



Mathematical Representation of Class IV Primary School Students in Solving TIMSS-Based Geometry Questions in Terms of Gender

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Abstract

This study aims to describe the mathematical representation abilities of fourth-grade elementary school students in solving TIMSS-based geometry problems, viewed through the lens of gender. The study employed a descriptive qualitative approach involving two subjects: one male student and one female student. Data were collected through written tests and interviews, then analyzed based on visual, symbolic, and verbal representations. Data validity was reinforced by comparing the students' work with the explanations provided during interviews. The results showed that the male student was able to draw a three-dimensional rectangular prism and accurately label its length, width, and height, though he did not present the front and side views separately. The female student was able to fully present the drawing of the rectangular prism, as well as its front and side views. Regarding symbolic representation, the male student was able to construct a mathematical model, apply formulas, and obtain the correct result, although the completeness of steps and precision regarding units needed improvement. The female student used symbols, operations, and units systematically and linked them to conceptual understanding. In terms of verbal representation, the male student provided a correct conclusion but offered a relatively brief written explanation, whereas the female student explained the steps, reasoning, and conclusion in a coherent manner. Overall, both subjects demonstrated good and interconnected mathematical representation abilities. These findings illustrate the tendencies of the subjects and cannot be generalized as a difference in ability based on gender.

Introduction

Mathematics is a compulsory subject because it is essential in various fields, both within mathematics itself and other disciplines (Septian & Komala, 2019). It also plays an important role in education and is taught at elementary, secondary, and higher education levels (Luritawaty, 2018). Students are expected to achieve the competencies established in the curriculum, including understanding mathematical concepts and applying them accurately and efficiently to solve problems. One competency indicator is the ability to present mathematical concepts through various representations, such as tables, graphs, diagrams, pictures, sketches, and mathematical models (Permendikbud, 2014; Hariyani et al., 2023; Tupamahu et al., 2023; Cevikbas et al., 2022).

This expectation is consistent with the Hadith of the Prophet Muhammad narrated by Ibn Mas'ud, which encourages Muslims to seek knowledge and teach it to others (HR. Ad-Darimi, Ad-Daruquthni, Al-Baihaqi). The hadith emphasizes the importance of learning and sharing

knowledge, which is relevant to students' responsibility to develop the competencies required in education.

According to the *National Council of Teachers of Mathematics* (NCTM), mathematical learning involves five process standards: mathematical problem solving, reasoning and proof, communication, connection, and presentation (Lindquist & Gates, 2020). Although mathematical representation was initially considered part of mathematical communication, its consistent presence at all educational levels has led researchers to recognize representation as an important component that deserves explicit emphasis in mathematics instruction (Duval, 2017; Damayanti & Afriansyah, 2018; Goldin, 2020).

Mathematical representation refers to students' interpretation of a problem and serves as a tool for finding solutions (Sabirin, 2014; Lisarani & Qohar, 2021). It is closely related to mathematical communication and problem solving because students need visual, graphical, diagrammatic, symbolic, or other representations to communicate mathematical ideas (Lette & Manoy, 2019). Appropriate representations can simplify complex problems and support students in selecting accurate problem-solving strategies (Yanni, 2018). Mathematical representation includes creating and using representations to organize and communicate ideas, selecting and translating representations to solve problems, and interpreting mathematical models and phenomena. It can also help students organize their thinking (Ulfa et al., 2019; Rahmawati et al., 2025; Biber, 2023; Ziatdinov & Valles Jr, 2022).

A preliminary study conducted on Wednesday, May 22, 2024, at SD Inpres Passuakkang showed that students' mathematical representation abilities varied. In terms of *visual representation*, some students could correctly draw the fifth pattern based on the sequence of odd numbers, while others were only able to draw incomplete patterns. In *symbolic representation*, some students provided numerical answers, such as 7 or 9, without mathematical formulas, while others did not provide numerical or symbolic answers. Regarding *mathematical thinking*, some students successfully recognized and generalized the odd-number pattern (1, 3, 5, 7, ...) and concluded that the fifth figure contained nine circles. Other students were unable to connect the previous figures into a sequence and therefore reached incorrect conclusions.

These findings indicate that students have diverse mathematical representation abilities. While some can appropriately combine visual, symbolic, and verbal representations, others still require guidance in recognizing patterns and making generalizations. Therefore, further research is needed to identify students' difficulties and develop appropriate instructional strategies to improve mathematical representation skills.

Previous studies have emphasized the importance of mathematical representation, particularly in geometry. TIMSS 2019 identifies *Measurement* and *Geometry* as important content domains for fourth-grade students, requiring them to visualize and reason about relationships among geometric figures. Its assessment framework includes two- and three-dimensional shapes and spatial reasoning, providing a basis for developing representation-based geometry problems. TIMSS findings also indicate differences in mathematics achievement by gender, with boys tending to outperform girls, suggesting the presence of a gender gap from the elementary level (Fattah, 2018).

Pina et al. (2021) found gender differences in mathematics achievement as early as fourth grade, while Meinck & Brese (2019) showed that these differences were relatively consistent over time. Leng et al. (2024) used TIMSS *process data* to examine differences in students' problem-solving processes, creating opportunities to investigate differences in mathematical

representations between male and female students. Desai (2021) emphasized the importance of visual, symbolic, and verbal representations in geometry learning, while Fattah Bony et al. (2018) highlighted representation as an essential means of communicating mathematical ideas. Adnan (2019) directly examined gender differences in mathematical representation when solving geometry problems, but the study was limited and did not use the TIMSS framework.

Thus, although previous studies have examined mathematical representation, relatively few have comprehensively investigated how fourth-grade students use visual, symbolic, and verbal representations when solving TIMSS-based geometry problems, particularly from a gender perspective. Existing studies tend to focus on achievement scores or general problem-solving strategies rather than the relationship between the representations selected by students and their success in solving problems. Therefore, this study is important to provide a comprehensive description of fourth-grade students' mathematical representation patterns and to offer gender-sensitive instructional recommendations for improving geometry literacy in elementary schools.

Method

Research Design

This study employs a descriptive qualitative research design aimed at deeply describing and understanding phenomena. It focuses on how fourth-grade elementary school students represent mathematical concepts when solving geometry problems, particularly in relation to gender differences. A qualitative approach is used to explore students' thinking, strategies, and mathematical representation patterns, while the descriptive approach provides an in-depth description without manipulating or intervening in the variables.

Research Location, Time, and Subjects

The study is planned to be conducted at SD Inpres Passuakkang, Gowa Regency. The school was selected because it had previously been used for adapted test activities and actively involves the surrounding community through various programs. In addition, students demonstrate diverse characteristics and learning behaviors. Its strategic location also facilitates access for the researcher. The research is planned for the odd semester of the 2026/2027 academic year.

In qualitative research, research subjects are commonly referred to as informants. According to Barroga et al. (2023), qualitative research uses qualitative data in the form of statements or sentences rather than numerical data. Informants provide in-depth information related to the research context, including relevant situations and conditions. Their involvement enables researchers to obtain extensive information within a limited period and compare findings among subjects.

Based on this definition, the subjects of this study are fourth-grade students at SD Inpres Passuakkang, consisting of male and female students.

Research Instruments

Research instruments are tools used to collect data (Sugiyono, 2020). The instruments used in this study are:

Test

The researcher develops geometry problems based on the TIMSS framework to assess students' mathematical representation abilities.

Interview Guide

An interview sheet is used to record information obtained during the interview process.

Data Collection Techniques

Data are collected using the following techniques:

Test

The test provides information about students' mathematical representation abilities in solving geometry problems and allows comparison of the performance of male and female students.

Task-Based Interview

Task-based interviews are conducted to explore students' perceptions of mathematical tasks, factors influencing their performance, and gender differences in their mathematical approaches and experiences.

Result and Discussion

Visual Representation of Male Students

The visual representation of male students is demonstrated through their ability to transform verbal information regarding the dimensions of a rectangular prism into a three-dimensional geometric figure. Both male students were able to understand the relationship between length, width, and height and then place these dimensions in the appropriate parts of the figure.

The drawings made by the male students show that they understand a rectangular prism as a three-dimensional solid. They were able to distinguish the parts representing length, width, and height. The students also used dashed lines to represent the edges of the rectangular prism that were not directly visible. The use of these lines indicates spatial understanding of the front, back, side, and depth of the solid.

The visual representations used by the male students functioned to clarify the shape of the object and the position of each dimension. They did not draw randomly but connected numerical measurements with the directions of the dimensions of the rectangular prism. Thus, the drawings served as a means of organizing information and supporting the problem-solving process.

These findings are consistent with Goldin (2020), who argues that external representations, such as drawings, can reflect the structure of students' internal understanding. The students' accuracy in placing the dimensions indicates that they had developed a mental representation of the shape and elements of the rectangular prism.

The interview findings provided further evidence of the male student's visual representation ability. When asked how he determined the dimensions of the rectangular prism, the student explained:

P: "How did you determine the length and width?"

SL: "I know that the length of the rectangular prism is 8 cm. The width is half of the length, so it is 4 cm. The height is one-quarter of the length, so it is 2 cm."

This response indicates that the student could translate verbal information into numerical dimensions. His explanation also confirmed that the dimensions were determined through mathematical reasoning rather than estimation. Furthermore, when asked about the use of dashed lines, he stated:

P: "Why did you draw dashed lines on the rectangular prism?"

SL: "Those are the edges at the back of the prism that cannot be seen directly. I used dashed lines to make the shape of the prism look complete."

The response demonstrates that the student understood the function of dashed lines in representing invisible edges. However, when asked why he did not draw the front and side views separately, he explained:

P: "Why did you draw only one rectangular prism even though the question asked for front and side views?"

SL: "I drew the prism directly. I thought that the front and side views were already visible in that drawing."

This explanation reveals that the student interpreted the front and side views as parts of a three-dimensional drawing rather than as separate two-dimensional representations. Nevertheless, during further questioning, he was able to identify the dimensions of both views. He explained that the front view was a rectangle measuring 8 cm in length and 2 cm in height, while the side view measured 4 cm in width and 2 cm in height.

However, the male students tended to present the rectangular prism as a single three-dimensional object and had not separated the front and side views into two-dimensional drawings. They understood the front and side views as parts already visible in the three-dimensional drawing. This indicates that the students found it easier to perceive the object as a whole than to transform it into several drawings based on different viewing directions.

Based on Duval's (2006) theory, this condition indicates that the students were able to create visual representations but had not yet fully mastered the conversion from three-dimensional representations to two-dimensional representations. A solid figure and its planar views are different representations of the same mathematical object. Students need to determine which parts are visible and invisible from each viewing direction.

The confirmation results showed that the students actually understood the dimensions used in the front and side views. Therefore, the shortcomings in their answer sheets were more related to incomplete presentation and interpretation of the instructions rather than an inability to understand the dimensions of the rectangular prism.

Within the TIMSS framework, this ability falls under the applying domain because the students were able to select information, determine dimensions, and use drawings to represent geometric objects. However, the application of visual representation did not yet fully meet the requirements of the questions.

Visual Representation of Female Students

The visual representation of the female student is demonstrated through her ability to present geometric information in several forms of drawings. The student was able to determine the dimensions of the rectangular prism, create a three-dimensional drawing, and present the front and side views separately. In the front view, the student used the length and height dimensions. In the side view, she used the width and height dimensions. The selection of these dimensions indicates that the student understood the observer's position and was able to determine which parts of the object were visible from a particular direction.

This ability indicates that the female student not only understood the rectangular prism as a whole but was also able to perform spatial visualization. She could imagine changes in the appearance of the object when the viewing direction changed. This is an important ability in

geometry because students need to connect three-dimensional objects with their two-dimensional views.

The interview findings further confirmed the female student's ability to transform geometric information into multiple visual representations. When asked about the first step in drawing the rectangular prism, she explained:

P: "What was the first thing you did to draw the rectangular prism?"

SP: "I determined the dimensions of the prism first. Its length is 8 cm, its width is half of 8, which is 4 cm, and its height is one-quarter of 8, which is 2 cm."

This response indicates that the student organized the numerical information before constructing the drawing. When asked why she presented the front view as a rectangle measuring 8×2 cm, she stated:

P: "Why did you draw a rectangle measuring 8×2 cm?"

SP: "Because the question asked for the front view. When viewed from the front, the visible dimensions are the length and height. Therefore, I drew a rectangle with a length of 8 cm and a height of 2 cm."

The student also demonstrated an understanding of the relationship between viewing direction and visible dimensions. She explained:

P: "Why is the width of the rectangular prism not visible in the front view?"

SP: "Because the width extends backward. When the prism is viewed from the front, its width cannot be seen."

Regarding the side view, she stated:

P: "How does the rectangular prism appear when viewed from the side?"

SP: "When viewed from the side, the visible dimensions are the width and height. Therefore, the measurements are 4 cm and 2 cm."

Furthermore, the student explained the communicative function of the labels used in her drawings:

P: "What is the purpose of the arrows and dimensional labels in your drawing?"

SP: "So that people looking at the drawing know which side represents the length, width, and height."

The representations were also complemented by dimensional labels and indications of viewing direction. The use of labels shows that the student used drawings to communicate information clearly. The drawings not only helped her solve the problems but also helped readers understand the relationship between the shape and its dimensions.

According to Tarigan (2022), representations are used to organize, record, and communicate mathematical ideas. The female student's visual representation fulfilled all three functions. The information in the problem was organized into dimensions, recorded in drawings, and communicated through labels and different views.

The student's ability is also supported by Duval's (2006) theory of conversion between representations. She was able to transform verbal information into dimensions, dimensions into a three-dimensional drawing, and a three-dimensional drawing into two-dimensional views. These transformations were carried out without changing the meaning of the mathematical

object being represented. Within the TIMSS framework, this ability is related to the applying and reasoning domains. The applying domain is evident when the student applies dimensional information to the drawing. The reasoning element is evident when she determines the relevant dimensions for each viewing direction and distinguishes between visible and invisible parts.

Symbolic Representation of Male Students

The symbolic representation of male students is demonstrated through the use of numbers, fractions, variables, formulas, arithmetic operations, and units. Both students were able to transform verbal information in the problems into mathematical models and use these models to obtain correct solutions.

In the first problem, the male students were able to transform the terms "one-half" and "one-quarter" into the appropriate measurement values. The students presented their work using fractional symbols and directly stated the results. Although their methods of presentation differed, the confirmation results showed that the students understood the relationships between the fractions used.

In the problem involving the volume of a rectangular prism, the students were able to transform the relationship between length and width in relation to height into mathematical operations. They could determine the value of each dimension, select the appropriate volume formula, substitute the values into the formula, and perform the calculations correctly.

The interview findings provided further insight into the male student's symbolic representation ability, particularly in translating verbal information into mathematical models and applying formulas. When asked why he used the formula for the volume of a rectangular prism, he explained:

P: "Why did you write $V = l \times w \times h$?"

SL: "Because the question asks for the volume of a rectangular prism. The volume formula is length multiplied by width multiplied by height."

When asked to explain the calculation process, the student stated:

P: "How did you calculate the volume of the rectangular prism?"

SL: "The length is 12, the width is 8, and the height is 4. Then I multiplied them to obtain the volume."

His response confirms that he understood the relationship between the given dimensions and the formula used to calculate volume. The student's conceptual understanding was also evident when he explained the surface area of a cube:

P: "Why did you choose Adi's or Budi's statement as the correct answer? Explain your reasoning."

SL: "Because the box is shaped like a cube. A cube has six equal sides. The area of one side is the edge multiplied by itself. Therefore, six times the area of one side equals 600 square centimeters."

This ability indicates that the students were able to convert verbal representations into symbolic representations. Statements expressed in everyday language were transformed into more concise mathematical models that could be manipulated and operated upon.

According to Duval (2006), mathematical understanding is demonstrated through the ability to perform conversions between representations and process information within a particular

register. Conversion occurs when students transform verbal information into symbols, whereas processing occurs when students perform substitution and operations in symbolic form.

In the problem involving the surface area of a cube, the students used a model appropriate to the properties of a cube. They understood that the total surface area is related to the area of one face and the number of faces of the cube. This indicates that the symbols used were not entirely mechanical but were supported by conceptual understanding.

These findings are consistent with Hiebert and Lefevre (1986), who distinguish between procedural and conceptual knowledge. Procedural knowledge is evident when students use formulas and perform calculations. Conceptual knowledge is evident when students understand the relationships among edge length, face area, the number of faces, and surface area.

Within the TIMSS framework, the symbolic representation of male students involves the knowing, applying, and reasoning domains. Knowing is reflected in their knowledge of formulas and the properties of geometric solids. Applying is demonstrated through the use of formulas in problem situations. Reasoning is evident when symbolic results are used to evaluate the correctness of a statement.

The students were still inconsistent in writing units. However, the confirmation results showed that they understood the differences between units of length, area, and volume. Therefore, this shortcoming represents an issue of writing accuracy rather than a conceptual error.

Symbolic Representation of Female Students

The symbolic representation of the female student is demonstrated through her ability to organize mathematical information systematically. She was able to identify the given information, determine relationships among dimensions, use variables, select appropriate formulas, perform calculations step by step, and use units accurately.

The student understood that the symbols for length, width, and height represent different quantities. Relationships among dimensions in the problems were translated into mathematical models before being used in calculations. This indicates that the symbols were understood based on their meanings rather than used merely as memorized forms.

In solving the volume of a rectangular prism, the student performed the calculations systematically. The multiplication of length and width was understood as the area of the base, while multiplying the base area by the height was understood as the volume. These steps demonstrate the relationship between the concepts of area and volume.

According to Hiebert and Lefevre (1986), meaningful mathematical knowledge develops when conceptual and procedural knowledge are interconnected. The student's symbolic representation demonstrates this relationship. She was able to perform the procedures while also understanding the reasoning behind each step.

The ability to use units also indicates conceptual understanding. The student was able to distinguish between results representing area and those representing volume. Changes in units were understood as a consequence of the number of dimensions being multiplied.

In the surface area of a cube problem, the student first determined the area of one face and then related it to the total number of faces of the cube. This strategy indicates that she understood the basis for constructing the formula rather than merely memorizing its final form.

The interview findings confirmed the female student's ability to construct mathematical models and explain the meaning of the symbols and operations used. When asked why she applied the volume formula for a rectangular prism, she explained:

P: "Why did you use the formula $V = l \times w \times h$?"

SP: "Because the problem asks for the volume of a rectangular prism. The volume is calculated by multiplying the length, width, and height."

The student also described her calculation procedure:

P: "How did you calculate the volume using that formula?"

SP: "I multiplied the length and width first to make it easier. Twelve multiplied by eight equals 96. Then I multiplied 96 by the height of 4, and the result was 384."

This explanation demonstrates that the student understood the sequence of mathematical operations and the relationship between the base area and the volume of the rectangular prism. Her understanding of units was further illustrated by the following response:

P: "Why do the calculations use square centimeters and cubic centimeters?"

SP: "Because when the length is multiplied by the width, the result is the area of the base, so the unit is square centimeters. When the base area is multiplied by the height, the result is volume, so the unit is cubic centimeters."

The student's explanation indicates that she understood the conceptual basis of the units used in the calculation. Furthermore, when explaining the surface area of a cube, she stated:

P: "Why did you multiply 100 by 6?"

SP: "Because a cube has six equal sides. The area of one side is calculated first, then multiplied by six."

These responses show that the student could connect mathematical symbols, operations, formulas, and geometric concepts. Her symbolic representation was therefore characterized by systematic procedures supported by conceptual reasoning rather than the mechanical application of formulas alone.

According to Duval's (2006) theory of representation, the student demonstrated the ability to perform processing within the symbolic register and convert verbal language into mathematical symbols. The symbolic results could also be related back to the problem context to determine the correct statement. Within the TIMSS framework, the knowing domain is reflected in the student's knowledge of the properties of rectangular prisms and cubes. The applying domain is demonstrated through the use of mathematical models to solve problems, while the reasoning domain is reflected in her ability to connect models, calculations, and conclusions.

Verbal Representation of Male Students

The verbal representation of male students is demonstrated through their ability to interpret calculation results and formulate conclusions. Both students were able to state the volume obtained and determine the correct statement based on surface area calculations.

This ability indicates that the students could transform symbolic results into verbal statements. The calculation results were not treated merely as numbers but were interpreted according to the context of the problem. In the gift-wrapping problem, the students used the surface area result to determine the appropriate statement.

The task-based interview provided additional evidence of the male student's verbal representation ability. Although his written explanation was relatively brief, the interview revealed that he could communicate the reasoning behind his mathematical procedures. When asked why he rewrote the final volume result, he explained:

P: "Why did you write the volume result again at the end?"

SL: "To make the final answer clear. After calculating, the volume of the rectangular prism is 384 cubic centimeters."

This response indicates that the student understood the purpose of stating a conclusion to emphasize the final result. His verbal reasoning was further demonstrated when he explained the surface area calculation:

P: "Could you explain further how you calculated the amount of wrapping paper needed?"

SL: "The gift box is shaped like a cube with an edge length of 10 cm. The area of one side is 10 multiplied by 10, which equals 100 square centimeters. Since there are six sides, the total area is 600 square centimeters. Therefore, Adi is correct."

The explanation demonstrates that the student could identify the geometric context, describe the calculation process, and formulate a conclusion based on mathematical evidence. When asked why he did not immediately select one of the statements without calculating, he responded:

P: "Why didn't you choose one of the answers directly without calculating?"

SL: "Because it has to be proven. If I do not calculate it, I do not know whether Adi or Budi is correct."

This response reveals that the student recognized the importance of mathematical verification before making a decision. Therefore, the interview findings show that his oral verbal representation was more comprehensive than his written explanation, particularly in describing the reasoning and justification underlying his solutions.

According to Polya (2023), problem solving does not end when the calculation is completed. Students need to review the results, assess their reasonableness, and ensure that they answer the question. The male students' ability to determine the correct statement indicates a process of interpreting and checking their results.

However, the students' written verbal representations tended to be brief. They relied more heavily on formulas and mathematical operations as explanations. The reasons for using particular formulas, relationships among quantities, and detailed explanations of the steps were not fully written.

Based on confirmation of their problem-solving processes, the students were actually able to explain their reasoning and steps more comprehensively. This indicates that their internal and oral verbal representations were more developed than their written verbal representations.

According to Goldin (2020), internal representations do not always appear completely in external forms. Students may have correct understanding but may not yet be able or accustomed to expressing it in writing. Therefore, analysis of students' answer sheets needs to be complemented by an examination of their reasoning.

The difference between oral and written explanations also indicates the need to strengthen mathematical communication. Tarigan (2022) emphasizes that students need to communicate their thinking coherently and clearly. Answers containing only symbols do not fully reveal students' reasoning and thought structures. Within the TIMSS framework, the verbal representation of male students is associated with the reasoning domain. They were able to

interpret results, compare them with statements, and formulate conclusions. However, their written arguments were not presented comprehensively.

Verbal Representation of Female Students

The verbal representation of the female student is demonstrated through her ability to explain the solution steps systematically, interpret results, provide conceptual reasoning, and formulate conclusions.

The student did not merely write the final answer but explained the sequence of the solution process. Each calculation step was connected to its mathematical meaning, making the solution easier for readers to follow and understand.

In the rectangular prism volume problem, the student explained the relationship between multiplying the dimensions of the base and multiplying the result by the height. In the surface area problem, she explained the relationship between the shape of the cube, the number of faces, the area of one face, and the total surface area.

This ability indicates that the student could connect verbal and symbolic representations. Symbols were used as evidence of calculations, while language was used to explain the reasoning and meaning behind those symbols.

The interview findings further supported the female student's verbal representation ability, particularly in explaining mathematical procedures and providing conceptual justifications. When asked why she presented the final volume result in written words, she explained:

P: "Why did you write the answer in words?"

SP: "To make the final answer clearer, showing that the result is three hundred and eighty-four cubic centimeters."

This response indicates that the student used verbal explanations to reinforce the meaning of her mathematical results. Her ability to explain mathematical procedures was also evident when she described the calculation of the surface area of a cube:

P: "Could you explain further which statement is correct?"

SP: "The gift box is shaped like a cube with an edge length of 10 cm. Each side is a square. The area of one side is 10 multiplied by 10, which equals 100 square centimeters. A cube has six equal sides, so the total surface area is 6 multiplied by 100, which equals 600 square centimeters. Therefore, Adi's statement is correct."

The explanation demonstrates that the student could organize mathematical information into a coherent sequence, connect geometric properties with calculation procedures, and formulate a conclusion supported by mathematical evidence. Her understanding of the relationship between geometric properties and mathematical operations was further confirmed when she explained:

P: "Why did you multiply 100 by 6?"

SP: "Because a cube has six equal sides. The area of one side is calculated first and then multiplied by six."

These responses indicate that the student could articulate the conceptual basis of her calculations rather than merely report numerical results. The interview data therefore complement the written test findings by demonstrating the relationship between her verbal explanations, symbolic procedures, and understanding of geometric concepts.

According to Tarigan (2022), mathematical communication helps students organize and clarify their thinking. When students explain their steps in words, they simultaneously reconstruct the relationships among the concepts they use. Thus, verbal representation is not merely a means of communication but also part of the process of developing understanding.

According to Duval's (2006) theory, the student's ability demonstrates conversion from the symbolic register to natural language. Mathematical operations were translated into explanations concerning the properties of geometric solids, calculation processes, and the meaning of the results.

The student's verbal representation also demonstrates her ability to provide arguments. Her conclusion regarding the correct statement was supported by logical relationships among the information provided, the properties of the cube, the calculation process, and the results. Therefore, her answer was not merely declarative but also included justification. Within the TIMSS framework, this ability belongs to the reasoning domain. The student was able to analyze information, connect several concepts, provide justification, and formulate conclusions based on mathematical evidence.

Based on the three forms of representation, both male and female students were able to correctly solve TIMSS-based geometry problems. The differences identified were primarily related to the completeness and manner of communicating their solutions.

Male students tended to use three-dimensional drawings and symbolic expressions as their primary forms of representation. They were able to understand the concepts and obtain accurate results; however, their presentation of two-dimensional views and written explanations was incomplete. Their understanding became more apparent after confirmation of their problem-solving processes.

Female students demonstrated a more complete interconnectedness among visual, symbolic, and verbal representations. They were able to present multiple forms of drawings, use mathematical models systematically, and explain the steps and reasoning in a coherent manner.

Table 1. Representation

Representation	Male Students	Female Students
Visual	Accurate in drawing a three-dimensional rectangular prism, but the front and side views were not presented separately.	Complete in presenting the three-dimensional drawing, front view, and side view.
Symbolic	Models and calculations were correct, but the completeness of steps and use of units still need improvement.	Systematic and consistent, supported by conceptual understanding.
Verbal	Conclusions were correct, but written explanations were relatively brief.	Explanations were coherent, contextual, and supported by reasoning.

The comparison indicates that both male and female students demonstrated adequate mathematical representation abilities across visual, symbolic, and verbal representations, but they differed in the completeness and integration of these representations. The male student was accurate in drawing a three-dimensional rectangular prism and produced correct symbolic models and calculations; however, the front and side views were not presented separately, the calculation steps and use of units needed further improvement, and his written conclusions, although correct, were relatively brief. In contrast, the female student provided a more

complete visual representation by presenting the three-dimensional drawing together with the front and side views, while her symbolic work was systematic and consistent and reflected stronger conceptual understanding. Her verbal explanations were also more coherent, contextual, and supported by reasoning. These findings suggest that the primary difference between the two students lies not in the correctness of their mathematical understanding, but in the completeness, organization, and integration of multiple representations when communicating that understanding.

Gender and Mathematical Representation

These findings should not be interpreted as evidence that female students are generally superior to male students. Hyde (2005), through the gender similarities hypothesis, explains that males and females are more similar than different across various psychological abilities. Similarly, Hyde et al. (2008) and Else-Quest et al. (2010) found that gender differences in mathematics performance are generally small and influenced by educational, social, cultural, experiential, and task-related factors.

Because this study involved only one male and one female student, the findings should be understood as tendencies in how the two subjects represented mathematical ideas rather than as general gender differences. Both students demonstrated good mathematical representation abilities, including transforming information into drawings, symbolic models, and conclusions. However, they differed in how comprehensively they connected these representations. The female student more consistently connected visual, symbolic, and verbal representations, whereas the male student relied more heavily on three-dimensional drawings and symbolic expressions. Confirmation results further showed that although the male student's written answer did not include complete front and side views of the rectangular prism, he actually understood the relevant dimensions. Thus, the difference was more related to incomplete externalization of understanding than to a lack of spatial ability.

These findings are consistent with Danlami et al. (2025), who found that active learning strategies improved geometry performance without significant gender differences in improvement. Arroyo-Barrigüete et al. (2023) similarly showed that gender gaps in mathematics may vary according to educational level and assessment methods and may disappear after learning experiences. Lennon-Maslin et al. (2024) further demonstrated that mathematics self-concept and spatial anxiety are related to perceptions of difficulty and performance, while gender itself was not a significant predictor after relevant factors were considered. These studies indicate that mathematical and visual-spatial abilities should not be viewed as fixed consequences of gender.

The role of learning experiences is also supported by Medina Herrera et al. (2024), who found that spatial visualization abilities can improve through practice and visualization tools. Drawing, manipulating objects, observing shapes from different perspectives, and connecting three-dimensional objects with two-dimensional views can therefore strengthen students' spatial abilities. Rolfes et al. (2022) found that multiple representations can support understanding and knowledge transfer, although they may also increase cognitive demands because students must process and connect several forms of information simultaneously. This may explain why the male student correctly used three-dimensional drawings and symbols but did not fully connect them with two-dimensional views and written explanations.

Post and Prediger (2024) emphasized that multiple representations strengthen conceptual understanding when their relationships are explicitly explained. Similarly, Dreher et al. (2024) argued that the quality of representation use depends not only on the number of representations

but also on their appropriateness and the clarity of their connections. These findings suggest that differences between the two subjects may also reflect learning habits, instructional practices, previous experiences, and classroom communication. Teachers should therefore encourage students not only to draw or calculate but also to explicitly explain the relationships among drawings, symbols, and problem contexts.

The importance of flexibility across representations is also supported by Thurm and Barzel (2022), who emphasized that moving between graphical, numerical, and algebraic representations is essential for mathematical conceptual understanding. In the present study, both students successfully transformed verbal information into symbolic models and obtained correct answers, but the female student demonstrated greater consistency in connecting symbols, drawings, and explanations. This indicates the need for instruction that deliberately develops students' ability to move between verbal, visual, and symbolic representations.

Ruiz-Loza et al. (2022) further found that three-dimensional visualization-based learning environments can improve visualization, modeling, reasoning, problem solving, symbol use, and mathematical communication. Therefore, mathematical representation ability should not be assessed solely from the correctness of the final answer but also from students' ability to represent objects, use symbols, construct models, communicate, and provide reasoning. Tytler et al. (2023) likewise emphasized that constructing, interpreting, revising, and connecting representations can promote deeper understanding. In the present study, this means that students should be encouraged to translate rectangular-prism drawings into front and side views, symbolic models, and verbal explanations.

The previous studies support three main conclusions. First, differences in mathematical representation cannot be attributed solely to gender; learning strategies, self-concept, spatial anxiety, learning experiences, cultural context, and task characteristics also contribute. Second, a correct answer does not fully demonstrate mathematical representation ability, which also involves selecting, using, explaining, and connecting representations. Third, representation ability can be developed through explicit instruction, visualization practice, discussion, multiple representations, and opportunities to communicate mathematical thinking.

Thus, this study does not demonstrate the absolute superiority of female students over male students. Instead, among the two subjects examined, the female student demonstrated more comprehensive connections among visual, symbolic, and verbal representations, while the male student relied more on three-dimensional drawings and symbols. These differences are more appropriately understood as individual tendencies in strategies for externalizing mathematical understanding. Since the study involved only one male and one female student, the findings cannot be generalized by gender and should instead be viewed as an in-depth description of the representational characteristics of the two subjects. Future research should involve larger and more balanced samples while considering mathematics achievement, learning experiences, self-concept, spatial anxiety, and social and cultural backgrounds.

Conclusion

Based on the findings of the study on the mathematical representation abilities of fourth-grade elementary school students in solving TIMSS-based geometry problems from a gender perspective, the following conclusions can be drawn: 1) The visual representation of male students was demonstrated through their ability to transform information from the problems into three-dimensional rectangular prism drawings and accurately indicate the length, width, and height. However, the students did not present the front and side views separately, although they conceptually understood both views; 2) The visual representation of female students was

demonstrated through their ability to draw a three-dimensional rectangular prism, front view, and side view completely. The female student was able to select the appropriate dimensions according to the viewing direction and label the drawings accurately; 3) The symbolic representation of male students was demonstrated through their ability to transform verbal information into mathematical models, use fractions, variables, formulas, and arithmetic operations, and obtain correct results. Nevertheless, the completeness of the solution steps and accuracy in writing units still need improvement; 4) The symbolic representation of female students was demonstrated through their ability to systematically construct mathematical models, use variables and operations appropriately, and connect calculation procedures with the underlying concepts and units; 5) The verbal representation of male students was demonstrated through their ability to interpret results and provide correct conclusions. However, their written explanations tended to be brief and relied more heavily on symbols, although the students were able to explain the process more comprehensively when asked for clarification; 6) The verbal representation of female students was demonstrated through their ability to explain the solution steps systematically, interpret results according to the context, provide conceptual reasoning, and formulate conclusions clearly.

Suggestions

For teachers, geometry instruction should provide activities that connect concrete objects, three-dimensional drawings, two-dimensional views, mathematical symbols, and written explanations. Teachers should also encourage students to explain the reasoning behind each step of the solution. For students, the ability to write complete solution processes should be improved, particularly in presenting drawings according to the instructions, using units accurately, and providing explanations and reasoning in words. For schools, appropriate geometry learning media should be provided, such as solid geometric models, nets, visualization applications, and teaching aids, to support students' spatial-visual and mathematical representation abilities. For future researchers, studies should involve a larger and more balanced number of subjects based on gender and consider factors such as mathematics achievement, learning experiences, self-concept, and spatial ability to obtain a more comprehensive understanding.

References

- Adnan, M. (2019). Students' mathematical representation in geometry problem solving based on sex differences. *International Journal of Trends in Mathematics Education Research*, 2(3), 117–121. <https://doi.org/10.33122/ijtmer.v2i3.50>
- Arroyo-Barrigüete, J. L., Carabias-López, S., Borrás-Pala, F., & Martín-Antón, G. (2023). Gender differences in mathematics achievement: The case of a business school in Spain. *SAGE Open*, 13(2). <https://doi.org/10.1177/21582440231166922>
- Barroga, E., Matanguihan, G. J., Furuta, A., Arima, M., Tsuchiya, S., Kawahara, C., ... & Izumi, M. (2023). Conducting and writing quantitative and qualitative research. *Journal of Korean medical science*, 38(37). <https://doi.org/10.3346/jkms.2023.38.e291>
- Biber, M. (2023). Constructing mental models: mathematical communication and discourses in conceptual understanding. *Necmettin Erbakan Üniversitesi Ereğli Eğitim Fakültesi Dergisi*, 5(Özel Sayı), 271-305.
- Cevikbas, M., Kaiser, G., & Schukajlow, S. (2022). A systematic literature review of the current discussion on mathematical modelling competencies: state-of-the-art developments in conceptualizing, measuring, and fostering: A systematic literature

review of the current discussion on mathematical modelling competencies: state-of-the-art developments in conceptualizing, measuring, and fostering. *Educational Studies in Mathematics*, 109(2), 205-236. <https://doi.org/10.1007/s10649-021-10104-6>

- Damayanti, R., & Afriansyah, E. A. (2018). Perbandingan kemampuan representasi matematis siswa antara contextual teaching and learning dan problem based learning. *JIPM (Jurnal Ilmiah Pendidikan Matematika)*, 7(1), 30-39. <https://doi.org/10.25273/jipm.v7i1.3078>
- Danlami, K. B., Zakariya, Y. F., Balarabe, B., Alotaibi, S. B., & Alrosaa, T. M. (2025). Improving students' performance in geometry: An empirical evidence of the effectiveness of brainstorming learning strategy. *Frontiers in Psychology*, 16, 1577912. <https://doi.org/10.3389/fpsyg.2025.1577912>
- Desai, S. (2021). Mathematical representations in the teaching and learning of geometry: A review of literature. *International Journal of Mathematical Education in Science and Technology*, 52(7), 987–1002. <https://doi.org/10.1080/0020739X.2021.1896825>
- Dreher, A., Wang, T.-Y., Feltes, P., Hsieh, F.-J., & Lindmeier, A. (2024). High-quality use of representations in the mathematics classroom: A matter of the cultural perspective? *ZDM—Mathematics Education*, 56, 965–980. <https://doi.org/10.1007/s11858-024-01597-5>
- Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational studies in mathematics*, 61(1), 103-131. <https://doi.org/10.1007/s10649-006-0400-z>
- Duval, R. (2017). Understanding the mathematical way of thinking-The registers of semiotic representations. *Switzerland: Springer International Publishing*.
- Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: a meta-analysis. *Psychological bulletin*, 136(1), 103. <https://doi.org/10.1037/a0018053>
- Fattah, B., Zawawi, I., & Midjan, M. (2018). Representasi Matematis Peserta Didik Menurut Pandangan Bruner Dalam Menyelesaikan Soal Geometri Ditinjau Dari Kemampuan Matematika Dan Jenis Kelamin. *DIDAKTIKA: Jurnal Pemikiran Pendidikan*, 24(2), 123-138.
- Fattah, R. A. (2018). Representasi matematis peserta didik sekolah dasar dalam pembelajaran matematika. *Jurnal Pendidikan Matematika*, 12(1), 45–56. <https://doi.org/10.35580/jpm.v12i1.12345>
- Goldin, G. A. (2020). Mathematical representations. *Encyclopedia of mathematics education*, 566-572.
- Hariyani, M., Suherman, S., Andriani, M., & Herawati, H. (2023, August). The Importance of mathematical representation ability for elementary school students: a literature review and its implications. In Syekh Nurjati *International Conference on Elementary Education* (Vol. 1, pp. 38-46). <https://doi.org/10.24235/sicee.v1i0.14579>
- Hiebert, J., & Lefevre, P. (1986). In Hiebert, J. *Conceptual and procedural knowledge in mathematics: An introductory analysis*.

- Hyde, J. S. (2005). The gender similarities hypothesis. *American psychologist*, 60(6), 581. <https://doi.org/10.1037/0003-066x.60.6.581>
- Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science*, 321(5888), 494-495. <https://doi.org/10.1126/science.1160364>
- Leng, Y., Lee, J., & Liu, L. (2024). Examining gender differences in TIMSS 2019 mathematics using process data. *Journal of Educational Measurement*, 61(1), 54–76. <https://doi.org/10.1111/jedm.12312>
- Lennon-Maslin, M., Quaiser-Pohl, C., & Wickord, L.-C. (2024). Beyond numbers: The role of mathematics self-concept and spatial anxiety in shaping mental rotation performance and STEM preferences in primary education. *Frontiers in Education*, 9, 1300598. <https://doi.org/10.3389/feduc.2024.1300598>
- Lette, I., & Manoy, J. T. (2019). Representasi Siswa SMP dalam Memecahkan Masalah Matematika Ditinjau dari Kemampuan Matematika. *MATHEdunesa*, 8(3), 569–575.
- Lindquist, M. M., & Gates, J. D. (2020). National Council of Teachers of Mathematics. *Teaching Children Mathematics*. <https://doi.org/10.5951/tcm.1.1.0053>
- Lisarani, V., & Qohar, A. (2021). Representasi matematis siswa SMP kelas 8 dan siswa SMA kelas 10 dalam mengerjakan soal cerita. *Jurnal Magister Pendidikan Matematika (JUMADIKA)*, 3(1), 1-7. <https://doi.org/10.30598/jumadikavol3iss1year2021page1-7>
- Luritawaty, I. P. (2018). Pembelajaran take and give dalam upaya mengembangkan kemampuan pemahaman konsep matematis. *Mosharafa: Jurnal Pendidikan Matematika*, 7(2), 179-188.
- Medina Herrera, L. M., Juárez Ordóñez, S., & Ruiz-Loza, S. (2024). Enhancing mathematical education with spatial visualization tools. *Frontiers in Education*, 9, 1229126. <https://doi.org/10.3389/feduc.2024.1229126>
- Meinck, S., & Brese, F. (2019). Trends in gender gaps: Using 20 years of evidence from TIMSS. *Large-Scale Assessments in Education*, 7(1), 1-23. <https://doi.org/10.1186/s40536-019-0076-3>
- Permendikbud. (2014). Permendikbud 79 Tahun 2014. Permendikbud 79 Tahun 2014 Tentang Muatan Lokal K13.
- Pina, R., Martínez-González, R. A., & Otero, J. (2021). Gender-based performance in mathematics: Evidence from TIMSS 2019. *Frontiers in Psychology*, 12, 650293. <https://doi.org/10.3389/fpsyg.2021.650293>
- Post, M., & Prediger, S. (2024). Teaching practices for unfolding information and connecting multiple representations: The case of conditional probability information. *Mathematics Education Research Journal*, 36, 997–1023. <https://doi.org/10.1007/s13394-022-00431-z>
- Rahmawati, A. N. L., Sa'dijah, C., & Sudirman, S. (2025). Exploring High School Students' Mathematical Representation Abilities: Translation from Verbal to Symbolic Using Higher-Order Thinking Skills. *TEM Journal*, 14(3), 2442. <https://doi.org/10.18421/TEM143-48>

- Rolfes, T., Roth, J., & Schnotz, W. (2022). Mono- and multi-representational learning of the covariational aspect of functional thinking. *Journal for STEM Education Research*, 5, 137–159. <https://doi.org/10.1007/s41979-021-00060-4>
- Ruiz-Loza, S., Medina Herrera, L. M., Molina Espinosa, J. M., & Huesca Juárez, G. (2022). Facilitating mathematical competencies development for undergraduate students during the pandemic through ad-hoc technological learning environments. *Frontiers in Education*, 7, 830167. <https://doi.org/10.3389/educ.2022.830167>
- Sabirin, M. (2014). Representasi dalam Pembelajaran Matematika. *Jurnal Pendidikan Matematika*, 1(2), 33. <https://doi.org/10.18592/jpm.v1i2.49>
- Septian, A., & Komala, E. (2019). Kemampuan Koneksi Matematik dan Motivasi Belajar Siswa dengan Menggunakan Model Problem-Based Learning (PBL) Berbantuan Geogebra di SMP. *Prisma*, 8(1), 1-13. <https://doi.org/10.35194/jp.v8i1.438>
- Shoufan, A. (2023). Can students without prior knowledge use ChatGPT to answer test questions? An empirical study. *ACM Transactions on Computing Education*, 23(4), 1-29.
- Sugiyono. (2020). Metode Penelitian Kuantitatif, Kualitatif, dan RD. Alfabeta, CV. https://elibrary.stikesghsby.ac.id/index.php?p=show_detail&id=1879&keywords=
- Tarigan, E. F. (2022). Implementation of think pair share (TPS) learning strategies to improve students' mathematical communication skills on integer materials in class VII SMP Negeri 1 Tigabinanga 2014/2015 Academic Year. *IJEMS: Indonesian Journal of Education and Mathematical Science*.
- Thurm, D., & Barzel, B. (2022). Teaching mathematics with technology: A multidimensional analysis of teacher beliefs. *Educational Studies in Mathematics*, 109, 41–63. <https://doi.org/10.1007/s10649-021-10072-x>
- Tupamahu, P. Z., Ratumanan, T. G., & Laamena, C. (2023). Students' mathematical representation and communication ability in mathematics problem solving. *Jurnal Didaktik Matematika*, 10(1). <https://doi.org/10.24815/jdm.v10i1.29376>
- Tytler, R., Prain, V., Kirk, M., Mulligan, J., Nielsen, C., Speldewinde, C., White, P., & Xu, L. (2023). Characterising a representation construction pedagogy for integrating science and mathematics in the primary school. *International Journal of Science and Mathematics Education*, 21, 1153–1175. <https://doi.org/10.1007/s10763-022-10284-4>
- Ulfa, F. M., Asikin, M., & Dwidayati, N. K. (2019). Membangun Kemampuan Berpikir Kreatif Matematis Siswa dengan Pembelajaran PjBL terintegrasi Pendekatan STEM. *Prosiding Seminar*.
- Yanni, R. P. (2018). Persepsi Mahasiswa PPKn Tentang Pelaksanaan dan Kebijakan Uang Kuliah Tunggal di Universitas Negeri Padang. *Journal of Civic Education*. <https://doi.org/10.24036/jce.v1i1.6>
- Ziatdinov, R., & Valles Jr, J. R. (2022). Synthesis of modeling, visualization, and programming in GeoGebra as an effective approach for teaching and learning STEM topics. *Mathematics*, 10(3), 398. <https://doi.org/10.3390/math10030398>