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Mathematical Representation Ability in HOTS Problems : A Study of Students' Learning Style

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Abstract: This study aims to analyze students' ability to represent mathematical concepts when solving High Order Thinking Skills (HOTS) questions, reviewed based on visual, auditory, and kinesthetic learning styles. This study used a qualitative approach with a case study method with the subjects of nine students from SMAN 88 Jakarta who were selected by purposive sampling. The research instruments included learning style questionnaires, mathematical representation ability tests, and interviews. The data analysis technique in this study uses the stages of reduction, presentation, and drawing conclusions based on the Miles and Huberman model. The results of the study showed that all students, regardless of their learning style, mastered the visual aspect more. Learners with visual and auditory learning styles generally excel in visual aspects but weak in verbal and symbolic aspects, while learners with kinesthetic learning styles show varied abilities, with visual aspects remaining the most dominant. The findings of this study can provide insights for education practitioners to optimize mathematics learning based on students' learning styles, while contributing theoretically to the development of academic theory and literature in the field of mathematics learning and mathematical representation.

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Introduction

Mathematics learning trains students to reason logically, solve problems, and create and present mathematical models to find solutions through their understanding and abilities (Gusteti & Neviyarni, 2022; Nurfitriyanti et al., 2020; Susilawati et al., 2020). According to Maryati (2021), the process and results of students' problem solving in mathematics subjects are related to their mathematical representation abilities. This statement supports the view Hayun & Syawaly (2020) which is said that one of the abilities of learners in interpreting and solving various mathematical problems is part of mathematical representation skills which is an important aspect because it involves the ability to communicate information through graphs, pictures, diagrams, or other visual representations that help in problem solving.

Mathematical representation is a way for learners to communicate their concepts and ideas in solving mathematical problems (Kusuma et al., 2020). According to Nurbayan & Basuki (2022), mathematical representation ability is the fundamental ability to create mathematical concepts and thinking that are used to solve a mathematical problem. Students' mathematical representation skills are their attempts to convey their ideas in visual, symbolic, or mathematical and verbal forms of expression. (Umaroh & Pujiastuti, 2020). Thus, mathematical representation skills allow students to build mathematical understanding by creating, comparing, and using different types of representations, as well as helping in communication about mathematics (Escarez Jr. & Ching, 2022; Septian et al., 2023).

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Mathematical representation skills are considered important for students to develop because they help them understand and communicate mathematical concepts (Baiduri & Suliani, 2020; Pasehah & Firmansyah, 2020). Moreover, Marliani & Puspitasari (2022) also explained that mathematical representation skills help students understand concepts, solve problems, communicate mathematically, make mathematical connections, and apply mathematical ideas through modeling.

However, students often find it difficult to understand the problem and make representations in various mathematical forms such as symbols, pictures, written texts, and mathematical expressions (Ulya & Rahayu, 2020; Yuwono et al., 2021). Based on research conducted by Rahmawati (2021) shows that students still have weaknesses in mathematical representation skills based on visual and symbolic aspects. Students' low mathematical representation skills can be caused by a lack of practice in solving problems using their own thinking (E. R. Sari, 2024). Students' low mathematical representation skills can result in a lack of understanding of the subject matter, which ultimately leads to difficulties in understanding and solving the given problems (Fitrianingrum & Basir, 2020).

The ability to represent mathematics is influenced by various interrelated factors, both from within the student and from the surrounding environment. Learning style is one of the factors that can affect students' mathematical representation abilities (Antika et al., 2024; Syakira & Surya, 2024). Learning style is an individual's tendency to receive and understand information during learning (Abdurrahman & Kibtiyah, 2021; Konilah et al., 2022). There are three types of learning styles, which include visual (seeing), auditory (hearing), and kinesthetic (doing) (Ha, 2022). According to Wulandari & Rusmana (2020), understanding learning styles is important to increase learning effectiveness, because the more variety of learning styles that students master, the better the learning process will run.

Differences in learning styles in each student affect how they absorb and understand information in learning activities. Nabela et al. (2021) said that students' understanding of learning with visual style is usually obtained through reading activities and looking at illustrations or visualizations, then in the auditory learning style they tend to understand learning by listening to the information provided, and in the kinesthetic learning style they tend to do direct practice to understand learning. However, each learning style has its drawbacks, such as visuals are difficult to learn in noisy and image-free environments, auditors are less interested in mathematical visual representations, and kinesthetics have difficulty in counting, visual perception, and transferring information (Damayanti et al., 2024; Irfan et al., 2022; Putri et al., 2021).

There are several previous studies that are in line with the discussion above. One of them is research conducted by Komala & Afrida (2020) who conducted research at the Vocational High School level on trigonometry materials with the results of their research showing that visual mathematical representation ability in students with visual and auditory learning styles is classified as sufficient, while students with kinesthetic learning styles show superior visual mathematical representation skills compared to the other two learning styles in mathematics learning. Then, research (Murtianto & Suhendar, 2020) conducted at the high school level in linear program materials shows that students' symbolic mathematical representation abilities are classified as high compared to visual and verbal mathematical representation abilities. In line with the research conducted by (Hardianti et al., 2021) at the same level and material shows that students' symbolic mathematical representation skills are higher than visual and verbal mathematical representation skills.

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Based on several previous studies, not many have conducted research by presenting a thorough analysis of each indicator of mathematical representation ability (visual, verbal, and symbolic) in solving HOTS problems reviewed from the three learning styles (visual, auditory, and kinesthetic). This study aims to analyze students' mathematical representation ability in solving HOTS questions based on their learning style. This research is expected to expand insights into the relationship between learning style and mathematical representation skills, as well as develop learning strategies tailored to students' learning styles to improve mathematical representation skills in solving HOTS problems.

Research Method

The method used in this study is a case study with a qualitative approach. Case studies are methods in qualitative research that aim to explore a phenomenon thoroughly and in detail of a single case that can be an individual, group, institution, program, activity, event, or process with the aim of comprehensively understanding the context, dynamics, and distinctive characteristics of the case (Fraenkel et al., 2011). The data collection process is carried out through the collection of test and non-test data. Test result data are in the form of answers from students using the mathematical representation ability test instrument. Furthermore, the non-test data came from the results of the learning style questionnaire that had been filled out by the students and interviews conducted with students. The stages in the implementation of this research are filling out questionnaire on learning style, working on mathematical representation ability test instruments, and interviews. Furthermore, the data from the research will go through an analysis process that includes the stages of reduction, presentation, and drawing conclusions (Miles et al., 2014).

This research was carried out at SMAN 88 Jakarta with the research subject consisting of 9 students who were selected by purposive sampling. The research subjects were selected through analysis of the results of the learning style questionnaire and the mathematical representation ability test. The selected subjects will be assigned codes based on categories as shown in the following table:

Table 1. Research Subject Categories

Learning Style	Number of Students	Code
Visual	3	V
Auditory	3	A
Kinesthetic	3	K

Based on table 1, there are codes that will be used to facilitate the explanation of the results of the analysis of students' mathematical representation abilities that vary based on visual, auditory, and kinesthetic learning styles. The test instruments used in this study are based on indicators of mathematical representation ability, which include:

Table 2. Indicators of Mathematical Representation Ability

No.	Indicator	Definition	Question Number
1.	Verbal	The ability of students to communicate their ideas or thoughts about the solution of mathematical problems in verbal or written form.	1, 2, and 3
2.	Visual	The ability of learners to communicate their ideas or thoughts about the solution of a mathematical problem in the form of pictures, diagrams, or graphs.	1, 3, and 4
3.	Symbolic	The ability of students to communicate their ideas or thoughts about the solution of mathematical problems in the form of symbols or mathematical models.	1, 2, and 3

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Source: (Marliani & Puspitasari, 2022; M. C. P. Sari et al., 2023)

Table 2 presents indicators from the mathematical representation test instrument used in this study to analyze the results of students' mathematical representation abilities. This test instrument has gone through a content validation process, where the validity of the content shows the extent to which the questions or question items in a test or instrument are able to represent the overall behavior of the research subject (Ramadhan et al., 2024). The validation process of this test instrument is carried out by two experts, namely a mathematics education lecturer and a mathematics teacher.

Results and Discussion

Refers to the results of filling out a learning style questionnaire as well as a mathematical representation test filled out by 100 students, there were 9 students who were selected as the main subjects in this study to analyze more deeply how their mathematical representation skills based on their learning styles. The Hots questions on the mathematical representation ability test instrument given to students are in the form of 4 questions with quadratic function material. After analyzing the results of learning style questionnaires, mathematical representation ability test instruments, and also interviews with students, in-depth analysis of each research subject was obtained as follows.

Mathematical Representation Skills with Visual Learning Styles

Analysis of the results of the work on the questions and interviews of three students with visual learning styles showed that there was a variation in mathematical representation skills. In general, all three subjects showed the most outstanding ability in the visual aspect, characterized by the ability to accurately depict curves and geometric shapes. However, there are differences in the achievement of verbal and symbolic aspects. This shows that learners with visual learning styles are superior in representing data or information into the form of diagrams, graphs, or tables (Nursaodah et al., 2024). The following description will explain in detail the results of the analysis of the three subjects based on data obtained from the work on the questions and interviews.

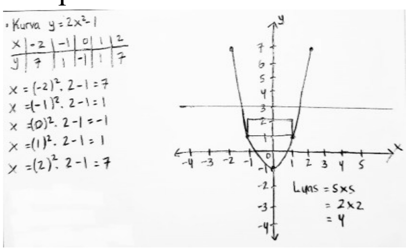

Figure 1. Results of V1

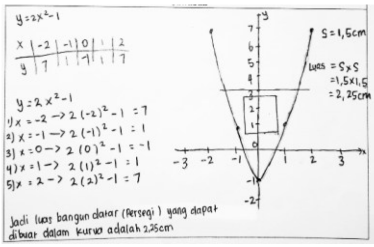

Figure 2. Results of V2

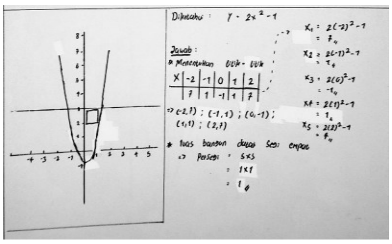

Figure 3. Results of V3

Figure 1 shows the results of V1 in solving problem number 1 which has a visual learning style and is able to meet 1 indicator of mathematical representation ability, namely the visual aspect. V1 is able to detail and accurately describe the shape of the requested curve and rectangle. However, V1 has not yet met the aspects of verbal and symbolic mathematical representation ability. V1 is able to provide a mathematical explanation of the answer, but the solution given is not precise in determining the area of the rectangle and cannot write down the solution to solve the problem in verbal form. Then, V1 can write down the steps to solve the problem using mathematical models and symbols, but the solution obtained is not right when determining the area of the rectangle. Here are the results of the interview with V1.

Researcher: "How do you understand the question given?"

V1: "I first read the question and it was the same as the question I had been given before."

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Researcher: "How do you solve the problem?"
V1: "I determined the values of x and y in advance to draw the curve. After that, I draw a curve and draw a rectangle and determine the area of the rectangle with the formula of the sides multiplied by the sides."
Researcher: "Are there any difficulties you feel when using mathematical models or symbols to solve this problem? If so, in what parts do you find difficult?"
V1: "I find it a little difficult when determining the x and y values for points on the curve."

Figure 2 shows the results of V2 with a visual learning style in answering question number 1, which succeeded in meeting two indicators of mathematical representation ability, namely verbal and visual aspects. V2 is able to explain the solution to the problem mathematically in detail using the right words by providing a solution to the problem in the form of a square area verbally. Then, V2 is able to communicate his thoughts precisely in determining the solution to the problem in the problem using curve and square drawings. However, V2 has not been able to find the right square area calculation solution even though it has used mathematical models and symbols correctly.

Figure 3 shows the results of V3 who has a visual learning style in solving problem number 1, where the subject is able to meet three indicators of mathematical representation ability, namely verbal, visual, and symbolic aspects. The presentation of the solution in verbal form made by V3 is already reasonable and logically arranged when determining the coordinate points on the curve and square area. Furthermore, V3 is able to depict curves and squares in the form of squares in detail and precisely. Then, the mathematical models and symbols used by the V3 are correct and are able to find detailed and precise calculation solutions to determine the coordinate points on the curve and square area. Here are the results of the interview with V3.
Researcher: "How do you understand the question given?"
V3: "I understand in advance what is known and what is asked."
Researcher: "How do you solve the problem?"
V3: "First I determine the coordinate point for the curve, then I make the curve and build a square flat, then I find the area according to the distance between the points and the other points."
Researcher: "Why did you choose to use the image to solve the problem you were given?"
V3: "I think it's more efficient because it's not too complex for the square area formula."
Researcher: "Are there any difficulties when you use mathematical models and symbols?"
V3: "I don't think it's difficult, because I use models and symbols that I already understand."

Mathematical Representation Skills with Auditory Learning Style

Analysis of students with auditory learning styles showed differences in achievement in mathematical representation skills. In general, students with this learning style tend to show strength in the verbal aspect, although not all of them are able to make optimal use of this aspect. Some students also showed quite good visual skills, but there are still limitations in the proper use of mathematical models and symbols. This is in accordance with research conducted by Amalia et al. (2021) which states that students with auditory learning styles tend to be able to form equations or mathematical models of given problems and can convert data or information into visual form. The following description presents the results of work and interviews on three subjects with auditory learning styles.

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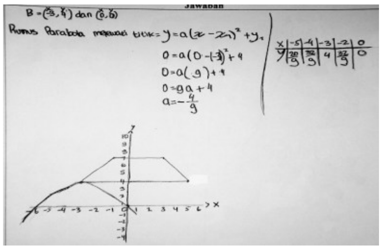

Figure 4. Results of A1

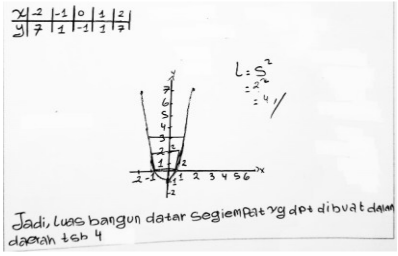

Figure 5. Results of A2

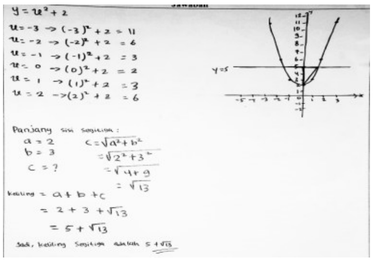

Figure 6. Results of A3

Figure 4 shows the results of A1 in solving problem number 3 which has an auditory learning style and is able to meet 1 indicator of mathematical representation ability, namely the visual aspect. A1 is able to accurately describe the curve in solving the given problem. However, A1 is unable to write down the completion steps in verbal form and cannot understand the intent of the given problem. Then, in determining the solution to the solution of the parabolic equation, there is only a little that is right from the mathematical model used. Next, the results of the interview were presented with A1.

Researcher: "How do you understand the question?"

A1: "Honestly for this question I'm confused about the meaning of the question."

Researcher: "Which parts do you find difficult or confusing?"

A1: "I find it difficult from the question, but from the picture I can understand."

The work of A2 is presented in Figure 5 in solving problem number 1 which has an auditory learning style and is able to meet 2 indicators of mathematical representation ability, namely verbal and visual aspects. When solving the problems presented, A2 is able to create curves and rectangles precisely. A2 is also able to write down the solution requested verbally regarding the area of the rectangle that has been created. However, A2 did not write a mathematical model to determine the coordinate points on the curve and there was little use of mathematical symbols to find solutions to the calculations performed.

Figure 6 shows the results of A3 in solving problem number 4 which has an auditory learning style and is able to meet 3 components of mathematical representation skills that include verbal, visual, and symbolic aspects. The results of A3 have provided a detailed and logical mathematical explanation by writing down the steps of solving and solving the circumference of the triangle in verbal form precisely. Then, A3 is able to depict curves and triangles in detail and precisely. A3 also uses mathematical models and mathematical symbols in detail and precisely in determining the coordinate points on the curve, the length of each side of the triangle, and the circumference of the triangle. Next, the results of the interview were presented with A3.

Researcher: "How do you solve the problem?"

A3: "First I found out that there was a line $y = 5$, then I drew the line into the graph, after which I looked for an equation that could offend the line."

Researcher: "Is there a sentence in the question that you find difficult to understand?"

A3: "At first I was confused about what the t-line is, after I read it a few times it turned out that the t-line was the $y = 5$ line."

Researcher: "Why did you choose the drawing of the curve and the flat build as a solution to the problem?"

A3: "I chose the curve because of the equation I have created and I chose the circumference of the triangle so that the drawing and the solution used are not monotonous."

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Mathematical Representation Skills with Kinesthetic Learning Styles

Analysis of students with kinesthetic learning styles showed variations in the achievement of mathematical representation skills. Generally, students with this learning style tend to be superior in visual representation, as seen from their ability to draw geometric shapes such as curves and flat buildings in detail and precisely. Some students began to show an understanding of the use of mathematical models and symbols, although there were still mistakes in their application. This shows that students with kinesthetic learning styles excel in visual and symbolic representations (Nay et al., 2022). The following description will explain the results of the work and interviews of three students with a kinesthetic learning style.

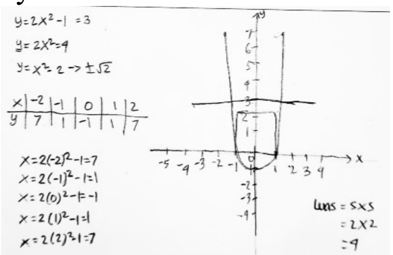

Figure 7. Results of K1

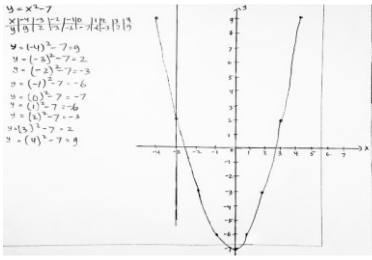

Figure 8. Results of K2

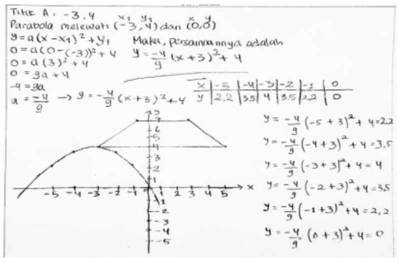

Figure 9. Results of K3

Figure 7 shows the results of K1 who have a kinesthetic learning style in working on problem number 1, with the achievement of one of the indicators of mathematical representation ability, namely the visual aspect. K1 fulfills the aspect of visual mathematical representation ability because it is able to make curves and squares in detail and precisely as a solution step to find solutions to solve given problems. Meanwhile, in terms of verbal and symbolic mathematical representation skills, K1 has not met based on the results of its work. There are only a few verbal presentations used in solving questions. Then, there is still an error in the use of mathematical symbols to determine the coordinate points on a curve that are supposed to look for the y point but K1 writes with the x symbol.

Figure 8 shows the results of K2 in solving problem number 2, which has a kinesthetic learning style and is able to meet two indicators of mathematical representation ability, namely visual and symbolic aspects. Based on the results of the work, K2 is able to create a curve drawing that can offend the line as instructed in the question. Then, K2 can also find the coordinate point on the curve as a solution step using the right mathematical model and symbols. However, there are no settlement steps or solutions in the verbal form used by K2 in answering questions. Furthermore, the results of the interview were presented with K2.

Researcher: "Why did you choose the completion step?"
K2: "I first try to find an equation that can cross the t-line and I find the equation, then I substitute the value of x to get the value of y, and finally I draw the curve."
Researcher: "Is there a difficult part of the question to understand?"
K2: "Nothing, but it's complicated to explain the workmanship."

Figure 9 shows the results of K3 in solving problem number 3 which has a kinesthetic learning style and successfully meets three indicators of mathematical representation ability, namely verbal, visual, and symbolic aspects. K3 is able to provide mathematical explanations in verbal form precisely in providing solutions in the form of parabolic equations that use the apex point on the lower side of the trapezoidal and through the origin point. The parabolic image made by K3 is also appropriate based on the parabolic equation that K3 has obtained and according to the conditions given in the question. Then, in determining the solution of

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parabolic equations and coordinate points on a parabola, K3 has used mathematical models and symbols in detail and precisely.

Based on the results of the analysis above, it can be concluded that students with visual, auditory, and kinesthetic learning styles tend to have better visual mathematical representation skills compared to verbal and symbolic aspects. The results of the analysis are supported by a form of problem solving that requires students to represent their answers in visual form in the form of images or graphs. These results are in line with the results of research conducted by Setyawati et al. (2022) which show that students with visual, auditory, and kinesthetic learning styles are better able to solve problems with visual aspects. This is because visual mathematical representation skills tend to be easier for students to master than symbolic or verbal categories based on the level of academic ability and mastery of mathematical representation indicators possessed by students (Khoerunnisa & Maryati, 2022; Sunanti et al., 2022; Wahidah & Hakim, 2022). The results of this study show that the influence of learning style on mathematical representation skills, especially students with visual, auditory, and kinesthetic learning styles tend to master visual representations more than verbal and symbolic. Based on these findings, teachers can later consider the use of visual approaches, such as images, graphs, and illustrations in mathematics learning, to help students understand and solve problems more effectively according to their learning style.

Conclusion

Based on the results and discussion, it can be concluded that the mathematical representation ability of students with visual, auditory, and kinesthetic learning styles shows a similar tendency, namely more dominant in visual aspects than verbal and symbolic aspects. Students with visual learning styles are generally able to describe curves and flat shapes in detail and precisely, but still have difficulty in conveying solutions verbally or using mathematical symbols appropriately. Similarly, learners with auditory learning styles tend to be strong in visual aspects and partially able to convey verbal explanations, but weak in symbolic aspects. Meanwhile, students with kinesthetic learning styles showed a variety of abilities, from those who only mastered visual aspects to those who were able to fulfill all three aspects of representation completely, although visual remained the most prominent aspect. This corroborates the finding that visual representation skills are easier for learners to master than verbal and symbolic aspects, which require a higher level of conceptual understanding.

Recommendation

Based on the findings, it is recommended for educators to design learning that not only develops visual aspects, but also encourages learners to improve verbal and symbolic representation skills. Educators can provide exercises that involve verbal explanations and the writing of mathematical symbols in stages, as well as using an approach that suits students' learning styles to maximize their potential in each aspect of representation. For further research, it is recommended that it be carried out on a wider and more diverse sample so that the results are more representative, as well as to investigate more deeply about other factors that affect mathematical representation skills, such as learning motivation, level of concept understanding, or the use of interactive learning media.

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