Profile of multi-modal representation ability of junior high school students on science material in Sleman district

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Abstract. This study aims to determine the profile of multi-modal representation ability of junior high school students in science material in Sleman district. The method used in this research is a survey with a quantitative approach and document study with a qualitative approach. The object of research is 10 junior high schools with a total of 1,555 students in the Sleman district. The data used are the results of the national examinations on science learning in 2019 from the Education Assessment Center, Ministry of Education and Culture Republic of Indonesia and 40 items of the national exam documents on science subjects. The results reveal that the ability of student representation on the type of verbal-verbal questions was 50.45%, verbal-visual by 78.14%, verbal-symbolic by 66.03%, verbal-mathematical by 50.45%, visual-verbal by 72.71%, visual-visual by 76.25%, visual-symbolic by 81.57%, and visual-mathematical by 61.55%. From these results it can be concluded that the lowest student representation ability in the type of verbal-mathematical, verbal-verbal, and visual-mathematical problems.

1. Introduction
Science is one branch of knowledge that studies about natural phenomena or processes and the nature of substances contained in them. Natural phenomena and the nature of these substances can be investigated through observation, experimentation, measurement and analysis so that physical quantities can be found in a descriptive and mathematical formulation. [1].

Science learning that is carried out in schools certainly has an important role in developing students' abilities in understanding the relationships of these quantities and solving the problems presented correctly. In addition, through science learning students are expected to be able to obtain a number of concepts, understand and apply these concepts flexibly based on certain rules they learn.

Most of the concepts of physics are presented not only in one format but in various formats of representation or what is referred to as multi-representation. A series of scientific concepts can be explained by using various representations, both symbols, text, images, graphs, diagrams, tables, to mathematical equations [2], [3]. Another opinion states that science can be translated into four representations, namely verbal representations, visual representations, mathematical and symbolic representations [4], [5]. Representation can help students understand problems before they use mathematical equations to solve problems quantitatively or qualitatively. Students who are able to master a concept that has been conveyed by the teacher, can certainly re-represent the concept in various formats or so-called multi-modal representations [6], [7].
Multi-modal representation as a characteristic possessed in the presentation of science concepts has several functions, namely as a complement, limiting interpretation, and forming deeper understanding [8]. It also serves to limit the possibility of errors in interpreting in using other interpretations and to explore the inherent properties of one representation to limit other representations [9].

The concept of science presented in various forms of representation requires the teacher to be able to develop the ability of representation possessed by students. Science as a subject requires understanding and ability of different ways of representation for the same concept or theme [10], [11]. Another opinion states that, students’ success in solving physics problems is influenced by the representation format of the given problem [12]. This shows that students’ representation skills as an ability that must be possessed to interpret and apply various concepts in solving problems appropriately, are important to be identified by the teacher.

The real ability of students should not only be measured by their success in answering questions in the form of mathematical representation, because it is not certain that they have mastered the concepts in the problem. There is an assumption that students’ success in solving mathematical problems means that they have understood the concept of science, even though many of them succeed in solving mathematical problems but do not understand the real science concept, because it only memorizes the algorithm [13].

Based on this background, teachers in the field of science generally only make problems with solutions in the form of mathematical representations without regard to the ability of students to master the concepts as a whole. Therefore, in this study it is necessary to know the multi-modal ability profile of junior high school student representation on science material in Sleman district. This research is expected to provide a description of the typical question and its correlated with the ability of students to resolve the issue. So that it can trigger the teacher to map students’ skills and enhancement efforts.

2. Method
The method used in this research is survey and document study using quantitative and qualitative descriptive approaches [14]. The research object used was 10 public junior high schools (MTsN) under the Ministry of Religion with a total of 1,555 students in Sleman district. The data used are the results of the 2019 national science learning exam from the Educational Assessment Center, Ministry of Education and Culture of the Republic of Indonesia and 40 items of national exam questions from package 1 [15]. Data analysis techniques for the national examination results are grouped into three groups: high, medium and low ability groups. Grouping is done using the rules of value conversion with norm-referenced evaluation [16] as shown in Table 1.

### Table 1. Criteria for grouping schools

| Category      | Ability Level | Average Score                    |
|---------------|---------------|----------------------------------|
| High Ability  | \( \text{Average Score} > \mu + 0.5\sigma \) | \( \text{Average Score} > 62.19 \) |
| Medium Ability| \( \mu - 0.5\sigma \leq \text{Average Score} \leq \mu + 0.5\sigma \) | \( 56.48 \leq \text{Average Score} \leq 62.19 \) |
| Low Ability   | \( \text{Average Score} < \mu - 0.5\sigma \) | \( \text{Average Score} < 56.48 \) |

3. Results and Discussion
From table 1, it can be classified, 10 schools that were used as research objects based on the absorption of the results of the national science test in 2019, as shown in Table 2.
Table 2. Stratification of schools based on the absorption of science tests

| No. | School                          | Average Science Score | Category |
|-----|--------------------------------|-----------------------|----------|
| 1   | MTs Negeri 6 Sleman             | 71.56                 | High     |
| 2   | MTs Negeri 8 Sleman             | 62.75                 | High     |
| 3   | MTs Negeri 5 Sleman             | 62.10                 | Medium   |
| 4   | MTs Negeri 7 Sleman             | 61.01                 | Medium   |
| 5   | MTs Negeri 10 Sleman            | 60.65                 | Medium   |
| 6   | MTs Negeri 4 Sleman             | 60.62                 | Medium   |
| 7   | MTs Negeri 9 Sleman             | 57.67                 | Medium   |
| 8   | MTs Negeri 2 Sleman             | 52.91                 | Low      |
| 9   | MTs Negeri 3 Sleman             | 52.81                 | Low      |
| 10  | MTs Negeri 1 Sleman             | 51.30                 | Low      |

The results of the national examination of science subjects at the MTs level in 2019 in Sleman district can be statistically descriptive shown in Table 3.

Table 3. Descriptive statistics of national science test scores at the MTsN level

| Statistic   | Value |
|-------------|-------|
| Average     | 59.31 |
| Minimum     | 25.00 |
| Maximum     | 97.50 |
| Standard deviation | 13.07 |

In detail the distribution of national science student test scores in table 4.

Table 4. Distribution of national science test scores at the MTsN level

| Score Range  | Count | Percentage (%) |
|--------------|-------|----------------|
| 0.00-5.00    | -     | -              |
| 5.01-10.00   | -     | -              |
| 10.01-15.00  | -     | -              |
| 15.01-20.00  | -     | -              |
| 20.01-25.00  | 1     | 0.06           |
| 25.01-30.00  | 6     | 0.39           |
| 30.01-35.00  | 39    | 2.51           |
| 35.01-40.00  | 70    | 4.50           |
| 40.01-45.00  | 141   | 9.07           |
| 45.01-50.00  | 187   | 12.03          |
| 50.01-55.00  | 225   | 14.47          |
| 55.01-60.00  | 231   | 14.86          |
| 60.01-65.00  | 190   | 12.22          |
| 65.01-70.00  | 171   | 11.00          |
| 70.01-75.00  | 131   | 8.42           |
| 75.01-80.00  | 81    | 5.21           |
| 80.01-85.00  | 44    | 2.83           |
| 85.01-90.00  | 22    | 1.41           |
| 90.01-95.00  | 10    | 0.64           |
| 95.01-100.00 | 6     | 0.39           |

More deeply, the level of absorption based on indicators tested at MTsN in Sleman district in 2019 in science subjects is shown in Table 5.
Table 5. Absorption Indicators of the 2019 National Examination in science subjects

| No. | Tested Indicator [17]                                                                 | Absorption (%) |
|-----|---------------------------------------------------------------------------------------|----------------|
| 1   | Determine the principal quantities that make up the amount of the derivative            | 68.61          |
| 2   | Identifying the properties of objects based on the table                                | 83.34          |
| 3   | Presented several events changing form. Determine two changes in form that release/require heat | 77.75          |
| 4   | An illustration of the results of temperature measurements using a certain scale thermometer is presented. Convert temperature to another scale thermometer | 71.67          |
| 5   | Presented table of test results of the test solution with litmus paper. Indicates acid, base or salt solutions precisely | 75.19          |
| 6   | Expressed statement. Identify physical or chemical changes correctly                     | 72.93          |
| 7   | Expressed atomic image. Sorts protons, neutrons and electrons precisely                 | 82.89          |
| 8   | Presented examples of substances/drugs. Classifying the content of addictive-psychotropic substances appropriately | 66.31          |
| 9   | Presented illustration, Determine the method of separation of the mixture appropriately | 49.92          |
| 10  | An illustration about a ship sailing while loading goods is presented. Determine the maximum amount that can be transported | 47.80          |

2. Mechanics and Solar System

| No. | Tested Indicator [17]                                                                 | Absorption (%) |
|-----|---------------------------------------------------------------------------------------|----------------|
| 11  | Presented images of toy cars moving on three tracks down, flat, up. Determine the appropriate velocity graph \((v) of \(t)\) | 76.25          |
| 12  | Presented four beam images, each subject to three styles with a certain value. Determine the biggest and smallest acceleration | 86.12          |
| 13  | Determine people who can help push objects to move a certain distance                  | 89.24          |
| 14  | Expressed a picture of a hanging bar and four weights are placed depending on the road. Determine the action so that the state of the rod is balanced | 46.53          |
| 15  | Determine the characteristics of the two planets presented in the table               | 83.09          |
| 16  | Presented a diagram of the earth's circulation to the sun. Explain the conditions of day and night in the northern and southern hemisphere | 77.82          |

3. Waves, Electricity and Magnetism

| No. | Tested Indicator [17]                                                                 | Absorption (%) |
|-----|---------------------------------------------------------------------------------------|----------------|
| 17  | Presented illustration of objects that are above the waves of sea water. Calculate one of the quantities | 52.42          |
| 18  | Presented a diagram of an object located between two mirrors that form an angle. Determine the number of shadows produced | 57.91          |
| 19  | Presented illustration two people with eye defects using glasses. Determine the reading distance comparison between the two people | 29.89          |
| 20  | Presented illustrations of electric loading events. Determine the process of losing/receiving electrons which are presented in tabular form | 68.00          |
| 21  | Presented a series of drawings consisting of 3 obstacles arranged in series, parallel, and combined. Determine the amount of strong current in the circuit | 62.66          |
| 22  | Can calculate the power tool if it is connected to a certain electrical voltage value. | 36.11          |
| 23  | Presented transformer diagram. Determine the value of one of the quantities and types of the transformer | 52.29          |
No. | Tested Indicator [17] | Absorption (%) |
--- | --- | --- |
24 | Determine images that show three (3) characteristics of living things. | 90.69 |
25 | Mention the biotechnology process in processing certain foodstuffs | 68.31 |
26 | Determine the type of interaction of the two components in the ecosystem | 66.49 |
27 | Explain the strengths/weaknesses of the efforts made to overcome environmental damage. | 73.49 |
28 | Explain the natural selection process in a given case | 68.94 |
29 | Analyzing a more stable ecosystem if one and the same organism in both ecosystems becomes extinct with reasons | 90.37 |

### 5. Structure and Function of Living Things

30 | Explain the characteristics of blood vessels | 60.41 |
31 | Identify the excretion system that plays a role in the process of secretion of metabolic substances | 82.46 |
32 | Identifying reproductive organs that undergo a particular process. | 86.96 |
33 | Explain how the bones / muscles / joints that support certain movements work | 72.13 |
34 | Explain the process of digestion that is disturbed due to certain diseases | 58.89 |
35 | Explain the purpose of human breathing experiments | 67.71 |
36 | Analyzing data from photosynthetic experiments based on certain variables | 73.31 |
37 | Identify the relationship between cells, tissue, and tissue function | 73.45 |
38 | Explain the factors that drive the transportation process in transport experiments on plant stems | 57.86 |
39 | Identify the type of gamete that forms in crosses with 2 different properties | 47.19 |
40 | Explain the relationship between organ systems in humans | 65.24 |

Based on Table 5, the grouping and analysis of the manuscripts of the national science test for the national science group of questions is done by categorizing the type of answer based on verbal (ver), visual (vis), symbolic (sim) and mathematical (mat) to determine the ability of multi-modal representation students, as shown in Table 6.

#### Table 6. Data Analysis Forms of Representations of Questions and Answers

| Type   | Question Number | Count | Percentage (%) | Average Absorption (%) |
|--------|-----------------|-------|----------------|------------------------|
| Ver-Ver| 1, 9, 25, 27, 28, 30, 31, 33, 34 | 9     | 22.50          | 67.02                  |
| Ver-Vis| 2, 15, 20       | 3     | 7.50           | 78.14                  |
| Ver-Sim| 3, 6, 8, 39     | 4     | 10.00          | 66.03                  |
| Ver-Mat| 4, 10, 17, 19   | 4     | 10.00          | 50.45                  |
| Vis-Ver| 7, 16, 26, 29, 35, 36, 38, 40 | 8     | 20.00          | 72.71                  |
| Vis-Vis| 11              | 1     | 2.50           | 76.25                  |
| Vis-Sim| 5, 24, 32, 37   | 4     | 10.00          | 81.57                  |
| Vis-Mat| 12, 13, 14, 18, 21, 22, 23 | 7     | 17.50          | 61.55                  |
| **Total** |                  | **40** |                |                        |

The results reveal that the ability of student representation on the type of verbal-verbal questions was 67.02%, verbal-visual by 78.14%, verbal-symbolic by 66.03%, verbal-mathematical by 50.45%, visual-verbal by 72.71%, visual-visual by 76.25%, visual-symbolic by 81.57%, and visual-mathematical by 61.55%. From these results it can be concluded that the lowest student representation
ability in the type of visual-mathematical problems. The results of other studies conducted also show the conclusion that the ability of representation also illustrates the level of student understanding [18][19]. Figure 1 shows the percentage of the relationship between the questions and answers in the National Examination (UN) question in terms of the multi-representation aspect.

**Figure 1.** Percentage of Multirepresentation analyse of question-answer relation on UN test 2019

Based on Figure 1, it can be seen that the verbal-verbal aspect has the highest percentage of problem forms while the visual forms have the lowest representation. These results can be analyzed to see how the influence of the form of questions on the ability to answer students analyzed through absorption. Based on Table 7, it can be seen that the highest absorptive capacity is in the form of visual problems with answers in the form of symbols.

**Figure 2.** Percentage of Multirepresentation analyse of question text on UN test 2019

Figure 2 is a form of questions that are reviewed from each indicator. Based on Figure 2, it can be seen that the form of the questions only consists of two types of questions namely verbal and visual. the indicators Measurements, Substances, and Their Properties have a verbal problem with a percentage of 80% and visual form 20%. This indicator group has a percentage of absorption of 69.63%. Indocator mechanics and solar systems have a distribution of 16.67% of verbal questions and 83.33% of visual questions with an absorption of 76.51%. The indicator of wave, electricity and magnetism has a form of verbal problems of 42.86% and visual problems of 57.14% with an average absorption of 51.33%. Next, living thins and their environment indicators have a balanced form of verbal and visual problems with an average absorption of 76.38%. the latter is an indicator of structure.
and function of living things which has a verbal problem of 45.45% and a visual problem of 54.55% with an average absorptive capacity of 67.78%.

![Figure 3. Percentage of Multirepresentation analyse of answered text on UN test 2019](image)

Next is the distribution of the form of representation of UN questions in terms of the form of answers presented. Unlike the form of questions, answers have a more varied form. This can be seen by the form of answers in each of the expected representations. Based on Figure 3, it can be seen that the measurement, substance, and their properties indicators have the distribution of the answer patterns that exist in each form of representation. If it is reviewed the relationship with the absorptive capacity obtained by students on each indicator, it can be stated that the answers with the slightest variation in form enable students to more easily analyze the answers. However, this is independent of the level of difficulty of the questions that must be solved by students. This demonstrates that the level of material absorption and learning content is influenced by the representation of the object. It is also supported by the results of previous research on models and learning styles of students [20], [21]. A diverse and interesting form of representation will automatically give students more convenience to activate the senses and imagination in interpreting the problem. Overall, the total distribution of questions in the 2019 UN questions and answers can be seen in Figure 4 and Figure 5.

![Figure 4. Percentage of multirepresentation type on UN question](image)
To further illustrate, the following are some examples of answer-questions related to the multimodal representation of the 2019 national science exam, the visual-mathematical type, as shown in Figure 6.

18. Two mirrors are arranged forming angles so that the image as follow:

![Figure 6. Visual-mathematical type questions](image)

If the angle is reduced to 15° then the number of images becomes….
A. 9
B. 7
C. 6
D. 5

Figure 6. Visual-mathematical type questions

The problem in Figure 6 can be answered correctly by 57.91% of students. This problem measures the ability of students to understand the concept of images formation by a mirror and can determine the number of images produced by objects located between two mirrors that form angles. Students who are wrong in answering the problem most likely do not understand the relationship/pattern of the formation of the number of images displayed in the problem or students lack understanding in reading explanations of illustrated images (unusual question format) [22], [23].

In addition to the visual-mathematical type, it was also found that students had difficulty in correctly working on the verbal-mathematical type, as indicated by the questions in Figure 7.

19. Ahmad and Budi suffered hypermetropi eye and use glasses with a size of each + 2.5 D and + 1 D. Comparison of the eyes read Ahmad and Budi if they do not use glasses is....
A. 1 : 2
B. 2 : 1
C. 2 : 5
D. 5 : 2

Figure 7. Visual-mathematical type questions
The type of problem shown in Figure 7 can be answered correctly by 29.89% of students, meaning that as much as 70.11% of students answer it incorrectly. This problem measures the ability to analyze in distinguishing the characteristics of glasses with different lens strengths. Students who incorrectly answer the question most likely do not master the mathematical formula to determine how the vision of a sign using glasses [24]. It is one indication that shows the correlation between mathematical mastery and problem solving in science. These results are also in accordance with other research results stating that the mastery of student science content is directly proportional to the mathematical abilities owned [25].

4. Conclusion
The multi-modal profile analysis of the representation of MTsN students in Sleman district has been successfully carried out, showing the greatest weakness in solving verbal-mathematical, verbal-verbal, and visual-mathematical problems type problems. Errors in answering are caused because the questions are presented in context/stimulus that is not routine or even complex, causing complexity in problem solving. Therefore, students need to be given regular training to deal with problems that are equipped with multi-modal representation so that they are skilled in interpreting visualizations, getting adequate information, and then processing them to solve problems in daily life. The results of this research can also be used as an ingredient for consideration and teacher referral to the efforts of delivering learning materials/content. So it will indirectly prepare students with diverse needs and habits.

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