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MATHEMATICAL REPRESENTATION ABILITIES IN BRUNER'S REPRESENTATION STAGES: A PHENOMENOLOGICAL STUDY OF HIGH SCHOOL STUDENTS

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ABSTRACT

Mathematical representation ability is important in helping students understand mathematical concepts and solve problems meaningfully. However, studies on mathematical representation abilities through Bruner's stages of representation remain limited, while students still experience difficulties in connecting various forms of representation. This study aims to describe the characteristics of students' mathematical representation abilities at each stage of Jerome Bruner's development. The study employed a qualitative method with a phenomenological approach involving 104 tenth-grade high school students in Indonesia Selected through purposive sampling. Data were collected through mathematical representation tests, Focus Group Discussions (FGD), and non-systematic observation sheets, then analyzed thematically, with themes derived entirely from students' responses to address the research questions. The results indicate that students' mathematical representation abilities vary across Bruner's stages of representation. In the enactive stage, students use object manipulation to understand problems, although not optimally. In the iconic stage, students use visual representations such as tables, figures, and diagrams, but some are still unsystematic and do not fully reflect the problem structure. At the symbolic stage, students are able to construct mathematical models and apply algebraic procedures, although errors in modeling, method application, and calculation are still found. In addition, students' verbal representation abilities remain limited, as indicated by their difficulty in drawing conclusions that connect results to the problem context. These findings indicate that mastery of the enactive and iconic stages contributes to students' success in reaching symbolic representation and may serve as a basis for developing more meaningful mathematics learning strategies.

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INTRODUCTION

The ability to represent mathematics has become one of the topics that has received more and more attention in mathematics education research in recent years. A search on the

ScienceDirect database with the keyword *"mathematical representation ability"* shows a very clear trend of increasing the number of publications, from 278 articles in 2021 to 1,137 articles in 2025. The data shows that topics related to mathematical representation continue to gain an important position and become one of the strategic focuses in the development of mathematics education research at the global level.

In line with that, *National Council of Teachers of Mathematics* (NCTM) establishes five standards for the mathematics learning process, namely representational skills, communication, reasoning and proof, problem solving, and mathematical connections. (NCTM, 2000). This shows that representation skills are one of the important skills that need to be developed in mathematics learning. Furthermore, the importance of representational skills is explained by Ulfa & Sundayana (2022) that this ability also helps learners connect abstract concepts with real-world applications, making it easier to understand and solve mathematical problems. In addition, representation is used as a basis for students to understand and apply mathematical concepts (Khoerunnisa & Maryati, 2022). One example can be seen in mathematics education in Indonesia, where the mathematics curriculum places representation skills as one of the skills developed in addition to communication skills, as stated in Permendikbud Number 21 of 2016.

Representational skills refer to an individual's ability to understand, transform, and communicate mathematical concepts through various forms, such as symbols, notations, graphs, tables, diagrams, graphs, and equations, to illustrate or solve mathematical problems (Salsabila & Tsurayya, 2024; Septian, 2023). Further, Salsabila *et al*., (2023) It is also argued that mathematical representation is the ability to integrate concept understanding, logical reasoning, communication skills, and problem-solving strategies through various forms of presentation that are in accordance with the mathematical context. Based on this, it is stated that mathematical representation ability is the ability of individuals to relate abstract mathematical concepts with real-world applications, as well as the ability to visualize, understand, and solve mathematical problems through various representations such as symbols, graphs, tables, and other mathematical expressions.

As previously stated, representational ability plays an important role in mathematics learning. However, several studies indicate that students' mathematical representation skills are still relatively low. These difficulties are reflected in students' obstacles in constructing equations, developing mathematical models, understanding contextual problems, and performing basic arithmetic operations (Muharani *et al*., 2025; Riani *et al*., 2022; Hardianti & Effendi 2021). Similar findings have also been reported in international contexts. Studies conducted in the United States and Turkey show that students still experience difficulties in transforming one form of mathematical representation into another, such as converting equations into graphs or interpreting graphs into symbolic forms (Erdoğan et al., 2021; Lin et al., 2016). This indicates that mathematical representation ability remains a challenge in mathematics learning across various educational contexts. In line with these findings, the initial observation conducted by the researcher at one of the senior high schools in Indonesia also revealed similar problems. It was found that some students experienced difficulties in representing visual information into an appropriate mathematical model.

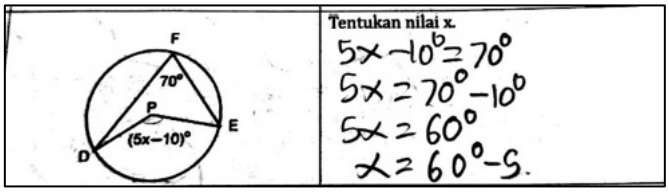


Figure 1. Student's answer

Figure 1 shows that students still have difficulties in interpreting visual information into symbolic form, and are less careful in performing algebraic operations. These findings indicate that students' mathematical representation abilities, particularly in translating and connecting different forms of representation, still require further attention in the learning process.

Although research on mathematical representation skills has shown an increase in recent years, most studies still focus on the effectiveness of learning models, approaches, or analyses of improving representational skills in general, For example, through the application of the learning model *Connecting, Organizing, Reflecting, and Extending* (CORE) as well as ethnomathematical approaches (see e.g. Salam & Khusna, 2025; Song et al., 2025; Atikasuri & Kusaeri, 2024; Hariyani & Andriani, 2023). There have not been many studies that specifically examine students' mathematical representation abilities through the theoretical framework of representation development. Some existing studies generally examine representational abilities using other theoretical frameworks. For example, research Wulandari & Ishartono (2022) examine students' mathematical representation abilities based on Van Hiele's level of thinking. Furthermore, Nugroho, (2015) using Dienes and Van Hiele's learning theory to aid the development of mathematical representation skills. However, research that specifically examines the ability of mathematical representation based on the theoretical framework of representation development is still relatively limited.

One of the theories relevant to mathematical representation abilities is Bruner's theory of learning, put forward by Jerome Bruner (Salsabila and Hakim, 2025). According to Bruner, the learning process is part of cognitive development that takes place gradually. In the theory of representation that he puts forward, cognitive development is explained through three stages, namely enactive (action-based), iconic (image-based), and symbolic (abstract symbol-based) (Rahmania et al., 2025). These three stages show that the process of learning mathematics does not take place instantly, but through a gradual development from concrete experience to abstract understanding. Each stage provides an opportunity for students to represent mathematical concepts in a different way, according to their way of thinking at that stage. In the enactive stage, concepts are represented through direct actions or manipulation of concrete objects, so that learners can understand concepts through real experience. Furthermore, at the iconic stage, concepts begin to be represented through images or visualizations that help students see the relationships between concepts more clearly. Meanwhile, at the symbolic stage, students have been able to represent mathematical concepts using symbols or abstract notation. The difference in the form of representation shows that the way students understand and convey mathematical concepts develops along with the development of their way of thinking.

Although high school students are generally considered to be at the symbolic stage of cognitive development, understanding abstract mathematical concepts still requires support from concrete and visual representations. The enactive and iconic stages remain important in helping students gradually construct conceptual understanding before reaching more abstract symbolic representations. Unfortunately, studies of mathematical representation abilities based on each of Bruner's stages are still limited. Therefore, it is important to conduct research that describes in detail the characteristics of students' mathematical representation abilities at each stage of Bruner's development based on the forms of representation that emerge. Through this mapping, a more comprehensive picture is obtained of how students represent mathematical concepts according to their thinking development, so that it can be the basis for designing more adaptive and meaningful learning strategies.

METHOD

This study seeks to describe the characteristics of students' mathematical representation abilities at each stage of Bruner's development based on the form of representation that appears. This

research applies a qualitative method with a phenomenological approach, used to understand subjective experiences and meanings that individuals construct related to certain phenomena (Creswell & Creswell, 2018). The phenomenological approach was chosen to deeply understand the students' experience in displaying mathematical representations according to the stages of Burner development. The subjects in this study are 104 students of grade X of high school in Indonesia, the selection of participants is carried out through techniques *purposive sampling*, which is a deliberate selection technique of participants based on certain considerations (Creswell & Creswell, 2018). The criteria for participants in this study include: (1) willingness and permission from the homeroom teacher and subject teacher, and (2) having a willingness to be involved in the research.

The data used came from several instruments, namely (1) a mathematical representation ability test, consisting of four description questions arranged based on Bruner's developmental stage theory (enactive, iconic, and symbolic). In addition, an additional description question is included at the enactive stage which is carried out in a *Focus Group Discussion*(FGD) with material *Three-Variable Linear Equation System* (SPLTV). This test aims to identify the forms of representation that emerge from students, both in the form of concrete actions, visualizations, and the use of mathematical symbols; and (2) non-systematic observation sheets, used to record students' behavior, strategies, and spontaneous responses when taking tests and during the process *Focus Group Discussion* (FGD). The instrument has been consulted and reviewed by experts to ensure the suitability of the content, clarity of indicators, and feasibility of use in the field. Process *Review* Conducted by experts in the field of mathematics education, certified and experienced mathematics teachers. The indicators used in the mathematical representation ability test instrument refer to Abdurahman et al. (2023) as shown in Table 1.

Table 1. Indicators of Mathematical Representation Ability

No.	Indicator	Description
1.	Visual	Students' ability to solve problems through visual representations, such as pictures, diagrams, graphs, and other visual forms.
2.	Symbolic	The ability of students to solve problems by using mathematical models and symbols, such as numbers, letters, or other notations, to represent complex concepts or objects.
3.	Verbal	The ability of students to express ideas and concepts through language, both verbally and in writing, as well as in understanding the message conveyed in verbal form.

Furthermore, there is an indicator of mathematical representation ability based on Bruner's developmental stage theory (Bruner, 1966) in Table 2.

Table 2. Indicators of Mathematical Representation Ability Based on Bruner's Theory

No.	Stages	Description
1.	Enactive	Learners' ability to illustrate problems presented with hands-on experience or action in the field
2.	Iconic	The ability of learners to represent mathematical concepts through drawings, diagrams, sketches, or other visual forms that illustrate the relationships between concepts, even without direct manipulation of physical objects;
3.	Symbolic	Students' ability to use formal symbolic notation in presenting mathematical concepts, such as numbers, letters, formulas, and mathematical symbols in an abstract manner without the help of concrete objects or visualizations.

The data analysis technique used is thematic analysis, which is an approach used to examine data with the aim of revealing the main patterns or themes contained in it, based on the results of data collection by researchers (Braun & Clarke, 2006). The thematic analysis in this study follows the six stages proposed by Braun and Clarke (2006). These stages include: (1) recognizing and understanding data; (2) create the initial code; (3) grouping the code into themes; (4) reviewing the theme; (5) define and name the theme; and (6) compiling a report on the results of the analysis. At this stage, the theme formed is entirely sourced from the students' answers, which are then analyzed to answer the research questions.

RESULTS AND DISCUSSION

Results

Based on the results of the analysis of the description test of 104 students, several characteristics were obtained that were reflected in the participants' responses to the given problems, reviewed based on the Burner stage.

In the active stage, the analysis of students' responses in solving contextual problems of the Three-Variable Linear Equation System (SPLTV) based on the manipulation of concrete objects regarding the determination of the price of a combination of stationery produced a number of themes, as presented in Table 3.

Table 3. Theme of Enactive Stage Representation on SPLTV Contextual Problems regarding Pricing of Stationery Combinations

Theme	Percentage		
Manipulation of Functional Objects	74.04%		
Constructive Procedure		14,42%	
Constructive-Transitional		1,92%	
Inaccurate Constructive-Transitional			1,92%
Constructive-Instructional		4,81%	
Constructive-Calculative Discrepancy		6,73%	
Constructive Independent Analytics		13,46%	
Constructive Responsive Analytics		28,85%	
Guided Interactive Constructive		0,96%	
Partial Manipulation		0,96%	
Manipulation of Non-Functional Objects	25.96%		
Non-Manipulation		16,35%	
Imitative Manipulation		9,61%	

The enactive stage is related to the ability of students to manipulate objects through actions, both real and mental. Table 3, shows that the most prominent tendency is seen in the functional object manipulation category, which shows that most learners are able to use objects appropriately to represent problem situations. Among the various construction patterns in this category, constructive responsive analytics emerged as the most dominant form of interaction, reflecting the learner's ability to construct relevant representations based on available information. In contrast, guided interactive constructive and partial manipulation appear only in a small percentage of learners, indicating limitations in exploration or dependence on assistance. On the other hand, there are still students who are in the category of non-functional object manipulation, which describes the use of objects that do not fully support the optimal representation of the problem, even in some cases students do not manipulate the available objects at all.

In contrast to the enactive stage that focuses on object manipulation, the iconic stage reflects the learner's ability to form visual representations, such as tables, diagrams, schematics, or

contextual images. At this stage, the analysis is focused on the tendency of visual representations that learners use in solving problems. Based on the students' responses to the contextual problem of SPLTV which describes the situation of purchasing three types of fruits with variations in capital in a few days, a number of visual representation themes were obtained presented in Table 4.

Table 4. Theme of Iconic Stage Representation on SPLTV's Contextual Issues regarding the Purchase of Three Types of Fruit

Response	Theme	Percentage			
Correct		82.69%			
	Table/Tabulation Representation		75.96%		
	Categorical Tabulation (percolumns)			69.23%	
	Categorical labeled symbolic				10.58%
	Purely categorical				57.69%
	Schematic tabulation				0.96%
	Inventory Tables (by Baris)			6.73%	
	Narrative-Textual Inventory				5,77%
	Symbolic Inventory				0.96%
	Contextual Image/Visual Representation		3.85%		
	Contextual Pictorial Illustration			3.85%	
	Murni Pictorial				1.92%
	Pictorial Labeled Symbol				1.92%
	Diagram Representation		2.88%		
	Diagram Batang Tunggal			1.92%	
	Group Bar Chart			0.96%	
Incorrect		17.31%			
	Table/Tabulation Representation		9.62%		
	Non-Systematic (Reductive) Tabulation			9.62%	
	Deficit Tabulation				3.85%
	Mis-Data Tabulation				5.77%
	Contextual Image/Visual Representation		2.88%		
	Schematic-Symbolic Representation			2.88%	
	Information Deficit Schematics				2.88%
	Limited/Absent Iconic Representation		4.81%		

Table 4 shows the students' responses to SPLTV's contextual problems regarding the purchase of three types of fruit. In the true category, the most dominant tendency is seen in the use of table representations or tabulations. Most students compile information through categorical tabulation per column, either in the form of categorical symbolic labels or purely categorical without additional labels. In addition, there is also a form of inventory tabulation per line which is presented in narrative-textual and symbolic forms. Meanwhile, the representations that appear in very limited numbers are diagram representations, both in the form of single bar charts and group bar charts, which show that only a small percentage of learners use diagrams as a means of data visualization. A small number of others use contextual representations of images or visuals, such as pure pictorial illustrations or pictorial illustrations equipped with symbolic labels to describe the situation in the problem. As for incorrect answers, non-systematic tabulation, deficit tabulation, and mis-data are still found, which indicates that some students are not fully able to compile iconic representations systematically and completely.

In another context, namely the determination of table height based on the position of the cat and turtle, the analysis of the iconic stages of the learner's response shows a number of visual representation themes presented in Table 5.

Table 5. The Theme of Iconic Stage Representation on SPLTV's Contextual Problems Relates to Table Height Determination Based on the Position of Cats and Turtles

Response	Theme	Percentage			
Correct		73.07%			
	Table/Tabulation Representation		23.07%		
	Categorical Tabulation (percolumns)			22.12%	
	Categorically labeled symbols				3.85%
	Purely categorical				18.27%
	Inventory Tables (by Baris)			0.96%	
	Narrative-Textual Inventory				0.96%
	Contextual Image/Visual Representation		50%		
	Contextual Pictorial Illustration			4.81%	
	Murni Pictorial				3.85%
	Pictorial Labeled Symbol				0.96%
	Schematic Representation			9.62%	
	Schematic labeled symbolic				6.73%
	Pure schematics				2.88%
	Situational model visualization			35.58%	
	Visualization of abstract models				9.62%
	Pure model visualization				25.96%
Incorrect		22.12%			
	Table/Tabulation Representation		6.73%		
	Non-Systematic (Reductive) Tabulation			6.73%	
	Deficit Tabulation				0.96%
	Mis-Data Tabulation				5.77%
	Contextual Image/Visual Representation		5.77%		
	Contextual Pictorial Illustration			3.85%	
	Pictorial Defisit				3.85%
	Situational model visualization			1.92%	
	Visualization of Deficit Model				1.92%
	Limited/Absent Iconic Representation		9.62%		
No Response		4.81%			

At the iconic stage, based on the SPLTV's contextual problem of the determination of table height from the position of the cat and turtle, Table 5 shows that in the correct category, the most dominant representation is seen in the use of image representations or contextual visuals, in particular in the subtheme of visualization of the situational model with the greatest proportions. This shows that most learners tend to represent information through visual modeling that depicts the situation directly. In addition, table representations or tabulations are also used, although in smaller proportions, mainly in the form of categorical tabulations per column. The representation that appears most rarely in the correct category is the inventory tabulation per line, as well as some forms of pictorial illustrations labeled symbols, which indicate that only a small percentage of students use these variations of representations.

Meanwhile, in the wrong category, the most dominant error was found in limited or absent iconic representations, which indicated that some students were not able to display visual representation adequately. Errors are also found in non-systematic tabulation as well as

incomplete contextual visual representations. The forms of errors found are deficit tabulation and deficit model visualization, which indicate limitations in presenting visual representations systematically.

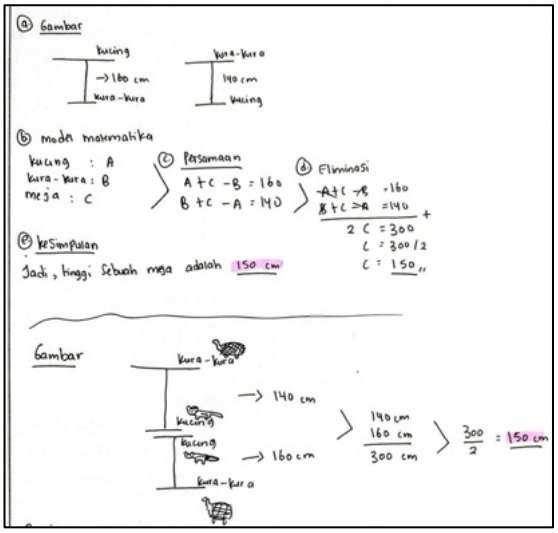


Figure 2. Correct Category Answer in the Subtheme of Contextual Model Visualization

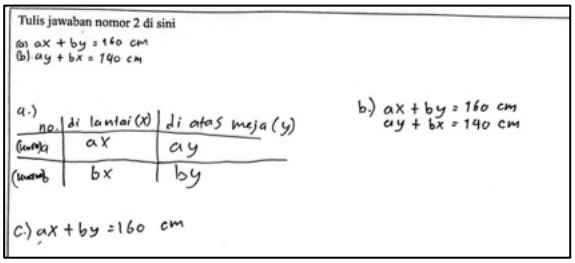


Figure 3. Incorrect Category Answer in the Subtheme of Non-Systematic Tabulation

Figure 2 shows the students' ability to transform problem information into a visual representation. Meanwhile, Figure 3 indicates that the students attempted to use a table as a representation; however, the resulting output is not yet fully accurate and lacks a systematic organization of the information.

Furthermore, in the context of determining the size of the beam based on the circumference of its sides, the analysis of the iconic stage of the learner's response resulted in a number of visual representation themes presented in Table 6.

Table 6. The theme of Iconic Stage Representation on the SPLTV Contextual problem of Determining the Size of Beams based on the Circumference of Their Sides.

Response	Theme	Percentage		
Correct		44.23%		
	Table/Tabulation Representation		2.88%	
	Categorical Tabulation (percolumns)			2.88%
	Categorically labeled symbols			2.88%
	Contextual Image/Visual Representation		41.35%	
	Schematic-Symbolic Representation			9.62%
	Symbolic schematics			2.88%
	Pure schematics			6.73%
	Situational model visualization			31.73%
	Visualization of abstract models			8.65%

	Pure model visualization				23.08%
Incorrect		52.89%			
	Table/Tabulation Representation		3.85%		
	Non-Systematic (Reductive) Tabulation			3.85%	
	Deficit Tabulation				2.88%
	Mis-Data Tabulation				0.96%
	Contextual Image/Visual Representation		23.08%		
	Situational model visualization			19.23%	
	Visualization of Deficit Model				19.23%
	Schematic-Symbolic Representation			3.85%	
	Information Deficit Schematics				3.85%
	Limited/Absent Iconic Representation		25.96%		
No Response		2.88%			

Table 6 shows that in the correct category, the most dominant tendency is seen in the use of contextual image or visual representations, especially in the form of situational model visualization that illustrates the relationships between elements in the problem through visual illustrations. Some students also develop these representations into abstract models or pure models, which reflect efforts to visualize the structure of mathematical relationships in a simpler way. Meanwhile, the representation that appears most rarely is the representation of tables or tabulations, especially in the form of categorical tabulations labeled symbolically used to organize information in the question. In addition, there are also students who use schematic-symbolic representations, both in the form of pure schematics and schematics labeled symbolically to describe the relationship between elements in the problem. However, in the category of incorrect answers, incomplete model visualizations, deficit and mis-data tabulations, and schemas that lost important information were still found. In addition, answers were found that did not adequately display iconic representations or skipped the iconic stage and switched to symbolic, i.e. on the theme of limited/absent iconic representation.

In another context, namely the determination of the price of stationery based on the combination and relationship between goods, the analysis of the iconic stage of the learner's response shows the variation in the theme of visual representation presented in Table 7.

Table 7. Theme of Iconic Stage Representation on SPLTV Contextual Issues on Stationery Pricing based on Combinations and Relationships Between Goods

Response	Theme	Percentage			
Correct		62,50%			
	Table/Tabulation Representation		43.27%		
	Categorical Tabulation (percolumns)			42.31%	
	Categorically labeled symbols				26.92%
	Purely categorical				15.39%
	Inventory Tables (by Baris)			0.96%	
	Symbolic Inventories				0.96%
	Contextual Image/Visual Representation		19.23%		
	Contextual Pictorial Illustration			16.35%	
	Murni Pictorial				2.88%
	Pictorial Labeled Symbol				13.46%
	Schematic Representation			2.88%	
	Pure schematics				2.88%
Incorrect		28.85%			
	Table/Tabulation Representation		12.50%		

	Non-Systematic (Reductive) Tabulation		12.50%	
	Deficit Tabulation			0.96%
	Mis-Data Tabulation			11.54%
	Contextual Image/Visual Representation	3.85%		
	Contextual Pictorial Illustration		2.88%	
	Pictorial Defisit			2.88%
	Schematic Representation		0.96%	
	Information Deficit Schematics			0.96%
	Limited/Absent Iconic Representation	12.50%		
No Response		8.65%		

Table 7, shows the themes, subthemes, and sub-sub-themes formed from students' visual representation (iconic stage) answers to SPLTV contextual problems regarding the determination of the price of stationery based on combinations and relationships between goods. In the correct category, the most dominant tendency is seen in the use of table representations or tabulations, particularly in the form of categorical tabulations per column either presented with symbolic labels or in purely categorical form without additional labels. In addition, there is also a form of symbolic inventory tabulation that presents information in the form of a structured list. Contextual image or visual representations are also used, albeit in smaller proportions, especially in the form of contextual pictorial illustrations or purely pictorial illustrations that depict problem situations. The least common representation is schematic representation, which is only displayed by a small percentage of learners to map the relationship between information through symbols or geometric shapes (such as boxes, circles, or other substitute signs) to represent objects, indicating the process of abstraction from the shape of the original object. In some cases, the illustration is also equipped with symbolic labels to clarify the relationship between the elements. Meanwhile, in the wrong category, the most dominant error is found in the use of tables or unsystematic tabulation, especially in the form of mis-data tabulation. In addition, there are still students who do not adequately display iconic representations, which are shown in the category of limited or absent iconic representation. Errors also appear in incomplete contextual and schematic visual representations, albeit in relatively small amounts. The forms of errors with low proportions, namely deficit tabulation and information deficit schematics, show incompleteness in the presentation of data.

Furthermore, at the symbolic stage, the analysis of students' responses to SPLTV contextual questions regarding the purchase of three types of fruits with capital variations in a few days resulted in a number of symbolic representation themes can be seen in Table 8.

Table 8. Theme of the Symbolic Stage on SPLTV's Contextual Problem of the Purchase of Three Types of Fruit

Response	Theme	Percentage		
Correct		75%		
	Precise modeling		75%	
	Precise modeling with variable definitions			57.69%
	Precise modeling without variable definition			17.31%
	Elimination-Substitution		64.42%	
	Precise method			60.57%
	Improper method			3.85%
	Substitution		5.76%	
	Precise method			2.88%
	Improper method			2.88%
	No Procedure		4.81%	

	Conclusion		69.23%	
	Symbolic			33.65%
	Narrative			29.81%
	Incorrect conclusion			3.85%
	No Conclusion		5.77%	
Incorrect		24,04%		
	Precise modeling		13.46%	
	Precise modeling with variable definitions			9.61%
	Precise modeling without variable definition			3.85%
	Inaccurate modeling		10.58%	
	Improper method		7.69%	
	Elimination-substitution			5.77%
	Eliminasi			1.92%
	No Procedure		3.85%	
	Errors in the calculation process		8.65%	
	No Conclusion		0.96%	
	Incorrect conclusion		13.46%	
	Not finished		3.85%	
No Response		0.96%		

The symbolic stage is concerned with the learner's ability to use equations, variables, operations, and formal mathematical procedures. The analysis was carried out on four problems of the Three-Variable Linear Equation System (SPLTV) which focused on modeling, the application of formal/algebraic methods, and the drawing of conclusions. As can be seen in table 8, most of the students gave the right answers. In the correct category, the most prominent tendency is seen in precise mathematical modeling, especially those accompanied by variable definitions, as well as the correct use of elimination-substitution methods. In addition, students also show the ability to draw conclusions, both in symbolic and narrative forms, although there are still a small number who do not include conclusions or use inappropriate procedures.

Meanwhile, in the wrong category, the most dominant error was in incorrect conclusions, followed by improper modeling and errors in the calculation process. In addition, there are still inappropriate use of methods, settlements without clear procedures, and unfinished answers. However, there are also some students who have been able to build the right modeling, but make mistakes at the procedural stage or final completion.

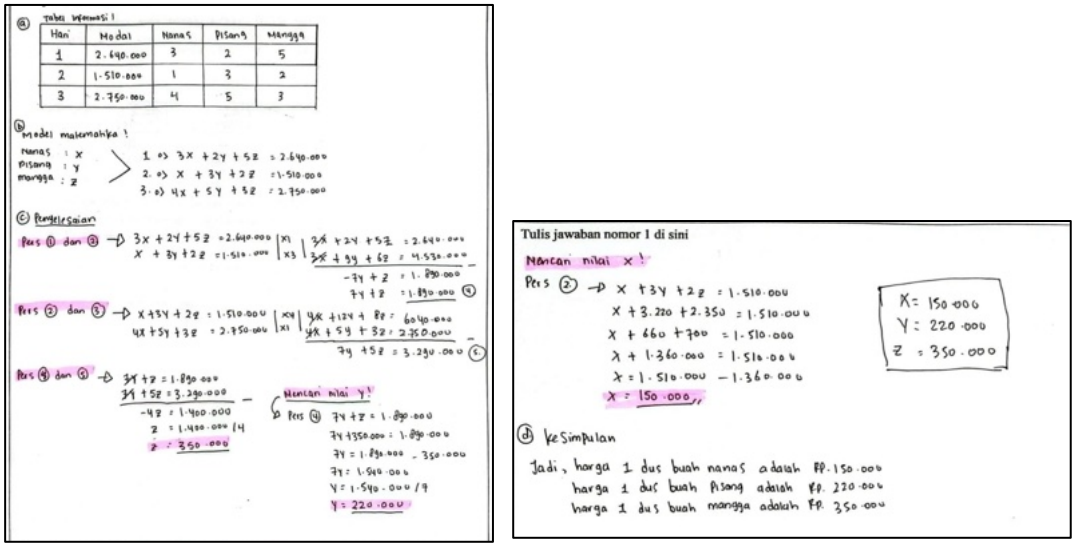


Figure 4. Student Answer in the Symbolic Stage, Correct Category in Table 8

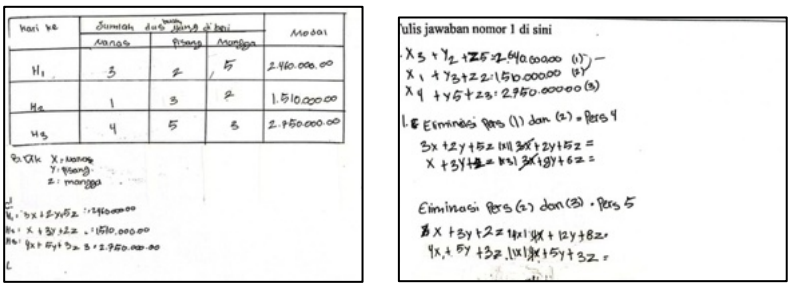


Figure 5. Student Answer in the Symbolic Stage, Incorrect Category in Table 8

Figure 4 shows that the students were able to understand, model, and solve the problem in symbolic form using the elimination and substitution methods accurately, and also present a conclusion as a form of verbal representation. In contrast, Figure 5 shows that the students were unable to apply the elimination and substitution methods correctly, resulting in an incomplete solution process, and did not provide a verbal representation in the form of a conclusion.

In another context, from the students' responses to contextual problems related to the determination of table height based on the position of cats and turtles, a number of symbolic representation themes were obtained presented in Table 9.

Table 9. Symbolic Stage Theme on SPLTV Problems Related to Table Height Determination Based on Cat and Tortoise Positions

Response	Theme	Percentage		
Correct		81.73%		
	Precise modeling		80.77%	
	Precise modeling with variable definitions			71.15%
	Precise modeling without variable definition			9.62%
	Inaccurate modeling		0.96%	
	Eliminasi		76.92%	
	Precise method			69.23%
	Improper method			7.69%
	Substitution		3.85%	
	Precise method			3.85%
	No Procedure		0.96%	
	Step explained		50%	
	Full explanation			28.85%
	Incomplete explanation			14.42%
	Explanation is not in accordance with procedure			6.73%
	No Step Explanation		31.73%	
	Conclusion		70.19%	
	Symbolic Conclusion			30.77%
	Narrative Conclusion			28.85%
	Incorrect conclusion			10.57%
	No Conclusion		11.54%	
Incorrect		12.50%		
	Precise modeling		6.73%	
	Precise modeling with variable definitions			5.77%
	Precise modeling without variable definition			0.96%
	Inaccurate modeling		2.88%	
	Data input errors			1.92%

	Variable relationship mismatch		0.96%
	Eliminasi	5.77%	
	Improper method		3.85%
	Errors in the calculation process		1.92%
	Step explained	7.69%	
	Incomplete explanation		0.96%
	Explanation of steps not in accordance with procedures		6.73%
	Irrelevant answers	0.96%	
	No Conclusion	2.88%	
	Incorrect conclusion	11.53%	
	Not Finished	3.85%	
	No Procedure	0.96%	
No Response		5.77%	

Table 9 shows that in the true category, the most dominant tendency is in precise mathematical modeling, especially those accompanied by variable definitions. In addition, the use of the elimination method also appears to be dominant, with most students able to apply it appropriately in the completion process. Students also show the ability to draw conclusions, both in symbolic and narrative form, as well as provide explanations of the completion steps, although there are still some who do not present a complete explanation. Although the majority of learners answered correctly, it was still found that the use of inappropriate modeling and methods, as well as non-procedural solutions.

Meanwhile, in the wrong category, the most dominant error is in the incorrect conclusion drawn, followed by inaccuracies in the explanation of the solution steps. In addition, errors are still found in the use of the elimination method, either due to improper procedures or errors in the calculation process. Errors also appear in improper modeling, albeit in a relatively small proportion. The most rare forms of error are irrelevant answers, as well as non-procedural solutions.

Furthermore, in another context, namely the determination of the size of the block based on the circumference of its sides, the analysis of the symbolic stage to the response of the students showed the variation in the theme of symbolic representation presented in Table 10.

Table 10. Theme of the Symbolic Stage in the SPLTV Contextual Question on Determining the Size of the Beam based on the Circumference of the Sides

Response	Theme	Percentage	
Correct		54.81%	
	Precise modeling	53.85%	
	Inaccurate modeling	0.96%	
	Elimination-Substitution	33.65%	
	Precise method		32,69%
	Improper method		0.96%
	Substitution	12.50%	
	Precise method		12.50%
	No Procedure	8.65%	
	Conclusion	52.88%	
	Symbolic		21.15%
	Narrative		31.73%
	No Conclusion	1.92%	
Incorrect		41.34%	

	Precise modeling	32.69%	
	Inaccurate modeling	3.85%	
	No Procedure	0.96%	
	Errors in the calculation process	7.69%	
	Incorrect conclusion	8.65%	
	Not finished	31.73%	
	Not Solving Core Questions		22.11%
	Incomplete procedure		3.85%
	Just the first step		5.77%
	Irrelevant answers	0.96%	
No Response		3.85%	

Table 10 shows that at the symbolic stage, some learners can give the correct answer, with a dominant tendency to correct mathematical modeling, followed by the use of elimination methods, as well as drawing conclusions. However, in the correct category, there are still some students who complete without clear procedures, use improper methods, or do not include conclusions. Meanwhile, in the category of mistakes, the most dominant errors are found in unfinished answers, mainly because they do not complete the core questions, only the initial steps and the procedure is not complete. In addition, errors also occur due to improper modeling, errors in the calculation process, and irrelevant answers. In addition, there are still a small number of blank answers or no responses.

In another context, namely the determination of the price of stationery based on the combination and relationship between goods, the analysis of the symbolic stage to the response of students shows the variation in the theme of symbolic representation presented in Table 11.

Table 11. Theme of the Symbolic Stage in the SPLTV Contextual Question on Determining the Price of Stationery based on Combinations and Relationships Between Goods

Response	Theme	Percentage	
Correct		54.81%	
	Precise modeling	54.81%	
	Precise modeling with variable definitions		51.92%
	Precise modeling without variable definition		2.89%
	Elimination-Substitution	7.69%	
	Precise method		7.69%
	Substitution	44.23%	
	Precise method		43.27%
	Improper method		0.96%
	No Procedure	2.88%	
	Conclusion	40.38%	
	Symbolic		20.19%
	Narrative		18.27%
	Incorrect conclusion		1.92%
	No Conclusion	14.42%	
Incorrect		37.50%	
	Precise modeling	29.81%	
	Precise modeling with variable definitions		26.92%
	Precise modeling without variable definition		2.88%
	Inaccurate modeling	7.69%	
	Variable relationship mismatch		7.69%
	Improper method	7.69%	

	Elimination-substitution		5.77%
	Substitution		1.92%
	No Procedure	0.96%	
	Errors in the calculation process	0.96%	
	Incorrect conclusion	7.69%	
	Not finished	26.92%	
	Not Solving Core Questions		14.42%
	Incomplete procedure		2.88%
	Just the first step		9.62%
	Irrelevant answers	0.96%	
No Response		7.69%	

It can be seen in table 11, in the category of correct answers there are several themes that emerge with the dominance of proper mathematical modeling, followed by the use of elimination–substitution, substitution, non-procedural solution, conclusion drawn, or no conclusion. However, it is still found that a small number of students use the method inappropriately, especially in substitution, and solve problems without a clear procedure. Meanwhile, in the category of incorrect answers, errors are dominated by incomplete answers, followed by improper modeling, the use of improper methods, errors in the calculation process, and irrelevant answers. In general, these findings show a variation in the characteristics of students' representation abilities in building mathematical models, choosing solution strategies, and drawing conclusions. Therefore, the findings will be discussed further to describe the characteristics at each stage based on the research findings.

Discussions

The results of a thematic analysis of mathematical representation abilities based on Bruner's theory of developmental stages at the high school level, especially class X, found that representation tendencies varied at each stage.

1. Mathematical Representation Ability at the Enactive Stage

The enactive stage deals with how learners manipulate objects or represent mathematical ideas through motor actions or physical models. In the context of written problem solving, this stage can be seen from the way students manage and manipulate the information of functional objects in the problem. In line with the opinion of Bruner (1996) who states that enactive is a direct action to understand a concept,

Based on the data in Table 1, most of the students have shown involvement in object manipulation activities directly when solving the given contextual problems. The most common form of manipulation is functional manipulation of objects, where learners use available objects or tools to represent the problem situation in a concrete way. The greatest tendency arises in the constructive subtheme of responsive analytics which indicates that learners are able to process the object information in the problem after receiving a clear stimulus or clue. Even so, students are still found in the categories of guided interactive constructive and partial manipulation. In this case, students still require explicit directions to answer the questions, as learning involves guidance and scaffolding to support students in completing tasks beyond their independent capabilities (Wood et al., 1976; Vygotsky, 1978). In addition, it was found that some of the students were classified as non-manipulative or imitative manipulation. In which, students show limitations in moving or organizing functional object information as part of a problem-solving strategy. This condition can be seen from manipulation activities that are still limited so that they do not fully support the process of constructing a more comprehensive understanding.

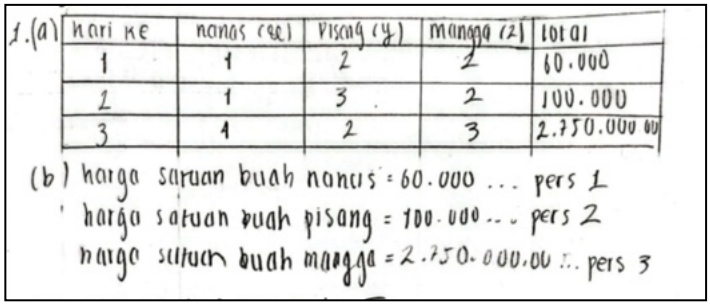
The research findings show that most learners have built a basic conceptual understanding through direct interaction with concrete objects, as Bruner explained in the enactive stage. This is also reflected in the dominance of the categories of responsive analytics and self-analysis which shows that many learners not only mimic actions, but are also able to understand the relationships between parts of the problem through physical manipulation. However, there are still groups of students who are in the non-functional category, indicating a gap in conceptual understanding, dependence on examples or patterns, and a lack of ability to transform information in the form of mathematical actions. These differences in characteristics show that mathematical representation skills at the enactive stage have not developed evenly in all students. This variation is important to note because the enactive representation is the basis for building the next form of representation, which is an iconic and symbolic representation in the process of understanding mathematical concepts (Murtafiah et al., 2024; Safitri et al., 2024). These findings are consistent with previous studies indicating that concrete object manipulation helps students build conceptual understanding before progressing to visual and symbolic representations (Ebner et al., 2025).

2. Mathematical Representation Abilities at Iconic Stages

At the iconic stage, the characteristics of mathematical representation abilities changed from action-based to visual-based. The mathematical representation of students is shown through the use of visual forms such as pictures, illustrations, and tabulations, which represent the relationships in the problem. The research data showed that the representation of the table dominated the choice of students, especially in the SPLTV contextual problem regarding the purchase of three types of fruit where 75.96% of students used the tabulation form with the dominance of categorical tabulation per column of 69.23%. Meanwhile, in the context of other questions, it was found that students used contextual images or visual schemes as a way to model problem situations.

However, an analysis of the students' answers shows that there are still several forms of visual representation at the iconic stage that have not been optimally developed. One of the findings that is quite prominent is the use of unsystematic tabulation. In some of the answers, students use tables to organize information, but the structure of the table has not fully described the relationships between the data contained in the problem. Some students only write down some information or place data in inappropriate columns so that the resulting table cannot support the problem solving process effectively. This can be seen in Figure 1, which shows the students' answers using a table as a visual representation, but the data presented is not in accordance with the context of the question so it is not able to accurately describe the relationship between information.

Day Pineapple (x) Banana (y) Mango (z) Total



1.(a)

hari ke	nanas (x)	pisang (y)	mangga (z)	total
1	1	2	2	60.000
2	1	3	2	100.000
3	1	2	3	2.750.000 00

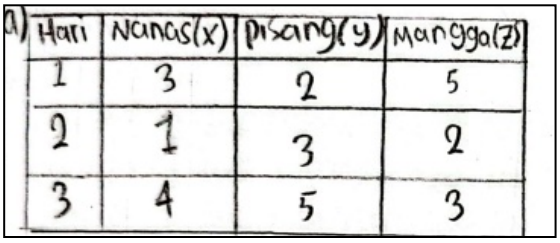
(b) harga satuan buah nanas = 60.000 ... pers 1
harga satuan buah pisang = 100.000 ... pers 2
harga satuan buah mangga = 2.750.000,00 ... pers 3

b) the unit price of pineapples = 60.000 ....equation (1)
the unit price of banana = 100.000 ....equation (2)
the unit price of mango = 2.750.000 ....equation (3)

Figure 1. Mis-data tabulation

In addition, visual representations were also found that experienced information deficits, both in contextual images, and in schemas. In this condition, students have tried to make a visual representation, but the information presented is incomplete or insufficient to describe the overall problem situation. As shown in Figure 2, students' answers are included in the deficit tabulation subtheme because the information written is incomplete, that is, it does not write the capital price in the table so that it does not represent the overall problem situation.

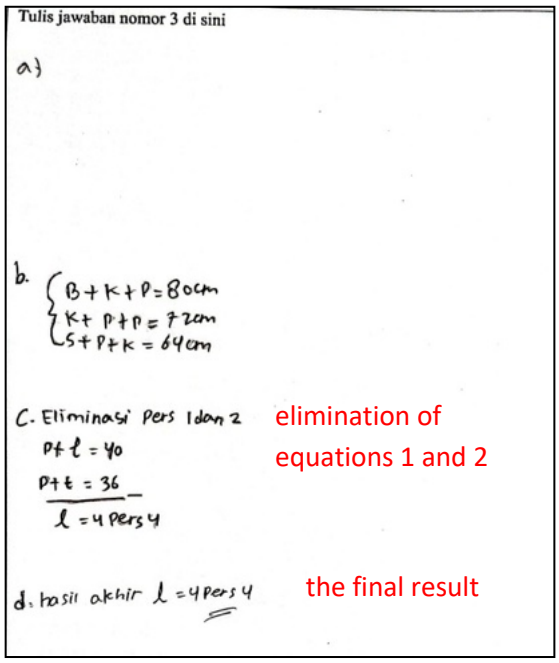
Day Pineapple (x) Banana (y) Mango (z)



a) Hari	Nanas(x)	Pisang(y)	Mangga(z)
1	3	2	5
2	1	3	2
3	4	5	3

Figure 2. Deficit tabulation

This indicates that students still have difficulty in translating the information about the questions into a complete and meaningful visual form. Another finding that is quite important is the appearance of iconic representations that are limited or even do not appear at all in some of the students' answers. This can be seen in Figure 3, which shows that learners immediately make a symbolic completion without presenting a visual representation first.



Tulis jawaban nomor 3 di sini

a)

b. $\begin{cases} B+K+P=80cm \\ K+P+P=72cm \\ S+P+K=64cm \end{cases}$

c. Eliminasi Pers 1 dan 2

$P+l=40$

$P+t=36$ −

$l=4$ Pers 4

elimination of equations 1 and 2

d. hasil akhir $l=4$ Pers 4

the final result

Figure 3. Sample Answers with Limited Iconic Representations

In some cases, students immediately try to solve the problem without making a visual representation first. This condition indicates that some students have not made the visual representation stage part of their problem-solving strategy. In line with the findings by Lisarani and Qahr's (2022) study, they found that representation has not been optimally utilized as a means to find solutions. In the process of constructing conceptual understanding, the iconic stage is considered to play an important role as a bridge between

concrete experience at the enactive stage and abstract representation at the symbolic stage. (Bruner, 1966).

In other cases, some students have used visual representations in the form of visualizations of the resulting situational models that are not entirely accurate. Students try to illustrate the problem situation through illustrations or schematics, but the relationships between the elements in the drawings do not fully represent the mathematical structure of the problem. The inability of students to meet the indicators of visual representation is influenced by the lack of accuracy in understanding the given problem and limitations in mastering the underlying concepts (Marina et al., 2025). This condition indicates that students' ability to construct visual models that accurately represent mathematical relationships still needs further development (Rahmah et al., 2026). In addition, it is also in line with Bruner's (1966) theory, which views that iconic representation through the use of visual imagery is a crucial foundation for students to be able to transform concrete information into more abstract symbolic forms.

In contrast to these findings, there are students who can use iconic representations appropriately in solving problems. This can be seen in Figure 4, where students present images as visual representations before making symbolic solutions, so as to obtain the right answer.

mathematical model

d. conclusion. difference between the longest and shortest ribs

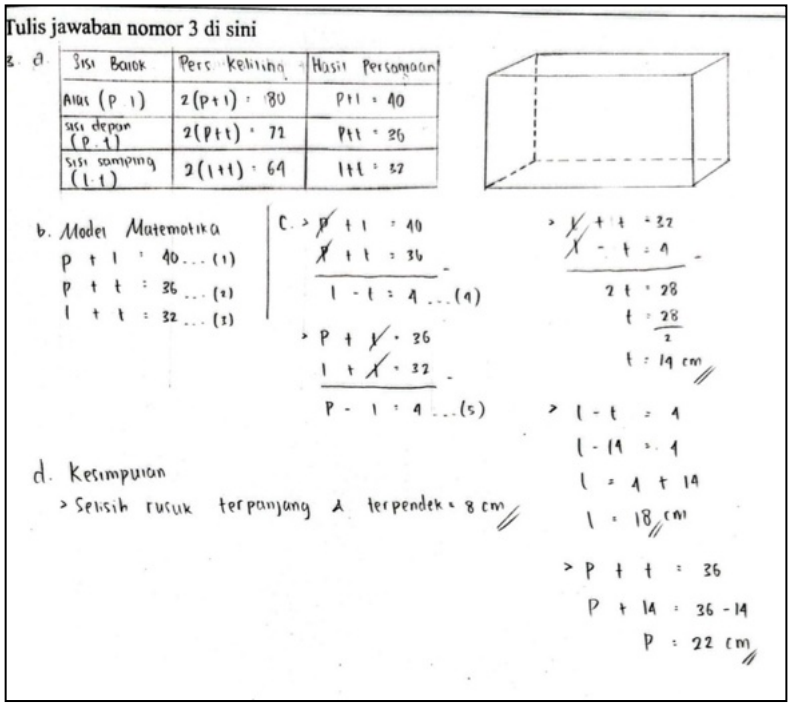


Figure 4. Examples of Exact Answers with Iconic Representations

Based on these findings, it can be understood that even though students have used various forms of visual representation, the quality and accuracy of the resulting representations still vary. Some students show the ability to use tables, pictures, or schemas to support the process of understanding problems. Meanwhile, some others still have difficulty in compiling systematic and informative visual representations. This indicates that the conceptual understanding developed at the previous stage may not yet be sufficiently stable to support more complex visualization processes, which is consistent with the findings of Zegaa (2025), that students with weak foundational conceptual understanding tend to experience difficulties in solving more complex problems. Thus, the characteristics of representation at the iconic stage are transitional students' ability to construct visual

representations is highly dependent on the robustness of the concept structure that has been obtained through concrete manipulation. If conceptual understanding is still weak, then visual representations tend to be unsystematic or even wrong (Ratumanan et al., 2022). These results are in line with Bruner's view that iconic representation depends on the ability to organize perception into meaningful visual forms (Bruner, 1966).

3. Mathematical Representation Ability at the Symbolic Stage

At the symbolic level, students are expected to be able to represent problems in the form of mathematical models and solve them using algebraic procedures. The results of the analysis showed that some students were able to build mathematical models that were appropriate to the problem situation and used solving procedures such as elimination and substitution to find solutions. In addition, research data show that students' symbolic representation abilities vary greatly depending on the complexity of the questions.

Some aspects at the symbolic stage still show the difficulties experienced by students. One of the findings that is quite prominent is the existence of modeling that is not entirely accurate. In some of the answers, students have tried to write down mathematical equations, but the relationships between the variables used have not fully represented the information contained in the problem. The modeling factor is not appropriate because it does not show the process of identifying the variables in the problem and does not make assumptions about the mathematical model needed to form equations (Febriani et al., 2024).

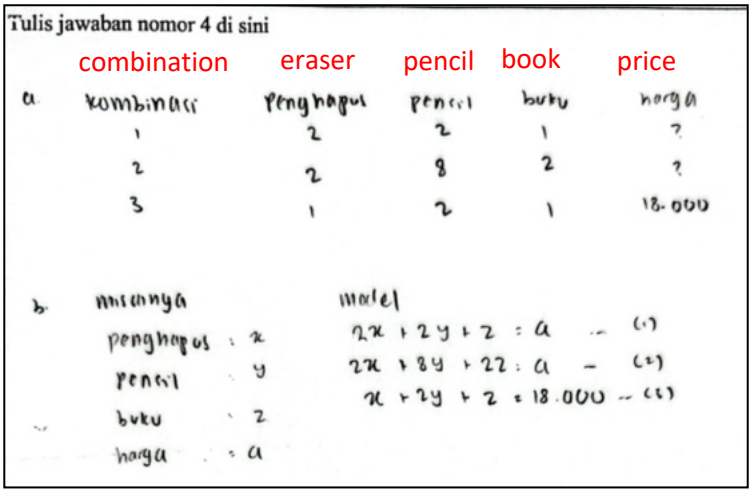


Figure 5. Examples of Inappropriate Modeling Answers

In Figure 5, it can be seen that students have written equations, but the relationships between variables are not in accordance with the information in the question. In addition, errors were also found in the selection or application of the settlement method. Some students use elimination or substitution methods, but the steps taken do not fully follow the proper procedures. It was found that in some responses, errors also occurred in the algebraic manipulation process so that the calculation results obtained did not match the model that had been built before. Another problem that is quite prominent is the incompleteness in solving problems. Some students have been able to build a mathematical model and start the completion process, but do not continue until they get a complete final answer. It can be seen from the answer, some students only write down the initial steps or stop at a certain stage without completing the calculation process. These errors are influenced by limited understanding of algebraic symbols, the ability to think abstractly, and the experience of forming equations so that the solution is not optimal (Musyarofah et al., 2025).

In addition, in some of the students' answers, solutions were found that were not accompanied by drawing conclusions. Even though the students have carried out the calculation process and obtained variable values, the results are not stated again in the form of statements that relate the solution to the context of the given problem. This condition also shows that in addition to symbolic representation, verbal representation skills have not fully appeared in students' answers. This can be seen from the limited number of students in expressing the results of the solution in the form of statements that relate the answers to the context of the problem. Verbal representation is considered to play an important role in clarifying the meaning of symbols and the results of the calculations obtained (Lalihatu et al., 2026). The absence of this verbal representation shows that the process of interpreting the results of the settlement has not taken place optimally (Maskur et al., 2022). This is in line with the findings of Nasrun et al. (2023) who state that verbal representation functions as an explanation as well as a guide for students in building a clearer mathematical model, so that the completion process is not just in the form of symbol manipulation, but also involves integrated meaning.

These findings show that although some students have been able to use symbolic representations in solving problems, the symbolic thinking process carried out is still not completely stable. Some students have succeeded in building models and performing the completion procedures correctly, but others still have difficulties in the modeling, application of procedures, and drawing conclusions. This finding is in line with Nurtiana et al., (2024), who found that some students were still unable to represent the results of their interpretations into mathematical models or equations appropriately. Furthermore, Imannia et al., (2022) reported that students were able to construct mathematical models from a problem correctly and completely; however, some students still provided correct answers without presenting complete solution steps. This condition shows that the characteristics of students' mathematical representation abilities at the symbolic stage still tend to focus on the calculation process, while representations that interpret the results in the context of the problem have not fully appeared in the students' answers. This indicates that symbolic representation demands integration between conceptual understanding and procedural capabilities (Astuti, 2015; Sifaunnazah et al., 2025). Students who only master the procedure mechanically without adequate understanding of concepts tend to have difficulty completing the process in its entirety, so the symbolic representation is incomplete or even misguided Hurrell (2021).

When related to the previous stage, students who demonstrate weaknesses in iconic representation tend to experience difficulties in progessing to the symbolic stage. As a result, they may struggle to bridge visual representations into symbolic forms. This is consistent with Bruner (1996), who states that symbolic representation is the highest stage of cognitive development, as students are required to master symbolic structures in order to organize knowledge more efficiently. Furthermore, the findings of this study support that students' success in algebra may be related to their abilities at the enactive and iconic stages as the foundation for constructing understanding. This is in line with Rahmania et al. (2025), who suggest that students reach the symbolic stage through a transitional process from the enactive stage to the iconic stage, which is based on abstract thinking.

These findings imply that the development of students' mathematical representation skills needs to be carried out gradually by emphasizing the relationship between the enactive, iconic, and symbolic stages in the learning process. Educators need to design activities that facilitate students in building an understanding of the manipulation of concrete objects to visual representations, and finally to meaningful symbolic forms. However, this study has some limitations. Although the number of participants in this study is relatively adequate,

the scope is limited to Grade 10 students; therefore, the findings may not fully represent the characteristics of mathematical representation abilities across broader educational levels. In addition, data collection through the FGD was limited, and only a small number of interviews were conducted. Furthermore, the data were not recorded verbatim, which may have reduced the depth of analysis and discussion. Therefore, future research should involve a larger and more diverse sample, encompassing various educational levels such as junior and senior high school, to ensure that the findings are more representative. In addition, data collection through FGD should be expanded to capture a wider range of students' perspectives, and interview data should be analyzed more rigorously and integrated into the discussion to provide a more comprehensive understanding of students' mathematical representation abilities.

CONCLUSION

The results of this study show that the characteristics of students' mathematical representation abilities vary at each stage of representation according to Bruner. In the enactive stage, students show the ability to use object manipulation to help understand problems even though they have not been fully utilized optimally. In the iconic stage, students use various visual representations such as tables, pictures, or schemes to illustrate the information in the problem, but some of the representations made are still not systematic or do not fully represent the structure of the problem. Meanwhile, at the symbolic stage, students have been able to build mathematical models and use algebraic procedures in the solving process, but inaccuracies are still found in the modeling, application of solution methods, and errors in the calculation process so that the symbolic representation produced has not fully interpreted the solution in the context of the problem. In addition, students' verbal representation abilities are still limited, as can be seen from the lack of drawing conclusions that relate the results of the calculation to the context of the problem, so that the process of interpreting the solution is not optimal. Overall, the findings of this study indicate a relationship between the mastery of the enactive and iconic stages to the success of students in reaching the symbolic representation stage, as well as providing a comprehensive picture of the characteristics of students' mathematical representation abilities that can be used as a basis for the development of more effective and meaningful learning strategies. Future research is recommended to involve broader educational levels and more comprehensive data collection in order to obtain a deeper understanding of students' mathematical representation abilities across Bruner's representation stages.

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