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EXPLORING NUMERICAL COMPETENCE: ANALYSIS OF STUDENTS' MATHEMATICAL REPRESENTATION SKILLS IN *PISA SPACE* AND *SHAPE* CONTENT

Ajda Audita Febriyani[1*], Nining Setyaningsih[2]
[1,2]Mathematics Education, Universitas Muhammadiyah Surakarta, Cetral Java Province, Indonesia
*Correspondence: a410200024@student.ums.ac.id

ABSTRACT

This research aims to analyze students' mathematical representation skills in solving PISA Space and Shape content questions, taking into account their numerical ab. Mathematical representation is a key skills in understanding and solving mathematical problems, while numerical skills play a vital role in developing an understanding of concepts and their applications in spatial and shape contexts.The research method employed is a qualitative approach, collecting data from students through written tests and interviews. The research instruments include questions reflecting Space and Shape content from PISA, as well as numerical skills tests.The research findings indicate a significant relationship between students' numerical skills and their skills to represent mathematical problems related to Space and Shape. Students with better numerical skills tend to have better mathematical representation skills. Furthermore, these findings can provide insights for educators and researchers to develop teaching strategies that integrate the development of numerical skills and mathematical representation, there by enhancing the quality of students' mathematical understanding at a global level.

Keywords: Representation Skills, PISA Problems, Numerical Skills

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PRELIMINARY

Education is a method used to develop Human Resources (HR) with students to optimize and enhance their critical thinking in the acceptance and processing of information through the utilization of their knowledge, as expressed by (Nuringtyas & Setyaningsih, 2023),(Facione, 2015) dan (Setyaningsih & Fatimah, 2022). By involving students in mathematical learning, we can accustom them to develop thinking habits. This helps students to master specific skills (Putri & Nining, 2022). Mathematics, as the foundation of various fields of knowledge, plays a central role in life. Mathematical literacy skills, as defined by (Setyaningsih & Fatimah, 2022), are a manifestation of a deep understanding of mathematical concepts that support individuals' skills to interpret,

evaluate, and apply mathematical information in everyday life and complex problem situations.

Mathematics education becomes a key element in preparing the younger generation to face global challenges in the 21st century. PISA, as an international assessment tool, provides a comprehensive overview of students' mathematical skills across various countries. The primary focus of PISA is to measure students' skills to apply mathematical concepts in everyday contexts. One section of the mathematical content in PISA questions revolves around the concepts of space and shape. This content is related to the field of geometry and is, in fact, one of the mathematical topics closely connected to students' daily lives. However, students often encounter difficulties in solving problems related to this geometry topic (Ma et al., 2020). Learners struggle to apply their acquired knowledge to solve non-routine problems (Novita et al., 2018).

In this regard, the skills of mathematical representation becomes a central aspect in assessing students' skills. Students' mathematical representation skills can be measured through several indicators: (1) visual representation, (2) mathematical equations or expressions, (3) words or written texts by (Huda et al., 2019); and (Sari et al., 2020). In my opinion (Johnson, 2018) Visual representation encompasses anything created by hand or generated by a computer that depicts concrete objects such as graphs, diagrams, calculations, or tables. Meanwhile, symbolic representation includes numbers, formulas, geometric concepts, and numeric or algebraic expressions. Verbal representation combines the use of specialized language related to the mathematical domain (e.g., fractions, probability, geometry). The skills to represent refers to situations in real life (e.g., using money while shopping), while physical representation involves concrete objects or manipulatives (like base-ten blocks, protractors, geoboards) designed to provide students with opportunities to understand mathematical concepts through manipulation.

According to Handayani & Juanda, 2018, the benefits of representation skills in mathematical learning include accommodating students with various levels of intelligence. Teaching mathematics employs representation as a standard method because it can support the understanding and development of concepts in the subject. Representation also serves to convey students' ideas or thoughts in written form, which then becomes a tool for teachers to evaluate the extent of students' understanding of new concepts by (Anugrah et al., 2023). So, to master mathematical concepts, communicate mathematical ideas, and solve mathematical problems, mathematical representation skills are required (Erita et al., 2023).

However, to understand and apply mathematical representation effectively, students need a strong foundation in numerical skills. According to (Melani et al., 2019), (Asshagab et al., 2023) , and (Amaliyah, 2018), numerical skills involve not only mastering basic skills such as addition, subtraction, multiplication, and division but also a profound understanding of these concepts. Numerical skills also influence students' success in mastering mathematics, as stated by (Sitriani et al., 2019). Students with a solid foundation in numerical skills are more capable of solving complex and contextual mathematical problems, especially in the context of PISA exams. (Sihombing & Naibaho, 2023) and (Ayu & Lestari, 2019) emphasize that numerical skills are not just a collection of arithmetic procedures but the foundation for more abstract and complex understanding in mathematics. By mastering numerical skills, students can develop critical thinking skills necessary for analyzing, interpreting, and solving mathematical problems successfully (Manik et al., 2020). Therefore, strengthening the understanding of numerical skills is a key step in improving the quality of students' mathematical representation, especially in facing the challenges of PISA exams that demand deep applicable mathematical understanding.

The analysis of the correlation and between numerical competence and students' mathematical representation skills has methodological and pedagogical significance in the context of evaluating students' mathematical performance, especially in solving PISA problems . In conducting this analysis, it is important to explore and identify factors contributing to imbalances or success in answering PISA questions, which often involve understanding and applying mathematical concepts in contextual contexts. A deep understanding of the interconnection between numerical and mathematical representation skills allows for a more detailed mapping of students' cognitive processes. Factors affecting students' performance in PISA questions may involve the level of understanding of mathematical concepts, the skills to model problems, and the skills to present answers clearly and accurately. Understanding this relationship is a crucial foundation for designing effective learning strategies, where the development of numerical skills is emphasized as an essential foundation for the development of higher-level mathematical representation skills.

Through this detailed understanding, educators can adjust their teaching approaches to identify and address weaknesses in numerical skills that may limit students' skills to represent mathematical problems. The implementation of targeted and tailored learning strategies can significantly contribute to improving student performance, especially in

facing PISA questions, where mathematical representation skills play a crucial role in measuring global mathematical competence. According to (Oktaviana & Prihatin, 2018), emphasizing that each student has diverse understandings in answering questions, it is important to simultaneously train students' representation skills to enhance numerical skills. The purpose of this research is to analyze the mathematical representation abilities exhibited by students of MTs Al-Mu'min Muhammadiyah Tembarak in solving PISA questions on space and shape, considering their high, moderate, and low numerical skills. Based on this explanation, the "exploring numerical competence: analysis of students' mathematical representation skills in pisa space and shape content".

METHODS

This research falls under the category of qualitative descriptive research. Qualitative research details the research topic and considers the subject context to generate data that achieves significant results through word descriptions, as stated by (Wantoro et al., 2019). The aim is to provide an overview of students' mathematical representation skills in solving PISA questions on the Space and Shape content, considering their numerical skills.

This research was conducted at MTs Al-mu'min Muhammadiyah Tembarak, Temanggung Regency, Central Java. The research subjects were students of class VIII-Tahfidz at MTs Al-mu'min Muhammadiyah Tembarak in the odd semester of the year 2023, totaling 24 students. The research utilized the descriptive test instrument of PISA content on Space and Shape to assess the mathematical representation skills of students, which had been validated for reliability by a mathematics education lecturer and a mathematics teacher at MTs. Supporting instruments used in this research included multiple-choice questions on numerical abilities and an interview guide conducted with one student exhibiting low numerical abilities, one with moderate numerical abilities, and one with high numerical abilities. The following presents the issues related to the PISA content on Space and Shape concerning the material of spatial structures for class VIII.

Gabriella has a koi fish pond shaped like a rectangular prism with a height of 80 cm, a width of 1 m, and a length of 1.5 m. To make the koi pond look more attractive, Gabriella wants to install tiles on the entire surface of the pond, with each tile measuring 20 cm x 20 cm. How many tiles are needed? If the price of one tile is Rp 30,000.00, how much does Gabriella have to pay the building supply store? How much water volume is needed to fill Gabriella's koi pond?

The research method employed is a qualitative approach, focusing on gaining in-depth understanding of the investigated phenomenon and seeking contextual understanding. To collect data, several steps were taken, including conducting a numerical ability test by collecting responses from eighth-grade Tahfidz students on multiple-choice questions that had been administered, implementing a mathematical representation test by collecting responses to open-ended questions on the mathematical representation test for eighth-grade Tahfidz students, and conducting interviews with three students with different numerical abilities. The interviews are expected to provide further insights and a deep understanding of how students think and approach mathematical problems. Data analysis is carried out through data collection, analysis, presentation, and drawing conclusions. The focus of this research is on mathematical representation skills, using guidelines that pay attention to how students understand and solve PISA questions on the content of Space and Shape, which serves as the basis for drawing conclusions.

RESULT AND DISCUSSION

From the assessment of the numerical mathematics skills of 24 students, the test scores for numerical skills are classified into three levels: high, medium, and low, as presented in the Table 1.

Table 1. Numerical skills table

Interval value	Category
≥ 80	High
$50 \leq x < 80$	Medium
< 50	Low

Each level of numerical skills is represented by one student as a research subject, so there are three students representing high, medium, and low numerical skills levels. The selection of these subjects is based on numerical skills test scores and recommendations from teachers at MTs Al-mu'min Muhammadiyah Tembarak. The three students who are the subjects of the research are coded as follows: A3 for the student with low numerical skills, A2 for the student with moderate numerical skills, and A1 for the student with high numerical skills.

Below is the analysis of students' mathematical representation skills based on numerical skills:

1. Subject with Low Numerical Skills. The answers of students with low numerical skills are presented in Figure 1:

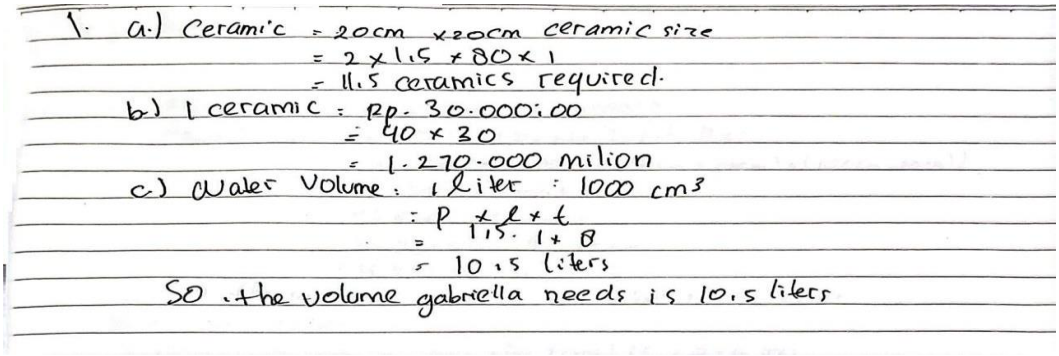

Figure 1. Result of Student A3's

To clarify the answers given by student A3 as shown in Figure 1, an interview was conducted as follows:

P: What do you know from this question?
A3: The length of the prism is 1.5m, the width is 80cm, the height is 1m, the tile's length is 20cm, and the tile price is 30,000.
P: What is being asked in this question?
A3: The number of tiles, the total price of all tiles, and the volume of the koi pond.
P: Take a look at your answer, why didn't you write down what is known, what is asked, and the conclusion of your answer?
A3: I think it's not necessary to write all of that, ma'am.
P: How many methods do you know to solve this question?
A3: Just that, ma'am, it's the only method I know.
P: To make it easier to answer this question, I think you can use illustrations or pictures. Why don't you try using that method?
A3: Because I haven't tried it before, ma'am.
P: But the teacher has explained it?
A3: Yes, ma'am, but I didn't understand it well.
P: What is your initial step in solving this problem?
A3: I converted meters (m) to centimeters (cm).
P: Why did you convert meters (m) to centimeters (cm)?
A3: To make it easier to work on, ma'am.
P: Then after you converted meters (m) to centimeters (cm)?
A3: I plugged it into the surface area formula, ma'am.
P: After plugging it into the formula, what did you do?
A3: I multiplied it to find the number of tiles, then calculated with the tile price, and found the water volume.
P: What are the results for the number of tiles, the total price, and the water volume?
A3: The results are 11.5 tiles, the price is Rp 1,270,000.00, and the water volume is 10.5 liters.

From the work results of subject-A3 above, in Figure 1, it can be seen that this subject has low mathematical skills. The indicator of mathematical representation skills that is fulfilled is the indicator of the skills to represent mathematical equations or expressions. Subject-A3 was able to create a mathematical model successfully; however, there were errors in the calculations, resulting in an incorrect solution. Subject-A3 made the mathematical model or formula correctly, but the calculations were not accurate in the

part of 2 x 1.5 x 80 x 1 = 11.5 tiles, 40 x 30,000 = 1,210,000 million, and 10.5 x 1 x 8 = 10.5 liters, so subject-A3 solved the problem incorrectly. This can be found in the notes or documents from the worksheet done by subject-A3 during the test.

The interview results depict that subject-A3 has the indicator of mathematical equations or expressions. Subject-A3 can clearly and comprehensively explain each question regarding the steps to solve the problem, but the calculations are still not precise.

2. Subject with Medium Numerical Skills. The answers of students with medium numerical skills are presented in Figure 2:

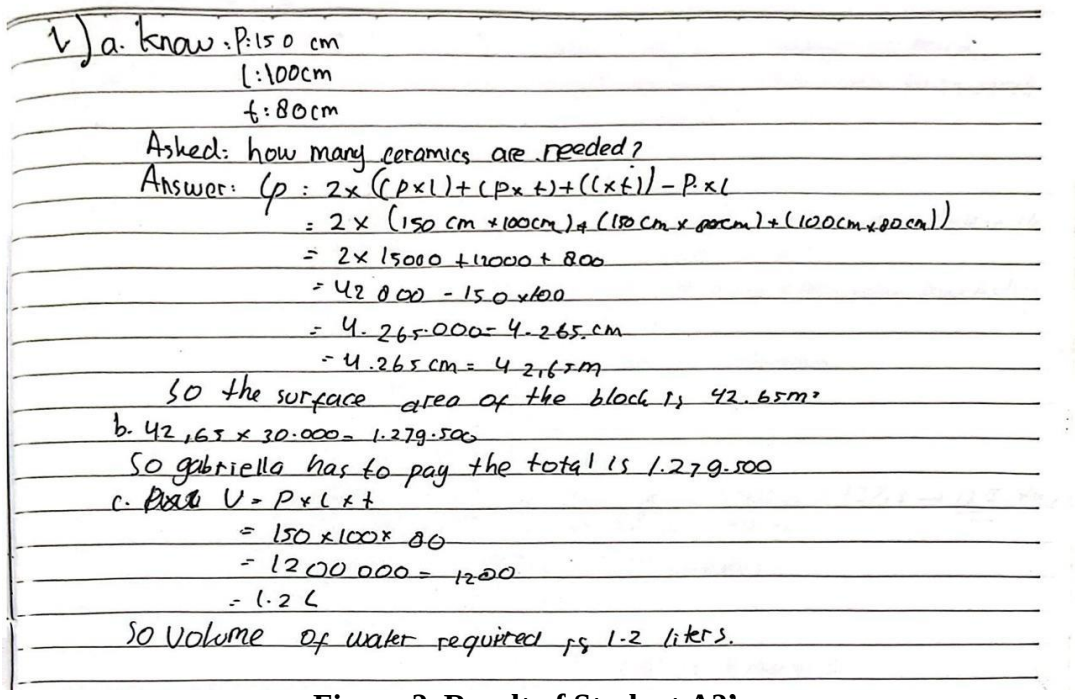

Figure 2. Result of Student A2's

To clarify the answers given by student A2 as shown in Figure 2, an interview was conducted as follows:

P: Then what is known in question number 1?
A2: The length of the prism is 1.5m, the width is 80cm, the height is 1m, the tile's length is 20cm, and the tile price is 30,000.
P: What is being asked?
A2: The number of tiles, the total price, and the water volume in the pond, ma'am.
P: Take a look at your answer, why did you write down what is known, what is asked, and the conclusion of your answer?
A2: To make it easier for me to work on, ma'am.
P: Then how many methods do you know to solve this question?
A2: There are 2 methods, ma'am. Namely, calculating the surface area and then subtracting the top part of the prism, and by drawing the parts of the pond (prism) separately, then calculating their areas one by one and combining them.
P: Why did you choose the first method?
A2: Because I haven't tried the other method, ma'am, I only know there is another way.

P: Okay, what is your initial step in solving this problem?
A2: I converted meters (m) to centimeters (cm), ma'am.
P: Why did you convert meters (m) to centimeters (cm)?
A2: To make it easier to work on, ma'am.
P: Then after you converted meters (m) to centimeters (cm)?
A2: I plugged it into the surface area formula, ma'am.
P: After plugging it into the formula, what did you do?
A2: I multiplied and divided to find the number of tiles, then multiplied by the price of one tile, and found the water volume.
P: What are the results for the number of tiles, the total price, and the water volume?
A2: The results are the surface area is 42.65 m2, the price is Rp 1,279,500.00, and the water volume is 1.2 liters.

From the work results of subject-A2 above, in Figure 2, it can be seen that this subject has medium mathematical skills. The indicator of mathematical representation skills that is fulfilled is the indicator of words or written texts, showing that subject-A2 can present solutions with words logically and systematically, but still less accurate.

This is evident from subject-A2 recording what is known and what is asked in the problem and the conclusion at the end of the answer. Regarding the indicator of mathematical equations or expressions, subject-A2 can create a mathematical model correctly, but subject-A2 performs calculations inaccurately, resulting in an incorrect final result. This is indicated by the result, which is the surface area is 42.65 m^2, and the water volume is 1,200,000 cm^3: 1,000 cm^3 = 1.2 liters.

The interview results above depict that subject-A2 has the indicator of words or written texts, marked by the student explaining the reasons for each question given in relation to the presented problem. Regarding the indicator of mathematical equations or expressions, subject-A2 can explain each question given regarding the steps to solve the problem in detail and clearly, but inaccurately due to errors in calculations.

3. Subject with High Numerical Skills. The answers of students with high numerical skills are presented in Figure 3 :

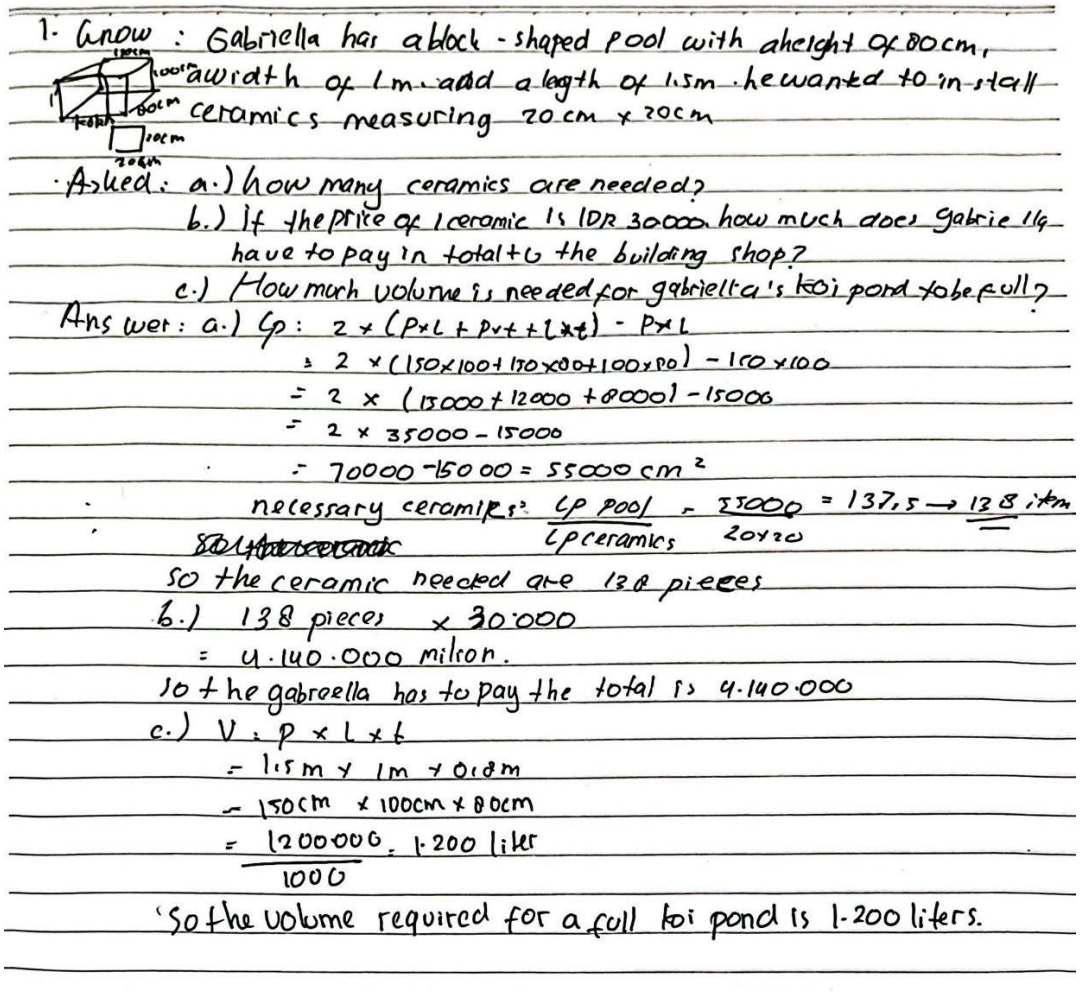

Figure 3. Result of Student A1's

To clarify the answers given by student A1 as shown in Figure 3, an interview was conducted as follows:

P: What do you know from this question?

A1: The length of the prism is 1.5m, the width is 80cm, the height is 1m, the tile's length is 20cm, and the tile price is 30,000.

P: What is being asked?

A1: The number of tiles, the total price, and the water volume in the pond, ma'am.

P: Take a look at your answer, why did you write down what is known, what is asked, and the conclusion of your answer?

A1: To make it easier for me to work on, ma'am.

P: How many methods do you know to solve this question?

A1: There are 2 methods, ma'am. Namely, calculating the surface area and then subtracting the top part of the prism, and by drawing the parts of the pond (prism) separately, then calculating their areas one by one and combining them.

P: Why did you choose the first method?

A1: Because I feel this method is easier, ma'am.

P: What is your initial step in solving this problem?

A1: I converted meters to centimeters and drew the rectangular prism and the tiles that will be installed.

P: Next, please explain the steps you took to solve this question.

A1: I entered it into the surface area formula, then subtracted the top part, resulting in 55,000 cm2, then divided it by the area of the tile, resulting in 137.5 tiles, then rounded up to 138 pieces.
P: Then what are you looking for?
A1: Then I calculated 138 tiles multiplied by the tile price of 30,000, the result is Rp 4,140,000.00; and for the water volume, I calculated it by entering it into the prism volume formula, so the result is 1,200,000 cm3, divided by 1,000 cm3, and the final result is 1,200 liters, ma'am.
P: So, what conclusion did you get?
A1: The number of tiles needed is 138 pieces with a total price of Rp 4,140,000.00, and the volume of the pond is 1,200 liters

From the work results of subject-A1 in Figure 3 above, it can be seen that this subject has high mathematical skills. The indicators of mathematical representation skills that are fulfilled are the indicators of words or written texts, showing that subject-A1 can present solutions with words logically and mathematically, as seen in the student writing down what is known, what is asked, and the conclusion. The indicator of visual representation, subject-A1 can produce illustrations to explain the problem and facilitate its comprehensive resolution. Subject-A1 successfully achieved an accurate solution, as evidenced by his skills to draw according to the problem in the question. The illustration made by Subject-A1 is accurate and detailed, as seen in Figure 3 on Subject-A1's answer sheet containing drawings of the prism and tiles. Regarding the indicator of mathematical equations or expressions, subject-A1 can create a mathematical model correctly. Subject-A1 also calculates accurately and successfully obtains a correct and comprehensive solution. Evidence can be seen from the results of Subject-A1 answer sheet in the first stage of solving the problem, changing the unit from meters (m) to centimeters (cm), and creating a mathematical model. Furthermore, Subject-A1 entered it into the mathematical model, so the final result for the number of tiles is 138 pieces with a price of 4,140,000 and the water volume is 1,200 liters, which is correct and in accordance with the answer key.

The interview results show that Subject-A1 can use visual representation skills through drawings when solving problems. In terms of using words or texts, Subject-A1 can provide explanations for the reasons for each question related to the problems faced in the question. In terms of mathematical equations or expressions, Subject-A1 can explain each question given in relation to the steps to solve the problem.Based on the analysis description conducted by the researcher, it is found that Subject-A1, Subject-A2, and Subject-A3 have different visual representation, verbal (word), and equation (expression) skills based on their numerical skills. According to (Deswantari et al., 2020), if identical

math problems are given to different individuals, the results will vary, just as with mathematical representation skills.

Subject-A3 and Subject-A2 with low and moderate numerical skills have differences in the verbal skill indicator. In the verbal skills indicator, Subject-A3 can express and detail problem situations based on provided data or representations using written words, but less precisely. On the other hand, Subject-A2 can create problem situations based on given data or representations using words, but due to the lack of details in the calculations and the absence of a written conclusion from the obtained answer. According to (Ratri & Setyaningsih, 2020), students with low and moderate numeracy levels have shortcomings in accuracy when answering questions. Often, students experience inaccuracies in calculating the results, or they may have difficulty finding the final answer to a problem. Subject-A1 with high numerical skills can create problem situations based on data or representations given using written words. Skills in understanding questions tend to be better in students with higher numerical skills than those with lower numerical skills.

Subject-A3 and Subject-A2 with low and moderate numerical skills in the visual representation skill indicator in solving geometry problems are not yet able to produce illustrations of geometric shapes to explain a problem. This condition affects the resolution process with inaccurate steps and incorrect final results. However, the advantage possessed by student A2 is using formulas and appropriate steps. Student A1, with high numerical skills, can draw geometric shapes to explain problems and facilitate their resolution, thus finding the correct answer. According to (Kurniawati & Juandi, 2023), visual representation skills is when students can articulate quantitative and relational statements, then transform them into relational equations with a situational model, including making object drawings and performing calculations.

In the mathematical expression skill indicator, Subject-A3 with low numerical skills, and Subject-A2 with moderate numerical skills, can identify appropriate solution steps based on the given problem, but due to lack of precision, it causes inaccuracies in calculations and incorrect final results. However, there is an advantage in Subject-A2, being able to write the length units at each step taken. According to (Pranasiwi, 2017), there is a strong relationship between how well students understand mathematics and how well they can use numbers and mathematical concepts in the problems they face. Subject-A1 with high numerical skills can create a mathematical model from the given mathematical representation. According to (Santoso & Setyaningsih, 2020), students with

high numeracy skills can understand problems well and solve them more accurately than students with moderate or low numeracy skills. On the other hand, in a study conducted by (Ratri & Setyaningsih, 2020), it is mentioned that when students have high numeracy skills, they tend to give correct answers. Students with high skills can describe information from the problem, identify existing problems, design problem-solving methods, and present solutions in a logical and clear sequence.

Based on the data analysis results, it is also found that some students make mistakes in answering questions, causing variations in representation skills. This is in line with the opinion of (Purwanti, 2016), that these differences can be caused by students' skills in mastering three indicators of mathematical representation skills, while some students only master two or even one indicator. Based on the presented data analysis, potential errors may include various aspects, such as students having difficulty visualizing the problem, inaccuracies in the use of mathematical symbols, and lack of precision. Other research indicates that students more often make mistakes in understanding and transformation compared to other types of errors (Wati & Murtiyasa, 2016). Additionally, according to (Hijriani et al., 2018), students' in skills to create accurate visual and symbolic representations when solving PISA problems is due to a lack of precision.

The representation skills of eighth-grade students in the content of space and shape in PISA questions are considered to have good quality. This is derived from the students' proficiency in visually depicting, mathematically expressing, and understanding written texts. Despite the acknowledgment of students' good representation skills, continuous efforts are needed by teachers to enhance them. This is because representation skills play a crucial role in the success of students in comprehending mathematical concepts. Nevertheless, there are still some students who have not mastered PISA questions well, leading to deficiencies in their mathematical representation skills. huA suggested recommendation is for teachers to provide more practice questions to sharpen students' representation skills, including non-routine questions similar to those in PISA. Further research is expected to focus more on the occurring differences, avoiding the use of too many indicators to ensure a more in-depth discussion in the provided analysis.

CONCLUSION

Based on the research results, students with low numerical skills have indicators of mathematical expression representation. This is indicated by students creating mathematical models effectively. However, there are errors in their calculations. Students

with moderate numerical skills exhibit indicators of mathematical expression and verbal representation, as shown by their use of known formulas and failure to illustrate geometric structures to solve problems. Although these students follow the correct steps, they provide incorrect answers in the final calculation stage. Students with high numerical skills demonstrate good visual representation skills, answering questions accurately and correctly.

In the context of students' responses to PISA space and shape content, there is a detected strong correlation between representation skills and the level of numerical proficiency for each student. High numerical proficiency tends to be associated with good representation skills, moderate numerical proficiency is associated with satisfactory representation skills, while low numerical proficiency is linked to less effective representation skills.

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