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Analysis of Students' Image Concept in Constructing Proof And Solving Mathematical Problems Seen From A Gender Perspective

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Abstrak

Penelitian ini bertujuan untuk menganalisis pemanfaatan concept image siswa dalam mengkonstruksi bukti dan memecahkan masalah matematis pada siswa. Penelitian ini menggunakan pendekatan kualitatif dengan metode grounded theory, Penelitian ini dilaksanakan SMA Swasta Pembangunan Galang populasi penelitian ini sebanyak 20 siswa, sampel 10 siswa laki-laki dan 10 siswa perempuan di kelas XI. Data penelitian diperoleh melalui analisis pekerjaan siswa, tes kemampuan pembuktian dan pemecahan masalah matematis, serta interpretasi terhadap proses berpikir siswa berdasarkan kategori kemampuan tinggi, sedang, dan rendah. Hasil penelitian menunjukkan bahwa konsep image memiliki peranan penting dalam membantu siswa memahami konsep, mengkonstruksi bukti, dan menyelesaikan masalah matematis. Siswa yang memiliki konsep image yang baik cenderung lebih mudah menyerap materi, lebih aktif dalam proses pembelajaran, serta memiliki pemahaman konsep yang lebih mendalam. Selain itu, penguasaan konsep image juga berkontribusi pada penguatan retensi belajar siswa dalam memahami materi matematika. Selain itu, penelitian ini juga menemukan adanya perbedaan pemanfaatan konsep image antara siswa laki-laki dan siswa perempuan, terutama dalam cara menentukan langkah awal, penggunaan bahasa matematis, serta strategi dalam menyajikan solusi terhadap masalah matematis.

***Kata Kunci**: Concept Image, Konstruksi Bukti, Pemecahan Masalah Matematis, Perbedaan Gender.*

Abstract

This study aims to analyze the use of students' concept images in constructing proofs and solving mathematical problems. This study uses a qualitative approach with a grounded theory method. This study was conducted at SMA Swasta Pembangunan Galang, with a population of 20 students and a sample of 10 male and 10 female students in grade XI. Research data were obtained through analysis of student work, mathematical proof and problem-solving ability tests, and the interpretation of students' thinking processes across high, medium, and low ability categories. The results of the study indicate that the concept image has an important role in helping students understand concepts, construct proofs, and solve mathematical problems. Students who have a good concept image tend to absorb material more

easily, are more active in the learning process, and have a deeper understanding of concepts. In addition, mastery of the concept image also contributes to strengthening students' retention of mathematical material. In addition, this study found differences in the use of the concept image between male and female students, especially in determining the initial steps, using mathematical language, and employing strategies for presenting solutions to mathematical problems.

Keywords: *Concept Image, Proof Construction, Mathematical Problem Solving, Gender Differences.*

A. Introduction

A student's concept image encompasses the entire set of cognitive structures associated with concepts, including mental images, traits and characteristics, and the processes involved in forming new concepts. (Amir, 2020). This suggests that the formation of each student's concept image varies by gender. Male and female students have different cognitive levels, resulting in varying mathematical abilities. These gender differences are evident not only in students' mathematical abilities but also in how they acquire mathematical knowledge, as they can impact students' mathematical thinking skills. The difference lies in how male and female students solve problems (Aini, N. N., & Mukhlis, 2020).

Each student has different learning experiences, which lead to a distinct understanding of the concept image formed through cognitive functions. (Tri Rahayu, 2020). Therefore, each student has their own perspective in interpreting a concept. From this perspective, they will understand each definition of the visual, traits, and processes inherent in mathematics. Understanding the concept of image plays a crucial role in mathematics learning, facilitating students' understanding of mathematics and enabling them to connect old and new concepts from previous learning. (Setyawati, R. D., & Ratu, 2021). This understanding of the concept of image is shown in Figure 1.

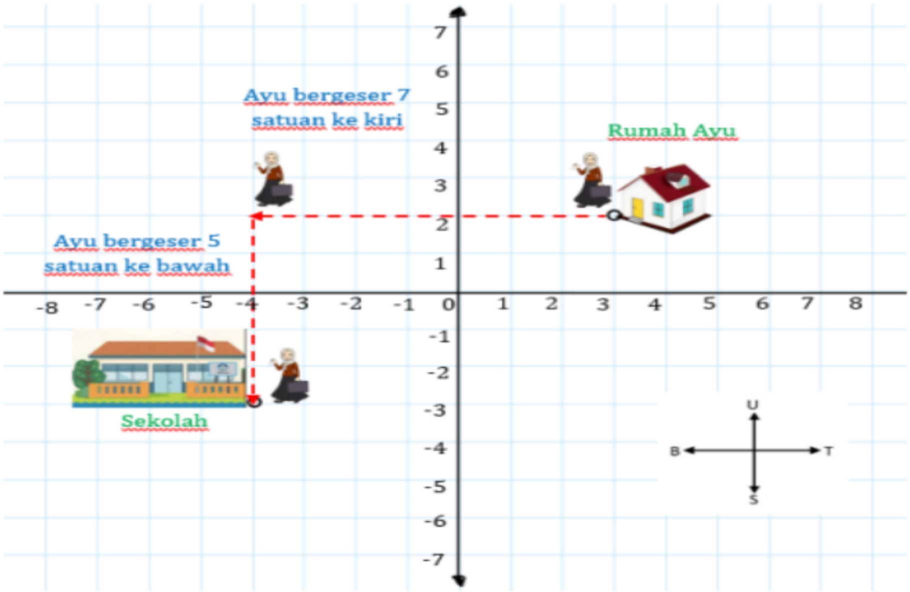

Figure 1. One example of a question on the Image Concept in Constructing Evidence

Figure 1 explains that the questions are based on students' conceptual image indicators, which are accompanied by their ability to construct proofs and mathematical solutions. Students are expected to be able to represent these images using their conceptual images. These images are then constructed in writing using mathematical problem-solving indicators. When a geometric situation is presented verbally to students, it may be important to imagine a corresponding image to provide intuitive input to the reasoning process.

This image is then transferred to an external medium, as shown in Figure 1, to solidify it. Further constructions may be visualized and added to the image, or various transformations may be imagined. Furthermore, in this study, the word "image" is used instead of "geometric image," with the understanding that it can refer to perception, image, or both, depending on the context (Ariyanti, S., Warli, & Rahayu, 2022). This is because the mind needs a way to represent something abstract or even a general concept of mathematics through mathematical problem-solving (Anwar, L., Nasution, S. H., Sudirman, 2021). Images cannot, but written words can fulfill this function. The concept of "image" is a mental representation that, in mathematical language, is expressed through the process of constructing proofs, resulting in a statement.

In reality, students simply memorize mathematical concepts presented by teachers or textbooks without understanding their meaning (Davita, P. W. C., & Pujiastuti, 2020) . Consequently, students are less able to define a concept and discover its properties. According to Viholainen, to understand a concept, a student must comprehend the definition of the concept in textbooks or modules and then form a conceptual image in their mind. Meanwhile, according to Vinner, to master a concept, students need to form a conceptual image more than the definition written in textbooks (Deo, Z., Pattisina, C., & Sopiany, 2022). This is because conceptual definitions are inactive and can be forgotten at any time, whereas conceptual images formed in students' minds can be activated at any time. Aspects of the conceptual image include mental images, properties, and processes related to the concept within the student's mind. The facts on the ground can be seen in the following figure, which differentiates the answers of female and male students (Fatio, 2020). Whether a student's conceptual understanding of a highly abstract concept is retained depends on the image. Male and female students' answers yield different findings. Even after learning textbook definitions, students may associate alternative meanings, causing confusion (Hanggara, Y., Aisyah, S. H., & Amelia, 2022)

Most common conceptions are like concrete objects acquired without definitions. However, definitions can introduce commonplace concepts. For instance, a Geometric Transformations problem given to eleventh-graders to introduce image and proof-building involves translation and reflection using an image of an everyday event (Hidayat, W., & Sariningsih, 2018). A pupil looking at a photo at school may find the definition helpful in forming a conceptual image.

Once the image forms, the definition fades. Addressing concept assertions leaves it inert or forgotten. Definitions help construct mental images but are vital to cognitive functions. They may prevent students from falling into conceptual image traps. A key notion in arithmetic is construction, and mathematical statements and proofs are used to convey solutions to mathematical problems through diagrams, tables, symbols, or graphs (Jatisunda, 2021). Proof construction challenges include understanding mathematical concepts, language and symbols, proof strategies, and proofreading (Jatisunda, 2017). This statement implies that mathematical proof begins with knowing a mathematical notion and then stating it in mathematical problem-solving language.

After comprehending the image, students should be able to build a proof and use it to solve math problems. In advanced mathematics, understanding images helps students develop mathematical concepts, retain knowledge, and use knowledge. (Nurwahyu, B., Tatag, Y. E. ., & Suwarsono, 2022). According to Piaget, Dubinsky, and McDonald, an individual's ability to abstract, create, and represent will develop throughout the study of higher mathematics. Thus, as students near completion, their understanding will grow (Sagala, 2009).

Math education relies heavily on problem-solving. Problem-solving requires planning and execution to solve a specific issue (Putri, D. K., Sulianto, J., & Azizah, 2021). Students must apply and combine many mathematical concepts and skills, and make decisions to solve problems in math (Khaeroh, A., Anriani, N., & Mutaqin, 2021). Teachers need problem-solving skills to help students solve geometric problems. (Polya, 1973) identified four steps of problem-solving: comprehending the problem, planning, executing, and reflecting (Laila, H. T., & Harefa, 2021). Polya's four stages teach pupils to understand the problem by knowing what is known and what is asked, and retelling it. Students then design a mathematical model or problem-solving plan. Students are then instructed to execute their solution. Next, students learn to reevaluate their answers and results. Students learn to solve new problems utilizing these processes, which they will utilize in daily life (Misu, L., Hasnawati, 2021).

Not all kids can understand an issue and create a plan to tackle it until they find the answer. When giving examples, teachers must clearly explain problem-solving methods so students can grasp and correctly solve practice problems (Mujib, 2021). Math teachers say this achievement is disappointing because kids are still not answering or solving questions correctly and thoroughly. This inaccuracy and incompleteness are attributable to pupils' lack of problem-solving knowledge. Therefore, teachers must present additional examples or address questions that lead to practice problems so students can answer them correctly. Each person solves problems differently, partly due to gender variances. Males and females solve math problems differently. Male and female students approach problems differently, resulting in a participation disparity. Gender disparities affect mathematics skill and learning (Nugraha, T. H., & Pujiastuti, 2022).

Psychosocial factors like gender influence how people act to fit in. Gender can affect how people think and solve problems. Male and female students approach problem-solving questions differently (Nurcholis, 2021). (Nurwahyu, B., Tatag, Y. E. ., & Suwarsono, 2022) says males and females differ in secondary traits, emotions, and psychological functions. According to him, men focus on intellectual, abstract, and objective topics, whereas women focus on concrete, practical, emotional, and personal matters (Putri, D. K., Sulianto, J., & Azizah, 2021). (Qureshi, H. A., & Ünlü, 2020) noted gender psychological disparities. The preceding description suggests a gender-sensitive study of characteristics of mathematical reasoning in problem-solving. Some academics think gender factors in mathematics are caused by biological variations in male' and female' brains. He said men focus on cerebral, abstract, and objective topics, while women focus on concrete, practical, emotional, and personal matters.

Research conducted by (S. Tuba, J., & B. Roble, 2020) only examined students' image concepts. The study did not examine other issues that might be related to students' image concepts. Meanwhile, students' image concepts are closely related to students' ability to construct proofs and solve mathematical problems. Once students' image concepts are well-formed, they can represent their ideas by constructing proofs expressed in mathematical writing/language. Gender differences can result in differences in students' learning psychology.

Several studies also indicate that gender influences mathematics learning due to biological differences in male' and female' brains. Likewise, in the formation of students' image concepts, gender is also a factor. Women generally pay attention to concrete, practical, emotional, and personal matters, while men will only focus on intellectually oriented, abstract, and objective matters. From this statement, we can see that there is no fundamental difference between the abilities of women and men; the difference lies in attitudes and perspectives. These differences in attitudes and perspectives also occur in the implementation of learning strategies. Based on the statements above, the research to be conducted is "Analysis of Students' Image Concept in Constructing Proof and Solving Mathematical Problems Viewed from Gender".

B. Research Method

Based on the research focus outlined in the introduction, a qualitative approach was used to obtain the research answers. This qualitative approach was chosen because it aligns with the stated research objectives. Several characteristics of this study align with the research objectives and align with the characteristics of qualitative research proposed by (W, 2016).

The research method was qualitative, using a grounded theory approach. Grounded theory is used to generate new theories directly by the researcher, who goes into the field to collect data (Sugiyono, 2015). The reason for choosing grounded theory research is that it aims to develop a theory based on empirical data obtained in the field, and data collection and analysis are carried out simultaneously (open, axial, selective coding), so that the theory develops along with the research. The research was conducted at SMA Swasta Pembangunan Galang in class XI. The population of this research is 20 students, the research sample is 10 male students and 10 female students. The rationale for selecting the sample size is based on a qualitative approach that emphasizes depth of analysis and the principle of data saturation. The sample was selected using purposive sampling, taking into account students' ability to communicate mathematical thinking processes. Furthermore, the sample had varying levels of mathematical ability (high, medium, low) to obtain a comprehensive picture of students' concept images in constructing proofs and solving mathematical problems, from a gender perspective.

Grounded theory research involves three sequential steps: open coding, selective coding, and theoretical coding. The details of each step are presented as follows:

1. Open Coding Stage
   In the open coding stage, researchers collected initial data by analyzing students' concept images on the initial learning test and by examining their ability to construct proofs and solve mathematical problems. There were four questions on concept image analysis in constructing proofs and solving mathematical problems, reviewed from a gender perspective, in the initial learning test.
2. Selective Coding Stage
   In the selective coding stage, researchers explored the categories obtained from the open coding stage, considering related subcategories to determine the core categories.
3. Theoretical Coding Stage
   The theoretical coding stage is the final stage in grounded theory, namely the development of a theory or conjecture.

C. Result and Discussion

In the selective coding stage, researchers identified and explored the core categories derived from the open coding stage. These categories served as the focus of further research, providing the basis for conjectures to be developed in subsequent stages. The core categories were developed based on the findings obtained in the open coding stage. The descriptions in the open coding stage showed the diversity in the quality of male and female students' work, based on the level of errors they made.

The results of the Grounded Theory steps are presented in the following description:

Open Coding Stage

Twenty eleventh-grade students were selected as study respondents. The research theory used was (Michael Jones & Irit Alony., 2011). The stages were image concept analysis, category identification, and core category determination. In the open coding stage, the researcher analyzed the work of all students in the study class on four questions concerning aspects of students' concepts in mathematical proofs and problem-solving from a gender perspective. These four questions met the requirements for a good instrument, as determined by the researcher's suitability test during the instrument pilot test.

The research findings indicated that tenth-grade students' understanding of the image concept in constructing proofs and solving problems was not uniform, showing varying results. To illustrate students' understanding of the image concept in constructing proofs and solving mathematical problems, in this open coding stage, the researcher analyzed all students' answer sheets for the four questions from a gender perspective.

The analysis of the questions aims to reveal mastery and understanding of the concept of image, as well as male and female students' ability to construct proofs and solve mathematical problems in the topic of translation-translation geometry (shift). The results of the analysis are in Table 1 and the following were found.

Table 1. Results of Students' Concept Image Test in Constructing Proof and Solving Mathematical Problems

Student Concept Image Indicators in Constructing Proofs and Solving Mathematical Problems	Gender	Success Percentage
Initial steps in using student concept images in constructing proofs and solving mathematical problems	Male	50%
	Female	70%
Proof strategies in explaining mathematical ideas and models used and selected	Male	50%
	Female	70%
Understanding and utilization of assumptions	Male	50%
	Female	70%
Accuracy and precision in constructing or writing arguments	Male	60%
	Female	70%
Concept image thought process used in constructing proofs and solving mathematical problems	Male	50%
	Female	70%
Key expressions (words/phrases)	Male	50%
	Female	70%
Use of mathematical notation, symbols, and terms	Male	60%
	Female	80%
Mastery, understanding, and utilization of concepts and theorems	Male	50%
	Female	60%
Mathematical problem-solving language in proofs	Male	50%
	Female	60%
Consistent proof steps	Male	50%
	Female	70%

The results in Table 1 are as follows: 13 of the 20 students (65%), comprising 5 males and 7 females, took the correct initial steps in proving and solving mathematical problems (language). 12 of the 20 students (60%), comprising 5 males and 7 females, used the correct problem-solving strategy, starting with the definitions of translation, reflection, and rotation to understand these concepts. They then used mathematical terms or symbols from transformation geometry, and then investigated the validity of the definitions of translation, reflection, and rotation. Meanwhile, 3 of the 20 students (15%), all three male, used the incorrect solution strategy. 12 of the 20 students (60%), consisting of 5 male and 7 female, utilized the assumed definitions of the concepts of translation, reflection, and rotation with elements of transformation geometry. 13 of 20 students (65%), consisting of 6 male and 7 female, formulated arguments correctly using the steps used. However, a significant percentage of students (35%), consisting of 4 males and 3 females, did not present appropriate arguments. These students were unable to convey the parts that should have been included in the proofs and solutions of mathematical problems. 12 of 20 students (60%), consisting of 5 males and 7 females, used a precise, clear, and logical thought process.

They began by defining the terms translation, reflection, and rotation; creating a table of coordinates for objects and their shadows; creating a drawing of the resulting shadow; and investigating each image individually, interpreting it and addressing questions about translation, reflection, and rotation. The number of key expressions (words/phrases) that should appear in the image concept test in constructing proofs is determined by the use of mathematical problem-solving, namely, mathematical language, both symbols and mathematical terms, in interpreting the proofs. These include symbols and terms for transformation geometry, proof matrices, properties and definitions of transformation geometry, matrix multiplication, and the use of arcs.

A total of 14 of 20 students (70%), consisting of 6 males and 8 females, made no errors in writing mathematical notation/symbols/terms when solving the translated problems. To construct proofs and interpret mathematical problem-solving correctly, a good understanding of the image concept in transformation geometry is required, including definitions, concepts, and theorems related to translation, reflection, and rotation. A total of 11 out of 20 students (55%), comprising 5 male and 6 female students, were able to use communicative proof language, which does not pose the potential for ambiguity when interpreting proofs written in appropriate mathematical problem-solving language. In contrast, the remaining 9 of 20 students (45%), comprising 5 male and 4 female students, did not display or use communicative mathematical language. A total of 12 out of 20 students (60%), comprising 5 male and 7 female students, demonstrated consistent proof steps by writing assumptions or arguments that were in accordance with the concepts of transformation geometry (translation, reflection, and rotation).

Based on the findings above, it was found that quite a few students experienced difficulties and errors in constructing proofs and solving mathematical problems due to a lack of mastery of the concept of images, resulting in errors of varying degrees. The level of these errors and difficulties indicates the quality of the proofs and mathematical problem-solving skills employed by the students.

To further explore this issue and to obtain some or all of the categories in Grounded Theory, the researchers conducted a more in-depth analysis of the initial findings. This was done to determine the level of diversity in the quality of students' work. The researchers furthered the initial findings by examining examples of student work that demonstrated the varying levels of errors and difficulties experienced by male and female students. The selected and analyzed student worksheets represent diverse qualities within each focus of analysis. The results of this in-depth analysis of the student work samples will be presented in the following description.

The analysis results show that male and female students differ in their approaches to constructing proofs and solving mathematical problems. Figure 2 provides examples of male and female students' work demonstrating appropriate initial steps.

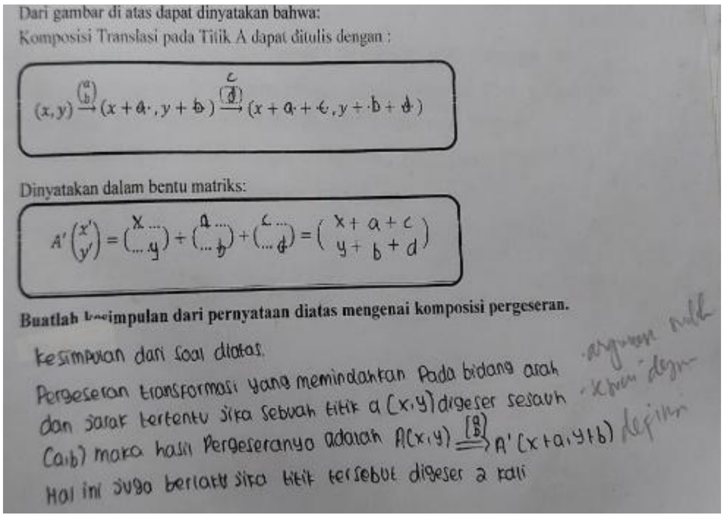

Figure 2. Male Student's Job

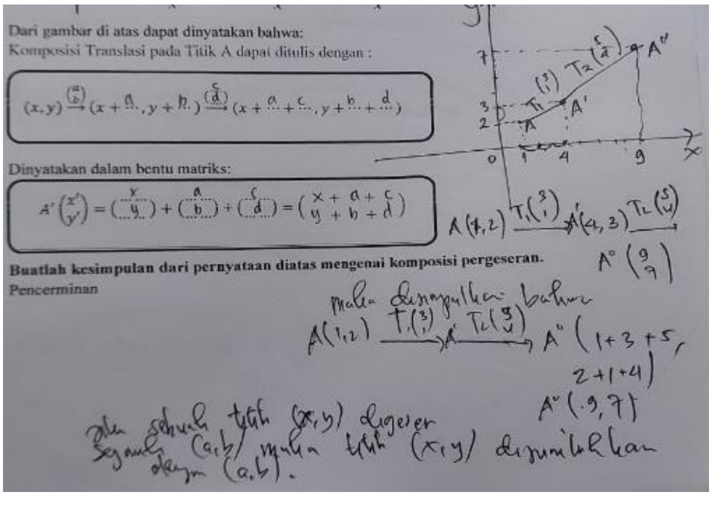

Figure 3. Female Student Work

In the picture, it can be seen that LT-12 and PT-20 students have a good understanding of determining the initial steps in utilizing the image concept in constructing proofs and solving mathematical problems that should be taken, namely, identifying the elements contained in the definition/concept of translation. The results of correctly identifying the elements of the translation concept indicate a good understanding of the requested concept. The good mastery of the image concept of LT-12 and PT-20 students regarding the elements of translation has supported the accuracy in determining the translation concept.

Selective Coding Core Categories

In the selective coding stage, researchers identified and explored the core categories derived from the open coding stage. These categories served as the focus of further research, providing the basis for conjectures to be developed in subsequent stages. The core categories were developed based on the findings obtained in the open coding stage. The descriptions in the open coding stage showed the diversity in the quality of male and female students' work, as reflected in the error levels they made. In summary, the percentage of errors made by male and female students in analyzing the concept of student image in constructing proofs and solving mathematical problems, from a gender perspective, across four test items, is presented in Table 2.

Table 2. Percentage of Findings of Students' Conceptual Image Errors in Proof Construction and Mathematical Problem Solving Reviewed from Gender

No.	Analysis Aspects	Errors Found (%)			
		Question Number			
		1	2	3	4
1	The initial steps (ideas) for constructing proofs and solving mathematical problems.	40%	25%	30%	35%
2	The proof strategy used.	40%	75%	20%	30%
3	Understanding and precision in utilizing assumptions or known facts.	40%	75%	25%	35%
4	Accuracy in constructing arguments.	35%	65%	45%	45%
5	The flow of thought (process) throughout the work.	40%	70%	50%	50%
6	Key expressions (words/phrases) that emerge and support the construction of proofs and solving mathematical problems.	40%	75%	55%	40%
7	Use of mathematical notation, symbols, or terms.	30%	75%	50%	25%
8	Mastery and utilization of relevant concepts or principles.	45%	70%	65%	45%
9	Use of proof language.	45%	70%	50%	50%
10	Relevant proof steps.	40%	70%	65%	50%

From the 10 code analysis in the open coding stage, it shows that there are several codes that are interrelated and lead to the same category, the proof category in one core category. Based on the data, a particularly striking aspect is the high error rate on question 2 across nearly all analyses. This indicates that students experience significant difficulties in constructing proofs and solving mathematical problems, particularly in proof strategies, understanding assumptions, and using mathematical expressions and notation. Furthermore, the dominant errors occur in conceptual aspects and higher-order thinking processes, indicating that students' concept images have not yet been fully formed and remain partial. Meanwhile, in questions 1 and 4, the error rates are relatively lower, indicating that students are better able to solve problems that are more familiar and procedural.

We can see that the proof strategy of Code-2 is directly related to the proof flow (process) in Code-5 and the proof steps in Code-10, so it can be considered the same core category, namely the proof flow. Understanding and accuracy in using assumptions or facts already known from concepts/definitions in Code-3 are directly related to the mastery and use of relevant concepts or principles in Code-8, and can therefore be seen as the same core category, namely, related concepts. The use of notation, symbols or mathematical terms in Code-7 is directly related to the use of proof language in Code-9, so it can be seen as the same core category, namely proof language. The other codes each constitute a category that needs further study and exploration.

Theoretical Coding

Based on the study of the description of the open coding, selective coding, and theoretical coding steps, researchers can conclude that there is a diversity in the use of the image concept on the quality of proof construction and mathematical problem solving reviewed from gender, determined based on 6 predetermined categories, namely 1) Initial Steps, 2) Proof Flow, 3) Related Concepts, 4) Arguments, 5) Key Expressions, and 6) Proof Language. Based on these six core categories, the use of the image concept in constructing proofs and solving mathematical problems across different ability levels and gender differences can be described as follows.

a. Initial Steps

Students who use imagery in their proof construction and employ high-level mathematical problem-solving skills can identify assumptions related to the problem's material concepts and knowns, including the statement to be proven. They can appropriately use these assumptions and concepts as a basis for determining proof construction steps and for using communicative mathematical language. There are differences between male and female students in their written work. Highly able female students can describe each assumption and known fact in a more substantial and specific form in the initial steps of the proof. The initial steps taken by female students demonstrate that they have already moved towards the required proof process. In some cases, the initial steps expressed by female students indicate that they already understand the ultimate goal of the required proof, as female students possess a richer concept of imagery than male students. The initial steps written by female students are also more logical because their language is easier to understand than that of male students.

b. Proof Flow

Male and female who use the image concept to construct proofs and solve high-level mathematical problems demonstrate a high level of proficiency in employing clear, precise proof flows and strategies. The use of the image concept in constructing proofs and solving mathematical problems by both male and female reflects a coherent line of thought, clearly in accordance with the proper line of proof. The steps taken by both male and female reflect a coherent line of thought and involve no logical leaps. For some problems, female' thought processes are superior to male' due to the more orderly sequence of solutions they employ.

c. Related Concepts

Male and female who use imagery to construct proofs and solve high-level mathematical problems will demonstrate a solid understanding of the concepts required. Female students will use familiar concepts to determine the steps in the proof and problem-solving process and to present written proofs. Female students will interpret and explain, in textual form, concepts that support the proof process with a good level of mastery.

d. Argumentation

Male and female who use imagery to construct proofs and solve high-level mathematical problems will be able to accurately construct arguments or basic statements from the steps taken and used in the proof process, and to interpret them in communicative language. Female students will be better able to convey arguments in verbal language than male students, resulting in more meaningful delivery because their sentences are more communicative. The conclusion and the conclusions formed throughout the proof process are interconnected and continuous, supported by appropriate arguments.

e. Key Expressions

Key expressions are fundamental elements that should be presented by male and female students in the proof process, using valid interpretations that the problem setter can determine. Male and female students, using the concept of imagery to construct proofs and solve high-level mathematical problems, will be able to correctly generate all key expressions in the proofs they construct.

f. Proof Language

Male and female students, using the concept of imagery to construct proofs and solve high-level mathematical problems, will present the results of their proof construction in communicative, meaningful proof language within the scope of their classroom learning community. Female students will express and write each word, phrase, and sentence in simple, clear terms. Female students will also use mathematical notation, symbols, and terms appropriately related to the concept.

Discussion

A concept image is a mental image a person has of a mathematical concept. This concept encompasses not only the formal definition but also various mental representations such as learning experiences, visualizations, and a student's intuitive understanding of a concept. According to David Tall and Shlomo Vinner, a concept image is the entire cognitive structure associated with a concept formed through a person's learning experiences. This structure can influence how students understand, construct proofs, and solve mathematical problems.

In mathematics learning, students' ability to construct proofs and solve problems is greatly influenced by how they construct concepts in their minds. Students with a strong concept image tend to logically connect various mathematical ideas, thereby constructing systematic arguments or proofs. Conversely, students with an inaccurate concept image often have difficulty understanding the relationships between mathematical concepts, which impacts their problem-solving abilities. Research shows that students with a strong conceptual understanding can identify key information in a mathematical problem, connect it to previously learned concepts, and logically formulate solution steps. This demonstrates that concept image plays a crucial role in students' mathematical thinking processes, particularly in constructing mathematical proofs (Sianturi, 2020).

Furthermore, the ability to construct mathematical proofs is closely related to students' logical reasoning processes. This process involves making assumptions, constructing arguments, and drawing conclusions based on applicable mathematical principles. Students who have a clear image of a mathematical concept will more easily understand the logical structure of a mathematical proof. Research by (Septiati, 2021) analyzed differences in students' concept images for the concept of quadrilaterals. This study found a gap between students' conceptual images and formal mathematical definitions, leading to errors in problem solving. Similarly, research by (Setyawati, R. D., & Ratu, 2021) demonstrated the phenomena of missing and misconceptions in geometry. This study concluded that students' cognitive styles influence how they construct concept images for mathematical concepts.

Based on the discussion, it can be concluded that concept imagery plays a crucial role in students' mathematical thinking processes, particularly in constructing proofs and solving mathematical problems. Strong concept imagery enables students to understand the relationships between mathematical concepts more deeply and to construct mathematical arguments logically.

Furthermore, there are differences in the way male and female students construct concept images and solve mathematical problems. These differences are more closely related to the thinking styles and learning strategies students use. Therefore, teachers need to design learning experiences that accommodate diverse student characteristics to develop students' mathematical thinking skills optimally.

D. Conclusion

This study concludes that each ability category has the following characteristics: Male and female students who utilize the image concept in constructing proofs and solving mathematical problems at a high level have the following characteristics: They have the ability to identify assumptions related to material concepts and knowns in the problem, including the statement to be proven. They are able to appropriately utilize these assumptions in the concept as a basis for determining proof construction steps and using communicative mathematical language. They possess a level of proficiency in using clear and precise proof flows or strategies. The use of the image concept in constructing proofs and solving mathematical problems by male and female students reflects their coherent thought processes, clearly in accordance with the correct proof flow.

Male and female students who use the image concept to construct proofs and solve mathematical problems at a moderate level have the following characteristics: They have difficulty identifying assumptions and knowns in the problem to formulate the statement to be proven, resulting in errors in determining the initial steps. Able to describe the chosen proof process flow in solving the problem to be formulated, but several sections are inconsistent with the proper proof flow, making it appear unsuitable. As a result, some of the written proof flow appears disjointed, the meaning is unclear, and there are leaps in logic. Male and female students who utilize the image concept in constructing proofs and solving low-level mathematical problems have the following characteristics: inability to identify assumptions and what must be known in the problem or statement to be proven, resulting in errors or an inability to determine the initial steps.

This study found that students' errors in constructing proofs and solving mathematical problems were driven primarily by weaknesses in conceptual understanding and higher-order thinking, particularly in problems requiring in-depth conceptual integration. Furthermore, six core categories representing the structure of students' concept images were identified: initial steps, proof flow, related concepts, argumentation, key expressions, and proof language. Gender differences indicate that female students tend to be more systematic and communicative, while male students tend to be more concise but less explicit.

However, several gaps remain, including the gap between concept image and concept definition, between conceptual understanding and proof ability, and a lack of conceptual integration and mastery of mathematical language. This indicates that mathematics learning has not yet fully developed comprehensive, higher-order mathematical thinking skills.

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