelligence is one important intelligence to solve mathematics problems, especially in geometry. The present research aims to find out junior high school students’ visual-spatial intelligence level and to identify the components of visual-spatial intelligence that are poorly mastered by students. The instrument of this research was a visual-spatial intelligence test. The test consisted of 18 multiple choice questions arranged based on three components of visual-spatial intelligence. The participants were 77 third grade junior high school students in Lombok, Indonesia. The collected data were analysed using descriptive quantitative method. The findings were 2 students had a high level of visual-spatial intelligence, 65 students had an average level of visual-spatial intelligence, and 10 students had a low level of visual-spatial intelligence. In terms of the ability to accurately perceive the visual world, students were still weak when it comes to counting a particular configuration question. In terms of transforming visual experience, students have difficulty when working on questions about mental rotation. In terms of modifying visual experience, questions about folding and unfolding a particular configuration were poorly mastered by students.

1. Introduction
Intelligence is one of the factors that support the success of students when participating in school learning, especially when participating in learning mathematics. According to Goldman, intelligences are some parts of human existence that has a prominent role in the prosperity of human life in all areas of life [1]. Intelligence is human competence to understand something and to express his own idea [2]. Intelligence is used to refer to a general intellectual competence and is usually measured by test of language and logic skills [3]. In other words, through their intelligence, humans can continuously maintain and improve their quality of life which is increasingly complex, through the process of thinking and learning and self-actualization (realizing self-quality through good and right actions) continuously.

Various terms of intelligence have been issued by experts. David Wechsler [4][5] and Charles Spearman [6] believed in unique intelligence theory. Sternberg [7] and Gardner believed in multiple intelligence [8][9][10]. Charles Spearman first proposed that intelligence consists of a single general ability, as well as more specific abilities [6]. This view has been extended by Carroll, which is one of a number of theories that have proposed a hierarchical model, with the above general abilities and more specific successive abilities at the lower levels, known as Cattell–Horn–Carroll theory [11].

Gardner developed a theory of multiple intelligences and asserted that each individual has not only one general intelligence, but multiple intelligences [12]. Multiple intelligences are an idea that every individual is capable of learning through the range of different intelligences. He initially proposed six
intelligences, but then added two additional intelligences. These intelligences are: logical-mathematical, verbal-linguistic, visual-spatial, intrapersonal, body-kinaesthetic, interpersonal, naturalistic and music intelligences [13][14][10][15]. Multiple intelligences theory not only offers significant from a theoretical perspective, but also has important practical implications for teaching practice [13]. One of the intelligences that is needed in learning mathematics is visual-spatial intelligence.

Gardner defined visual-spatial intelligence as recognizing the details of subjects and mentally changing observable things, and considered the submitting some programs such as presenting movie, maps and reading by pictures to strength this kind of intelligence in people [1]. Spatial intelligence is a competence to perceive visual word accurately, to transform and modify someone’s visual experience even when there is no relevant physical response [9]. This spatial intelligence covers a competence to imagine, to represent idea spatially, to self-orient accurately [2]. According to Malekian et al [1], visual-spatial intelligence refers to the ability to perceive the visual world accurately as in a hunter, a scout, or a guide and make transformations and modifications upon one's initial perceptions as what the creator do. In other words, students with good spatial intelligence learn relatively easily by using visual images. Students with this intelligence also have advantages in terms of imagination of visual forms and are able to repeat these shapes well and relatively prefer to be involved with visual objects compared to abstract symbols. They are better able to absorb learning if presented with the help of visual objects.

Studies suggest that visual-spatial intelligence greatly influences mathematics learning achievement [16][17][18][17][19]. Greenburg et al [20] stated that stronger visual-spatial intelligence skills in preschool were associated with significantly better outcomes for children’s standardized math and reading test scores in third, fourth, and fifth grades even after controlling for gender, SES, preschool cognitive, language, and social-emotional skills. Aziz et al [21] in their study found that students with high and middle spatial intelligence had better learning achievement than students who had low spatial intelligence. Students with high visual-spatial intelligence will more easily solve mathematical problems, especially visual spatial problems (imagine geometric or three-dimensional shapes) [22] [23]. He/she is able to observe the visual world accurately and transform his perception including the capacity to visualize and present spatial ideas precisely. This result is supported by Riastuti et al [24] who in their research found that students who have low visual-spatial intelligence will make more mistakes when working on geometry problems. Jamaan et al [25] also found that geometry learning outcomes of students having high spatial-visual intelligence were higher than students having low spatial-visual intelligence

Rimbamajo et al [14] conducted research about metacognition difficulty of students with visual-spatial intelligence. The results show that: (1) students with high visual-spatial intelligence have no difficulty on each metacognition aspects, (2) students with average visual-spatial intelligence have difficulty on strategy and cognitive tasks, (3) students with low visual-spatial intelligence have difficulty on three metacognition aspects: strategy, cognitive tasks and self-knowledge. Khoir et al [26] conducted research about mathematics literacy and visual-spatial intelligence. The result show that students with high visual-spatial intelligence can reach all of indicators in mathematics literacy, students with average visual-spatial intelligence have significant errors on each indicators of mathematics literacy, and students with low visual-spatial intelligence cannot achieve every indicators of mathematics literacy. Kobandaha et al [27] in his research on algebraic reasoning found that the student with visual-spatial intelligence were able to identify and represent what was known and asked in the problem and find the constituent elements of the pattern.

Visual-spatial intelligence is very important in mathematics learning. Rittle-Johnson et al [28] found that visual-spatial intelligence are very influential on the mathematical knowledge possessed by students. Therefore, mathematics learning must focus on improving students' visual-spatial abilities. Many studies about visual-spatial intelligence level in mathematics learning have been carried out. However, research on students' difficulties when working on visual-spatial intelligence tests is still not widely done. Many studies are still cantered on students' level of visual-spatial intelligence. Therefore, in this study, we wanted to find out junior high school students’ visual-spatial intelligence level and to identify the components of visual-spatial intelligence that are poorly mastered by students. By knowing the level and difficulty of students in carrying out visual-spatial intelligence tests, we as educators can provide assistance and appropriate teaching in accordance with student competencies and difficulties.
2. Methods
The participants of this research were 77 third grade junior high school students in Lombok, Indonesia. The participants consisted of 40 male and 37 female students. To collect the data, we conducted a visual-spatial intelligence test. Test of visual-spatial intelligence examines visual patterns, such as: points, lines, fields, and objects of space and their properties, their sizes and relationships with others. While having the ability to appropriately capture the world of space, and connect mathematics with the physical world or the real world are characteristics of students who have visual-spatial intelligence [25].

The test was carried out only for 15 minutes. The test contained of 18 multiple choice questions arranged based on three components of visual-spatial intelligence. Each component consists of two indicators, where in each indicator three questions are formed. The components and indicators of visual-spatial intelligence can be seen in Table 1. The question instruments were constructed to identify the components of visual-spatial intelligence that are poorly mastered by students.

| Table 1. Components of Visual-Spatial Intelligence |
|-----------------------------------------------|
| **Components** | **Indicators** | **Items** |
| A. The ability to accurately perceive the visual world | A1. Finding the hidden part of a particular configuration | Questions 1, 2, 3 |
| | A2. Counting a particular configuration | Questions 4, 5, 6 |
| B. Transforming visual experience | B1. Pairing the parts in a particular configuration | Questions 7, 8, 9 |
| | B2. Mental rotation | Questions 10, 11, 12 |
| C. Modifying visual experience | C1. Folding a particular configuration | Questions 13, 14, 15 |
| | C2. Unfolding a particular configuration | Questions 16, 17, 18 |

The test used in this study was first validated by the expert. This validation is intended so that the test questions can be said to be feasible and precisely measure what should be measured or revealed in this study. Validation by experts includes content validity and construct validity. Content validity is intended to determine whether the questions are designed according to the component of visual-spatial intelligence that will be tested. Construct validity determine whether the sentence does not lead to multiple interpretations, whether the sentence used is in accordance with good and correct Indonesian language rules, and whether the sentence uses words that are known by students or not.

The collected data were analysed using descriptive quantitative method. The scoring method is to give score 1 if the student’s answer is correct and 0 if the student’s answer is incorrect. Data were analysed using Microsoft Excel. To find out the level of students’ visual-spatial intelligence, the test results data conversion was conducted in the range of 0 to 100 by grouping into three criteria. Grouping data used can be seen in Table 2.

| Table 2. Grouping and Level Categories |
|---------------------------------------|
| **Level** | **Interval Score** | **Number of correct answers** |
| High | 75 < X ≤ 100 | 14 – 18 |
| Average | 25 < X ≤ 75 | 6- 13 |
| Low | 0 ≤ X ≤ 25 | 0 – 5 |

[29]
### 3. Results and Discussion

#### 3.1 Visual-Spatial Intelligence Level

The results of students’ visual-spatial intelligence test was described in Table 3. Of the 77 students who took the visual-spatial intelligence test, 2 students were at a high level, 65 students were at a moderate level, and 10 students were at a low level. There are no male students who have a high level of visual-spatial intelligence. The results indicate that there are differences in the level of visual-spatial intelligence between students. Slameto stated that the difference of visual-spatial intelligence level is influenced by some factors such as, genetic, social and economic background, environment, physic condition, and emotional structure [2].

| Level     | Male | Female | All students |
|-----------|------|--------|--------------|
| High      | 0    | 2      | 2            |
| Average   | 34   | 31     | 65           |
| Low       | 6    | 4      | 10           |

Of the 18 questions given, two female students with high levels of visual-spatial intelligence correctly answered 14 questions. From the results of their answers, at least one question from each component can be answered perfectly. Slameto stated that there many indicators about someone who shows high spatial intelligence; being aware of their environment, memorizing their place clearly, being able to visualize what they think about and what they listen to, creative, being able to differentiate shapes, being able to describe what they see, being able to analyze pictures in detail, and good at orientation direction [2].

Four female students with average levels of visual-spatial intelligence correctly answered 6 questions, six female students correctly answered 7 questions, eight female students correctly answered 9 questions, three female students correctly answered 10 questions, three female students correctly answered 11 questions, four female students correctly answered 12 questions, and two female students correctly answered 13 questions. Three female students with low levels of visual-spatial intelligence correctly answered 4 questions and one female student correctly answered 5 questions.

For male students, two students with average levels of visual-spatial intelligence correctly answered 6 questions, eight students correctly answered 7 questions, seven students correctly answered 8 questions, four students correctly answered 9 questions, six students correctly answered 10 questions, three students correctly answered 11 questions, three students correctly answered 12 questions, and one student correctly answered 13 questions. Four students with low levels of visual-spatial intelligence correctly answered 4 questions and two students correctly answered 5 questions.

#### 3.2 The Ability to Accurately Perceive The Visual World

In this component there are two indicators tested, namely finding the hidden part of a particular configuration (A1) and counting a particular configuration (A2). Figure 1 shows the questions for indicator A1 and Figure 2 shows the questions for indicator A2.

In questions number one through number three, students are asked to choose the answer letter that corresponds to a simple picture that she/he can find in each complex picture given. Students must be able to see simple pictures that are hidden in more complex images. In questions number four through number six, students are asked to choose one answer from each question by determining the number of blocks in each arrangement of units in the problem. Suppose the blocks are one with the other blocks overlap and cling together.
Based on the results of data collection, the following is the percentage of correct answers for indicator A1 and A2.

### Table 4. Percentage of Correct Answers for Indicator A1 and A2

| Finding the hidden part of a particular configuration (A1) | Question 1 | Question 2 | Question 3 |
|-----------------------------------------------------------|------------|------------|------------|
|                                                           | Male | Female | All | Male | Female | All | Male | Female | All |
| Correct Answers                                           | 30   | 23      | 53  | 12   | 26      | 38  | 34   | 31      | 65  |
| Percentage (%)                                            | 75%  | 62%     | 69% | 30%  | 70%     | 49% | 85%  | 84%     | 84% |

| Counting a particular configuration (A2)                   | Question 4 | Question 5 | Question 6 |
|-----------------------------------------------------------|------------|------------|------------|
|                                                           | Male | Female | All | Male | Female | All | Male | Female | All |
| Correct Answers                                           | 21   | 19      | 40  | 1   | 4      | 5   | 16   | 14      | 30  |
| Percentage (%)                                            | 53%  | 51%     | 52% | 3%  | 11%    | 6%  | 40%  | 38%     | 39% |

In indicator A1, question number 2 in Figure 1 is the question most frequently answered incorrectly by students. Out of 77 students, only 38 students answered correctly. The correct answer for question number 2 is "D", but 39 students answered "A" because they were fooled by the drawing of two adjoining triangles. The triangle in the question number 2 is a right triangle, while the triangle in the answer choice "A" is an isosceles triangle, so the two are not the same. Students cannot associate the picture they see with the concept they have learned, in this case the concept of a triangle. Student’s ability to defined the concept of the problem and relate it to prior knowledge is called conceptualizing [22][15]. So, the conceptualization process of students in this study were still weak. Students who cannot found geometric concepts related to the shape and character of geometric object were at level 0 of Van Hiele theory [22]. Rimbatmojo et al [15] found that students with low visual-spatial intelligence cannot determine the concept of the problem and associate it with prior knowledge (conceptualization).

Students still make errors when answering all questions for indicator A2. From Table 4 it can be seen that for questions number 5 through 6 in Figure 4, the correct answer does not reach 50%, meaning that almost half of the students answer incorrectly. The correct answer for question number 5 in Figure 2 is "D", but 72 students answered "E". For question number 6 in Figure 2, the correct answer is "B", but 47 students answered "C". The errors made by students in answering questions numbers 5 through 6 are because students only count the piles of cube shown in the picture. They do not count the piles of cubes that are not shown in the picture but actually exist. Gutiérrez stated that if students cannot visualize solids, their positions, or motions if they cannot see them, then these students were at level 1 of Van Hiele theory [30]. Whereas Wijaya et al [22] stated that most students at level 0 of Van Hiele theory had trouble in imagined what on their mind. They had difficulties represented the geometric shapes in their imagination into the image.
3.3 Transforming visual experience

In this component there are two indicators tested, namely pairing the parts in a particular configuration (B1) and mental rotation (B2). Figure 3 shows the questions for indicator B1 and Figure 4 shows the questions for indicator B2.

In questions number seven through number nine, students are asked to choose one of the answers to each problem by matching the basic image with the image that has been decomposed or vice versa which has broken down into basic images. In questions number ten through number twelve, students are asked to choose one of the logically suitable answers to occupy the blank space.

Based on the results of data collection, the following is the percentage of correct answers for indicator B1 and B2.

| Question 7     | Question 8     | Question 9     |
|----------------|----------------|----------------|
| Male | Female | All | Male | Female | All | Male | Female | All |
| Correct Answers | 30 | 27 | 57 | 32 | 33 | 65 | 23 | 28 | 51 |
| Percentage (%)  | 75% | 73% | 74% | 80% | 89% | 84% | 58% | 76% | 66% |

| Mental rotation (B2) |
|----------------------|
| Question 10 | Question 11 | Question 12 |
| Male | Female | All | Male | Female | All | Male | Female | All |
| Correct Answers | 18 | 16 | 34 | 13 | 13 | 26 | 4 | 4 | 8 |
| Percentage (%)  | 45% | 43% | 44% | 33% | 35% | 34% | 10% | 11% | 10% |

In indicator B1, question number 9 in Figure 3 is the question most frequently answered incorrectly by students. Out of 77 students, 51 students answered correctly. The correct answer for question number 9 in Figure 3 is "E", but 26 students answered "B" or "D".

Students still make errors when answering all questions for indicator B2. From Table 5 it can be seen that for questions number 10 through 12 in Figure 4, the correct answer does not reach 50%, meaning that almost half of the students answer incorrectly. The correct answer for question number 10 in Figure 4 is "B", only 34 students answered correctly. For question number 11 in Figure 4, the correct answer is "B", only 26 students answered correctly. For question number 12 in Figure 4, the correct answer is "E", only 8 students answered correctly. The errors made by students in answering questions numbers 10 through 12 are because students have difficulty rotating the space in the question in their minds. Lisi et al [31] in their research also found that most students had difficulty answering questions about mental rotation. Meanwhile, Awalah et al [32] stated that student mistakes in answering mental rotation questions are caused by students' inability to rotate three-dimensional objects rapidly and accurately in their mind. Awalah et al findings is accordance with the findings in this study.
3.4 Modifying visual experience

In this component, there are two indicators tested, namely folding a particular configuration (C1) and unfolding a particular configuration (C2). Figure 5 shows the questions for indicator C1 and Figure 6 shows the questions for indicator C2.

![Figure 5. Questions for Indicator C1](image)

![Figure 6. Questions for Indicator C2](image)

In questions number thirteen through number fifteen, students are asked to choose one of the answers that logically takes the form of a space that is formed from the fold pattern in question. In questions number sixteen through number eighteen, students are asked to choose one of the answers that is logically in the form of a pattern formed from the space in question.

Based on the results of data collection, the following is the percentage of correct answers for indicator C1 and C2.

| Table 6. Percentage of Correct Answers for Indicator C1 and C2 |
|---------------------------------------------------------------|
| **Folding a particular configuration (C1)**                  |
| Question 13 | Question 14 | Question 15 |
| Male | Female | All | Male | Female | All | Male | Female | All |
|---|---|---|---|---|---|---|---|---|
| Correct Answers | 20 | 23 | 43 | 10 | 8 | 18 | 29 | 28 | 57 |
| Percentage (%) | 50% | 62% | 56% | 25% | 22% | 27% | 73% | 76% | 74% |

| **Unfolding a particular configuration (C2)**                |
|-------------------------------------------------------------|
| Question 16 | Question 17 | Question 18 |
| Male | Female | All | Male | Female | All | Male | Female | All |
|---|---|---|---|---|---|---|---|---|
| Correct Answers | 3 | 9 | 12 | 17 | 12 | 29 | 15 | 8 | 23 |
| Percentage (%) | 8% | 24% | 16% | 43% | 32% | 38% | 38% | 22% | 30% |

In indicator C1, question number 14 in Figure 5 is the question most frequently answered incorrectly by students. Out of 77 students, 18 students answered correctly. The correct answer for question number 14 in Figure 5 is "A", but 59 students answered “D”. Students have difficulty changing 3-dimensional images into 2-dimensional image. Therefore, most students incorrectly answer questions number 16 through 18 about folding a particular configuration.

Students still make errors when answering all questions for indicator C2. From Table 6 it can be seen that for questions number 16 through 18 in Figure 6, the correct answer does not reach 50%, meaning that almost half of the students answer incorrectly. The correct answer for question number 16 in Figure 6 is "E", only 12 students answered correctly. For question number 17 in Figure 6, the correct answer is "A", only 29 students answered correctly. For question number 18 in Figure 6, the correct answer is "A", only 23 students answered correctly. Students have difficulty changing 2-dimensional images into 3-dimensional image. Therefore, most students incorrectly answer questions number 16 through 18 about unfolding a particular configuration.

Folding and unfolding a particular configuration process is called visual spatialization. Clements defined spatial sight as to be able to move 2 or 3-dimensional objects in one’s mind and to be able to
understand them [23]. Spatial sight is the ability to think that we are in another place, to imagine how this place looks like and also it is the skill that we use for understanding how the situation is when we slightly change the pose of the objects [23]. From the result, most of students have difficulty in visual spatialization aspect. They cannot transform 3-dimensional images into 2-dimensional images and vice versa.

4. Conclusion
There were differences level of visual-spatial intelligence between students in this study. Most students have an average level of visual-spatial intelligence. Only two students have a high level of visual-spatial intelligence, while ten students are at a low level. In terms of the ability to accurately perceive the visual world, students were still weak when it comes to counting a particular configuration question. Students cannot visualize solids, their positions, or motions if they cannot see them. Students only count the piles of cube shown in the picture. They do not count the piles of cubes that are not shown in the picture but actually exist.

In terms of transforming visual experience, students have difficulty when working on questions about mental rotation. Students have difficulty rotating the space in the question in their minds. In terms of modifying visual experience, questions about folding and unfolding a particular configuration were poorly mastered by students. Students have difficulty changing 2-dimensional images into 3-dimensional image and vice versa. Their visual spatialization abilities were still weak.

This research is only limited to find out junior high school students’ visual-spatial intelligence level and to identify the components of visual-spatial intelligence that are poorly mastered by students. There is a need for further research aimed to increasing students' level of visual-spatial intelligence. In addition, it is also necessary to find ways that can help overcome students' difficulties in answering visual-spatial intelligence tests.

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