Journal on Mathematics Education
Volume 15, No. 2, 2024, pp. 403-430

How do you solve number pattern problems through mathematical semiotics analysis and computational thinking?

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Received: 11 January 2024 | Revised: 2 February 2024 | Accepted: 14 February 2024 | Published Online: 1 March 2024

Abstract

Some countries, including Indonesia, have a framework for understanding how students receive and process math concepts as new knowledge through learning styles. Learning style, particularly Kolb's model, is one of the learning styles that contribute to students' success in learning. Experts have explored the characteristics of Kolb's learning style and found many effects on student learning outcomes as a starting point in learning mathematical concepts. However, the research still focuses on exploring integer operation materials in specific math abilities. The researchers hardly found any discourse to study, such as exploring number patterns in computational thinking and semiotic mathematics. Therefore, this study aims to explore mathematical semiotics and computational thinking on number patterns in terms of Kolb's learning style model. This research uses hermeneutic phenomenology to explore through written tests and interviews. An explanation of the components, characteristics, and semiotic characteristics of mathematical and computational thinking seen in students who have the Kolb model of learning in solving problems of number patterns is part of the interpretation. These findings can be used as benchmarks in developing mathematics materials. Thus, this knowledge is a concrete foundation to guide future advances in curriculum, assessment methods, and learning approaches in mathematics education, particularly in algebra.

Keywords: Computational Thinking, Mathematical Semiotics Analysis, Number Pattern

How to Cite: Purwasih, R., Turmudi, & Dahlan, J. A. (2024). How do you solve number pattern problems through mathematical semiotics analysis and computational thinking?. *Journal on Mathematics Education, 15*(2), 403-430. http://doi.org/10.22342/jme.v15i2.pp403-430

Mathematics is a field that studies various representations and communications, such as language, visual forms, body movements, and algebraic notation. Each of these representations has and can have different potential meanings in terms of education, especially mathematical signs such as words, symbols, diagrams, graphs, and schemes. Mathematic representations (words, symbols, diagrams, graphs, and schemes) act as intermediaries that help connect the internal understanding of the individual with the mathematics concepts and information in the outside world through semiotics (Mudaly, 2014). Semiotics represent signs, including code, symbols, words, icons, objects, and body movements.

The human senses can detect these signs, have implicit meanings, and play an essential role in communication. Suryaningrum and Ningtyas (2019) explain that the meaning of such signs may appear when a person is engaged in communication activities. Therefore, semiotics is the most essential aspect of communication, especially in mathematics. Some researchers have classified semiotics into several types or components, including Inganah and Subanji (2013), who divide semiotics into body movement, words, and symbols. Meanwhile, Peirce's Semiotics, known as the triadic term (Representation, Object,

http://doi.org/10.22342/jme.v15i2.pp403-430

and Interpretant), is used to uncover the student's thinking processes in mathematics, especially in the cognitive processes involved in student interpretation of signs in solving problems (Palayukan, 2022; Palayukan et al., 2020). Representation represents another equivalent symbol (Eco, 1978; Kralemann & Lattmann, 2013; Stjernfelt, 2015). The object is something that represents the resulting interpretation. Interpretation is the response to an object by interpreting symbols (Cartier et al., 2016; Font et al., 2008; Radford & Schubring, 2008). Fitriyah et al. (2021) revealed that the semiotics of problem-solving in Mason's generalization are word, symbol, and gesture.

Based on research from several sources and experts, semiotics in this research is a cognitive process involving individual thinking by pouring mathematical ideas into representations, mathematical objects, and interpretants. Representation is a semiotic that identifies a mathematical concept through images, symbols, or words. A mathematical object is a semiotic that refers to an attempt to associate, create, or solve a problem of a number pattern using concepts, symbols, images, graphs, or other mathematical expressions. An interpretant is a semiotic that refers to making meaning or concluding mathematical concepts that relate patterns of numbers in solving mathematics problems. Understanding and digestion of symbols are not independent of mathematical activity in meaning construction and problem-solving. We often use mathematical symbols, numbers, and other signs to understand, model, and solve math problems. Santi (2011) explains that mathematical activity and learning mathematics are intrinsically semiotic activities. Semiotics is associated with mathematics because math is the knowledge related to a symbol-based activity (Fadiana et al., 2018).

Mathematical learning involves many aspects that are more than just numbers and formulas. One of the essential aspects of learning mathematics is the use of mathematical semiotics. Mathematical semiotics involves various elements such as numbers, symbols, notations, graphs, diagrams, and mathematical languages. Each element has a specific meaning and convention that students must understand when they study mathematics. For example, numbers have particular values and sequences, mathematical symbols have special meanings, mathematical notations such as exponents and roots have specific rules, and graphs and diagrams describe mathematical relationships. Tarasenkova and Kovalenko (2015) affirmed the existence of semiotics that accompanied the process of understanding the abstract mathematical context. Even Godino et al. (2011) found that a semiotic system is a tool for describing the properties of mathematical objects. The generalization process is one of the mathematical processes that can take us into a specific semiotic realm. Generalization is an essential component of computational thinking that involves identifying patterns, rules, and relationships that are generally applicable in various mathematical contexts. In this case, mathematical semiotics plays an essential role because we use the signs and symbols of mathematics to describe and represent the patterns and rules found in generalization.

Generalization in the context of mathematics, especially about number patterns, is one of the essential aspects of computational thinking. Generalization is identifying patterns or rules generally applicable to numbers or mathematical data. Generalization is the process of finding a typical or broader pattern (Kusaeri et al., 2018; Stjernfelt, 2015). Mason et al. (2010) state that generalization is the process of finding patterns, generalizing relationships, and creating relationships in various levels of mathematical thinking. The generalization built shows a cognitive transformation in how students think about sequences together, marking the depth of the way. Students understand sequence through mathematical relationships that they find meaningful to be constructed into a concept (Rivera, 2010; Sercenia et al., 2023). It involves identifying relationships and properties that apply to a certain number of data and then generalizing the rules or patterns to apply to more general or varied situations. Tests on number patterns in mathematical learning can create new ideas and solve number pattern problems. Numbers need to develop algorithms or step-by-step methods to solve these problems. It helps students learn how to plan logical and organized actions to solutions that can enhance thinking skills and computational thinking (Pei et al., 2018).

The importance of computational thinking for students has been conveyed by previous researchers (Choi, 2010; Sung & Black, 2020; Wing, 2006; Zhong et al., 2016) stating that introducing the practice of computational thinking into the mathematics classroom was important because students would subsequently plunge into the professional world. Computational thinking involves understanding algorithms, programming, logic, and systematic problem-solving. Computational thinking is the essential ability of a person to solve problems (Curzon et al., 2014; Czerkawski & Lyman, 2015) by designing algorithms that solve complex problems as effectively and efficiently as possible (Choi et al., 2017). People with strong computational thinking in the context of number patterns can efficiently identify, analyze, and generalize number patterns. A person who can think computationally can decompose problems involving number patterns into more uncomplicated steps, identify the underlying rules or relationships, and then apply that knowledge to solve similar problems. They can formulate the mathematical rules that apply to the pattern and predict its development.

Computational thinking comprises algorithmic thinking, pattern recognition, abstraction, and decomposition (Grover & Pea, 2021). Furthermore, Angeli et al. (2016) show that the ability to think computationally has five skill elements: abstractions, generalization, decomposition, algorithms, and debugging. On the other hand, computing thinking has four operational skills: decommissioning, pattern recognition, and abstract thinking. Through these four skills, students are trained to formulate problems by separating them into small, easy-to-solve parts (Angeli & Valanides, 2020). This study's computational thinking components include decomposition, pattern identification, abstraction, generalization, and algorithms.

Understanding concepts in mathematics depends heavily on how students represent and interpret signs or symbols (Mudaly, 2014). If students can interpret the signs correctly, their understanding of mathematical concepts will be more profound. However, in reality, students often experience difficulties understanding the concept of signs in mathematics, especially in topics such as integers (Bishop et al., 2014; Sercenia et al., 2023; Whitacre et al., 2012). This problem includes understanding negative or positive signs (Bofferding & Wessman-Enzinger, 2017; Vlassis, 2008) in the context of number sequence relationships (Bishop et al., 2014; Schindler et al., 2017). Apart from that, students also face obstacles in solving problems related to the operation of calculating negative integers (Fuadiah et al., 2016) and difficulty understanding the use of signs in mathematical representations (Widjaja et al., 2011). Difficulty understanding these signs affects the student's ability to solve mathematical problems correctly (Khalid & Embong, 2020). These studies provide an overview of the relationship between signs or symbols and students' ability to solve mathematical problems. Difficulty in understanding such mathematic symbols contributes to student's lack of accurate understanding of mathematical concepts (Akhtar, 2018), which will ultimately affect student performance in solving problems and cause errors (Khalid & Embong, 2020; Ostler, 2011; Radford & Schubring, 2008).

Students solving a number pattern problem will write symbolic representations in particular recursive relationships between tribes in a sequence (Orton et al., 2016). However, solving the problem of number patterns between one student and the other students is different. This is because each student has a different way of gaining learning experience and the ability to absorb and process information. The easiest way for students to absorb, organize, and process information received in the learning process is called a learning style (Bire et al., 2014; Rijal & Bachtiar, 2015). Knisley (2003) states that the Kolb model is a learning style suitable for learning mathematics, especially mathematical problem-solving. Kolb's model also explains how students acquire information based on experience, which is good enough for further research. Furthermore, compared to the learning style expressed by Deporter Hernacki, the Kolb model's learning style still needs to be studied (Anwar et al., 2023). No study of mathematical semiotics on computational thinking has examined learning styles based on the Kolb model.

Mathematical semiotic analysis refers to understanding mathematical signs and symbols and how they are used to convey concepts. Computational thinking involves the ability to solve mathematical problems, including understanding number patterns and identifying applicable rules. A number pattern is a sequence of numbers that follows a particular pattern, and understanding this pattern requires mathematical semiotic analysis to decipher the meaning behind the symbols and notations used. When students understand the semiotics of mathematics, they can recognize and interpret the signs in the number patterns better according to the student's learning style. Understanding mathematical semiotics includes introducing and understanding various mathematical representations, such as symbols, diagrams, and algebraic notations. The student's learning style also plays a key role in this context. Students' learning styles, as identified in the Kolb model, affect the way they approach and process mathematical information. Converger, diverger, assimilator, and accommodator may have different preferences in understanding number pattern signs. For example, students with assimilation learning styles deal with learning through abstract conceptualization and transformation into reflective observation, while convergent students can solve problems and make decisions effectively. He tends to experiment with new concepts, simulations, and practical applications in the context of formal learning. By understanding the linkages between semiotic mathematics, computational thinking, and Kolb's model learning styles, this research is expected to provide valuable insights for developing more contextual and adaptive mathematical learning strategies.

Next, this research question is "What is the description of the computational thinking and semiotic mathematical of students with Kolb's model learning style in solving number pattern problems?". Therefore, this research aims to describe more in-depth the mathematical semiotics of computational thinking in terms of Kolb's model learning style. The results of this research are expected to be an additional reference for teachers and researchers in developing the semiotic and computational thought that students possess through learning mathematics.

METHODS

Research Design

This research used a qualitative approach with a phenomenological design. *A* phenomenological research design is a methodology that describes meaning generally by the conditions experienced by different individuals related to a concept or phenomenon (Creswell, 2012). Phenomenology is described as a method in research with a qualitative approach that focuses on understanding and embodying human life experience as a subject within its framework of reference about meaning and how meaning is derived from experience (Grbich, 2007; Langdridge, 2008). The phenomenological design used is hermeneutic phenomena (Ricoeur, 1991). The purpose of selecting hermeneutic phenomenology methods in this research is to interpret or give fertilization to the mathematical semiotic representation of the component of computational thinking that has the Kolb model of learning in solving the problem of number patterns through in-depth interviews. To gain valuable insights into the mathematical semiotic process of computational thinking instead of the concept of number patterns reviewed from the Kolb model learning style, this approach aims to provide an in-depth interpretation, systematic analysis, and understanding of the meaning of the research subject's experience. Using the Kolb Model in this study is a relevant approach to understanding how students process their computational thinking while exploring numerical patterns. David Kolb developed the model and proposed four main learning styles: converger, diverger, assimilator, and accommodator. The results of the synthesis of the use of Kolb's Model in the study can provide insights into how individual learning style contributes to the understanding and application of computational thought in solving numeric pattern problems. Thus, the analysis not only digs mathematical aspects but also integrates psychological dimensions through understanding student learning styles, enriching our understanding of the relationship between computing thinking and learning mathematics.

Participants

This study was conducted on ninth-grade 2023/2024 school students at one of the junior high schools in Bandung, consisting of one class with 30 students. The students comprised of males and females aged around 12-13 years. All students were given a learning style model adapted from Kolb's Learning Style Inventory (LSI) to identify and aggregate students into four learning styles. Learning style groups are assimilator, accommodator, convergent, and diverger. Based on the LSI analysis they conducted on 30 students in class IX, the Kolb model learning style mapping is presented in Table 1.

Table 1. Distribution of Kolb model learning styles on research participants

No	Learning Style Type	Students
1	Diverger	6
2	Assimilator	7
3	Converger	12
4	Accommodator	5

The sample for this study was selected using a purposive sampling technique (Etikan et al., 2016). The participants in this research represent the learning styles of the assimilator, accommodator, converger, and diverger as the subject of the study. The students ranged in age from 14-15 years. In the Indonesian curriculum, these students already had pattern numbers. The four participants can be seen in Table 2.

Table 2. Research subjects based on Kolb model learning styles

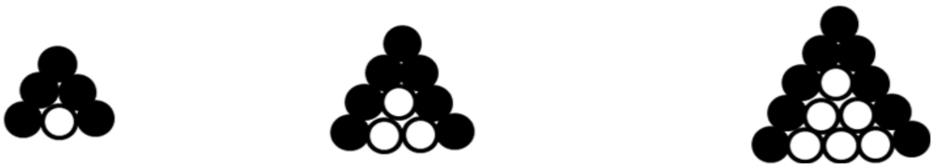
No	Student Initials	Learning Style	Participants	Age
1	RG	Assimilator	A	14
2	NV	Converger	B	14
3	MF	Accommodator	C	15
4	ID	Diverger	D	15

A number pattern is an area in mathematics that can describe a particular relationship and pattern. By choosing a number pattern, research can explore how students can use their computational thinking to understand, analyze, and identify complex mathematical patterns. In addition, mathematical semiotics is used to analyze how students use mathematic signs, symbols, and representations to understand and solve numbers' patterns. As an element of computational thinking, this study will explore how students use algorithms and computational processes to understand patterns. Thus, mathematical semiotics in the context of this research can help understand how students give meaning to number patterns through mathematics symbols and how computational thought is integrated into their interpretation of patterns.

Research Instruments

The research instruments, namely written tests of computational thinking, elevated learning styles, and interview guidelines, have been validated by three experts in algebra learning, pure mathematics, and mathematical practitioners. They gave feedback about the change in the question sentence in the test so that the subjects could understand it better. In addition, changes were made to one indicator in the interview, making the interview process more efficient and accessible. Triangulation is employed to ensure that the data remains unbiased. This study uses time triangulation, which involves cross-checking through written tests and interviews at different times or situations. If the data obtained shows consistency (many similarities), then the data from computational thinking tests and interviews are considered valid. The test instrument used in this study is the Computational Thinking Test related to number patterns (CTNP) (see Figure 1).

Nazrie is a young artist from West Java who plans to make a single exhibition to show his designs, the earth balls that he then arranged to form a triangle. The ground balls are made of a mixture of clay and recycled garbage. The balls were painted in black and white. In the first order, Nazrie needed five black and one white earth ball to form the triangles. Then, in the second order, he needed seven black and three white balls. Whereas in the third order, he needed nine black and six white. To fill the available space, Nazrie will make 15 balls, as seen in the picture below.



Is there any other method that can be used to determine the number of black circles on the 40th layout other than by continuing drawing? If any, please explain your answer!

Figure 1. Computational thinking test

Table 3 lists the components of Computational Thinking that were applied in this study.

Table 3. Description of components of computational thinking

Component of Computational Thinking	Description	Indicators	Code
Decomposition	The process of decomposing complex problems into more straightforward and easier-to-solve parts.	Students can identify problems when writing information that is known and asked.	T1
Pattern recognition	The process deals with similar or different rules or patterns to make predictions.	Students can recognize or identify similar or different patterns or rules to create relationships in the object configuration.	T2
Abstraction and Generalization	The process of transforming a mathematical problem into a mathematical model or formulating a solution into a general form to solve a problem.	Students can develop an object configuration problem-solving idea by creating a mathematical model or formulating a solution into a general form to solve the problem correctly and conclude it.	T3

Algorithms	The process describes the step-by-step, logical, and systematic steps used to solve problems.	Students can describe step-by-step and systematic steps used to solve problems. Using algorithmic processes to solve problems	T4

The mathematical semiotic components used in this research are adapted from several research results (Fitriyah et al., 2021; Palayukan, 2022; Palayukan et al., 2020; Suryaningrum et al., 2019), are summarized in Table 4.

Table 4. Components and indicators of mathematical semiotics concepts of number patterns

Mathematical Semiotic Components	General Definition	Indicators	Code
Representation	Semiotics refers to identifying a mathematical concept in images, symbols, notations, diagrams, equations, or expressions of mathematics as well as words or written texts.	• Students create pictures or diagrams to visualize rows of number patterns. • Students represent concepts, operations, variables, or ideas using arithmetic symbols. • Students use mathematical symbols to express pattern relationships or sequences of patterns of numbers. • Students create mathematical models on the concept of number patterns. • Students write concepts in different languages	S1.1 S1.2 S1.3 S1.4 S1.5
Mathematical Object	Semiotics refers to associating, forming, or solving problems of number patterns using concepts, symbols, images, graphs, or other mathematical structures.	• Students analyze the relationship of symbols between mathematical patterns in a sequence of numbers or data. • Students predict how the pattern changes from one iteration to the next. • Students solve problems involving number patterns. • Students find a sequence of numbers that follows a particular pattern. • Students associate symbols with previous knowledge.	S2.1 S2.2 S2.3 S2.4 S2.5
Interpretant	Semiotics refers to making meaning, applying, or concluding mathematical concepts related to number patterns.	• The students explain the meaning that associates the representation with the object studied. • Students provide arguments to validate and explain propositions and procedures. • Students explain why the pattern occurs and how the mathematical relationships in the patterns relate. • Students implement number patterns in a broader mathematical context. • Students write or define concepts that have been found	S3.1 S3.2 S3.3 S3.4 S3.5

Interview

This study used a Kolb model learning style questionnaire called the Learning Style Inventory (LSI). The purpose of using the questionnaire is to identify participants who have learning styles such as Assimilator, Converger, and Accommodator, Diverger (Anwar et al., 2023). The type of interview used is a semi-structured interview (Magaldi & Berler, 2020) with four participants. This question aims to understand the student's mathematical semiotics in computational thinking about number patterns. Researchers conducted semi-structured interviews in this study after performing a written test on four study participants. The interviews of these four participants were conducted in turns at different locations. As a result, during an interview, one student cannot hear the other student's questions. The researcher conducted the interview directly. The outcome of the interview and the data encoding of the documentation are shown in Table 5.

Table 5. Encoding interview data and documentation

Data Source	Coding	Description
Documents	Subject X in Sa.b	S: Semiotics' mathematics stage T: Computational Thinking Stage X: X: Subject of study, X = A, B, C, D a: The a-th stage of Semiotics' mathematics stage. A= 1,2,3,.. b: The b-th indicator of each stage of Semiotics' mathematics. B=1,2,3,…
	Subject X in Tc	c: The c-th computational thinking stage
Interview	P	P: Researcher
	X	X: Subject of study, X = A, B, C, D

The data collected in this study was analyzed descriptively. Data analysis was carried out after data collection, involving data from learning style questionnaires, computational thinking tests of number patterns for mathematical semiotic analysis, and interviews of student answers. The data analysis was done gradually according to the procedure suggested by Moleong (2020), which involves data reduction, data presentation, and conclusion. First, the data from the written test was analyzed by correcting the answers based on the key of the answer, classifying the result of a written test based on indicators of computational thinking listed in Table 3, and then describing and analyzing the data of the written test through triangulation of the data, with conclusions drawn based on Table 4. Secondly, the data from the interview was analyzed by replaying the interview recordings, making the transcripts, and reducing the transcript result by giving the codes as listed in Table 5. Re-checking was done afterward to ensure the consistency of the encoding results of the transcripts, then the interview data and documentation were described and analyzed through the triangulation of the data, and conclusions were drawn based on Table 4.

Data analysis techniques used in this study consist of three stages: data reduction, data presentation, and conclusion withdrawal (Miles et al., 2014). Data reduction measures include transcribing the verbal data collected from the results of the interview, reading the entire data from the students' answers in solving the problem of number patterns and interviews, and reducing the data by selecting and focusing on the essential data on the board gives a clear picture of the observation results. After that, compiling the data of the synthesis result at the reduction stage continues to identify the computational thinking and mathematical semiotics in the depth of each research subject.

Ethics Statement

This research has obtained approval from the research subjects, teachers, and students who signed the informed consent form (ICF). The implementation of this research has also received approval from the school principal, where the research subjects are located, through an official letter from the academic vice-rector of the researcher's campus. Therefore, the research team did not request a previous ethical assessment by the appropriate councils of the research project. Thus, this statement exempts the Journal on Mathematics Education from any consequences arising.

RESULTS AND DISCUSSION

Some similarities and differences can be identified in comparing the performance of four students with different Kolb model learning styles: converger, diverger, assimilator, and accommodator. Students with a converger learning style tend to be focused on conceptual thinking and problem-solving and prefer experimental learning activities. In contrast, students with a diverger style, focusing on associating mathematical concepts with examples or practical applications in everyday life, holistic understanding, and creativity, tend to excel in situations that require creative thinking and involve diverse perspectives. In the context of mathematical problems, students with an assimilator learning style can effectively integrate the information and the theory given, create summaries of key concepts, and logically present them. On the other hand, students of an accommodator study style prefer to try various approaches or explore concepts directly to understand them, see patterns or relationships emerging from concrete situations, and apply them to abstract concepts in mathematics.

Mathematical semiotic analysis in the context of computational thinking in high school students with the learning style of assimilator, diverger, accommodator, and converger in answering about number patterns can be described as follows.

Participant A: An Assimilator Learning Style

In the context of mathematical problems, individuals with an assimilator learning style can integrate the information and theory provided efficiently, compile summaries of key concepts, and present them systematically and logically. Students with an assimilator learning style deal with concepts and problems using logical and analytical thinking (Jalinus et al., 2020). This ability enhances their understanding of the learning material's theoretical principles and foundations. Students who have an assimilator learning style avoid insignificant details and concentrate on the core of what needs to be understood. They can convey ideas in ways that are easily understood by others (Rokhima et al., 2019). This includes the capacity to argue or explain concepts systematically and understandably.

The semiotic analysis of mathematics in the context of computational thinking on the concept of number patterns is seen from a learning style perspective involving three stages: representation, mathematical objects, and interpretant.

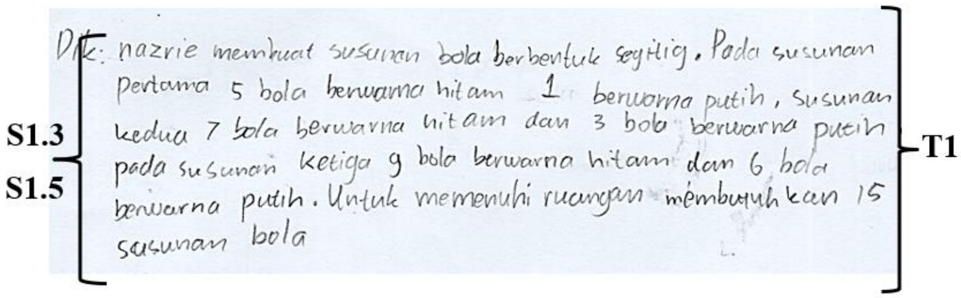


Figure 2. Participant A's response to the decomposition stage

Translation:

Nazrie made a triangular arrangement of balls. In the first arrangement, he needed five black ground balls and one white ball. In the second arrangement, he needed seven black and three white balls; in the third, he needed nine black and six white balls. To fill the available space, Nazrie would make 15 arrangements.

Figure 2 shows that participant A, in solving a problem, rewrites the information available in the subject. Participant A starts by reading and understanding the topic, identifying the information already known (**T1**). Next, the participant describes the information in the issue, demonstrating the ability to analyze the problem carefully and identify the various aspects and components. To verify the student's answers, the researchers conducted the following interviews.

*P: Tell me, what information did you get from reading about this? (**T1**)*
A: Uh... uh... what I know about finding patterns. It's a different pattern, and we use the formula we found ourselves to find that pattern.
P: Related to any concepts about it?
*A: Related to... hm... hm... it's my counting pattern of numbers (**T1**).*

Participant A can read carefully and explain every aspect of the matter well (see Figure 3). Participant rewrites the problem on the subject in another language **(S1.5).** The ability of students to communicate ideas well in various languages demonstrates a strong understanding of the material they are studying and flexibility in delivering information. Participant A used symbols, signs, and mathematical language to represent and think about mathematics concepts **(S1.4).** Semiotic analysis can help students demonstrate their understanding of matter when they rewrite mathematic questions. Participant A can read and understand written and visual information well. This aligns with Gooden et al. (2009), stating that assimilating students learn through observation (watching).

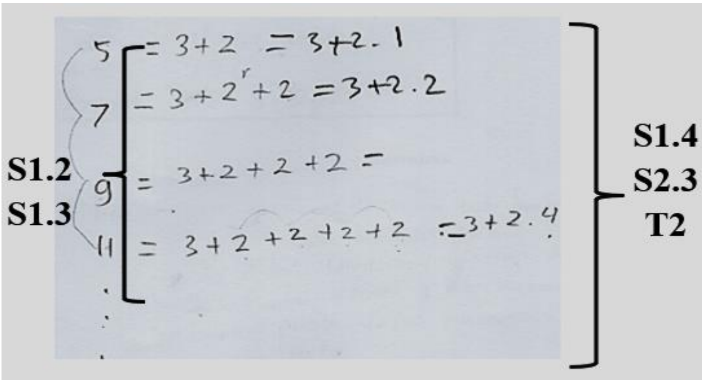


Figure 3. Participant A's response to the pattern recognition stage

Participant A can already read the sequence of numbers in the problem and understand it well. At the stage of the interview between the researcher and Participant A:

P: Why did you write that symbol to make the same pattern structure form a concept?
A: Yeah, ma'am. I wrote that symbol to make the same pattern structure.

At the stage of abstraction and generalization of the concept of a number pattern, Participant A used arithmetic symbols to describe a pattern (S1.3) (see Figure 4). When PA-1 subjects tried to find patterns or rules that connected the numbers 5, 7, 9, and 11, participant A could use an arithmetic symbol to illustrate this pattern (S2.1).

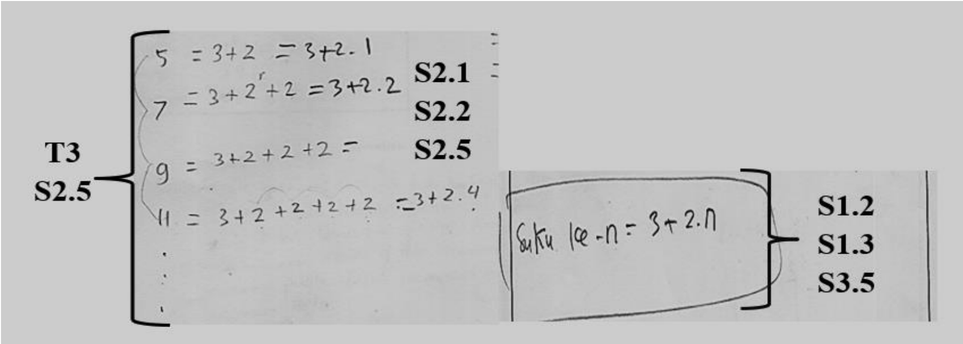


Figure 4. Participant A's response to the abstraction and generalization stages

Translation:
Pattern number n-th = 3 + 2n

Participant A has a strong understanding of number pattern recognition, which allows the participant to answer related questions quickly and with a high degree of accuracy. Participant A can represent concepts, operations, variables, or ideas in the form of arithmetic symbols, such as {2 x n + 3 and n x 5 + (n:2)} (S1.2). (S1.3). Using these symbols, students can identify, represent, and present number patterns efficiently, for example, in the context of number pattern sequences.

Participant A also created a mathematical model **(S1.4)** that describes the concepts of numerical patterns systematically and structured (Wicaksono et al., 2021). This shows that the participant recognized the numeric pattern and could describe it as a proper mathematical model. When faced with problems involving number patterns **(S2.3),** Participant A demonstrated a sufficiently profound ability to understand and deal with mathematical concepts related to the number sequence.

When Participant A observed mathematical patterns such as "3 + (2.1), 3 + (2.2), 3 + (2,3) ... etc.," the subject considered the relationship between each element. In this example, participant A could explain that the number 2 is multiplied by a consecutive integer number (in this case, "n" is the number of steps in a row), then added by 3. This relationship can be represented in mathematical notation as an = 3 + (2n), where "an" is a tribe of the row's n-thirds, "N" is a number of the steps in the rows, and "3" is the first quarter of the line. Participant A predicted how the pattern changes from one iteration to the next **(S2.2).**

The next step was to confirm the concept **(S3.5)** after finding and formulating a formula or picture in the context of a numeric pattern. This involves an in-depth understanding of the idea, including an understanding of how the idea works and its relationship with the numerical patterns. Through the interview, participant A could explain and interpret the idea accurately. The confirmation answer from Participant A through the discussion is as follows:

P: After you have outlined the pattern structure, what steps do you take to make the same pattern structures form concepts?
A: Maybe, ma'am.
P: Why did you write that symbol to make the same pattern structure form a concept?
A: Yes, ma'am. I wrote that symbol to make the pattern structure the same.

Figure 5 shows that the phase begins with an in-depth understanding of the problems to be solved, including the necessary preliminary information and results that match the purpose. Participant A shows the algorithm process in sequence, step by step, to obtain a solution. The phase of an algorithm in

Participants A occurred at the same time as the pattern recognition stage, even the phases of an algorithm occurring from the decomposition of the problem to the end.

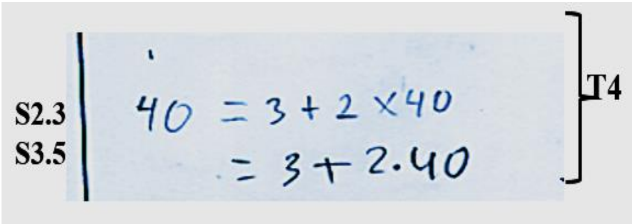


Figure 5. Participant A's response to the algorithm stage

The phase of the algorithm in Participant A co-occurred with the pattern recognition stage, even the phases of the algorithm occurring from the decomposition of the problem to the end. In the understanding of a number pattern, the stage of the use of a general rule involves the application of a mathematical formula or rule (**S3.5**) that is found or identified in systematic steps to solve a problem (**S2.3**) or find a value in a row or pattern of numbers.

P: From the properties or attributes of the object configuration, can you find a specific pattern?
A: There is a specific pattern written.
P: Are you sure the steps in solving the problem align with the resolution plan?
A: To settle the matter according to the plan, according to what was planned and Written.

At this stage, algorithm formulation is one of the most essential stages in computational thinking and problem-solving in general. It is the process of designing a systematic and structured set of steps that will help find the desired solution to a particular problem. It is in line with the results of research conducted by Apiati and Hermanto (2020) and Asmana (2021) that the individual assimilator in problem-solving is very careful and thorough and requires a long time.

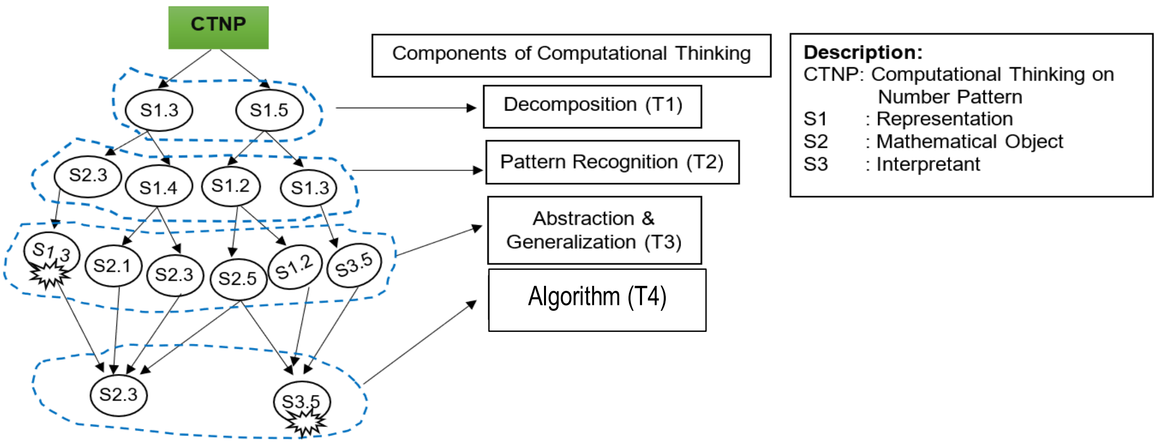


Figure 6. Mathematical semiotic analysis scheme for Participant A

Participant A has an assimilator learning style with the characteristics of the semiotics of computational thinking, performing recalculations, linking the information known in the problem with the subject, understanding the subject through observation, and explaining the steps clearly and logically. These findings are in line with the findings of Ghufron and Risnawita (2012), Kolb and Kolb (2005), and Winarti et al. (2017). The mathematical semiotic analysis scheme for Participant A in computational thinking patterns of numbers is presented in Figure 6.

Participant B: A Converger Learning Style

Mathematical semiotic analysis of the computational thinking concept of number patterns is reviewed from the learning style through the stages of representation, mathematical object, and interpretation by Participant B (Converger). At the decomposition stage, students can identify problems when writing known and asked information **(T1).** Participant B has shown patterns of numbers, arithmetic operations, variables, or ideas in arithmetic symbols **(S1.2)**, as shown in Figure 7.

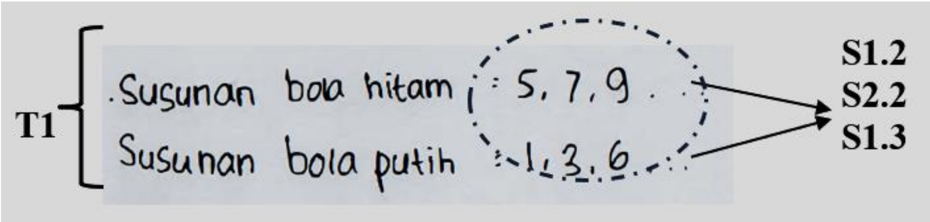


Figure 7. Participant B's response at the decomposition stage

Translation:
black ball arrangement = 5, 7, 9, …
white ball arrangement = 1, 3, 6, …

On Participant B's answer sheet above, a pattern of numbers can be seen, starting with five and adding two each step, namely 5, 7, 9, and so on. Participant B could also quickly identify and describe these patterns mathematically by using these symbols: the first quarter (in this case, a = 5) and the difference between the sequential tribes (in that case, d = 2). Participant B predicted the next tribe (**S2.2**) in this row without having to write each number explicitly for the number pattern. Students benefit from understanding and working with number patterns using arithmetic symbols (**S1.3**). Participant B's answer was confirmed through the interview as follows.

P: How do you react to the issue given?
A: It's hard, but yesterday, I could work on that.
P: Tell me, what information did you get from reading about this?
A: Can organize a specific pattern so you get the result.

In the above conversation, participant B identified information known to the subject. In this situation, the information learned is the sequence of numbers given, namely 5, 7, 9, and so on. To show the response, Participant B could write this sequence according to the number pattern contained in it. The ability of Participant B to identify and replicate these number patterns demonstrates an understanding of the information contained in the conversation, and the mathematical ability to recognize the number pattern. It is in line with research conducted by Eko et al. (2016), Ghufron and Risnawita (2012), and Peker (2009) that students with a converger learning style are dominated by conceptual abstract and active experiments, thus presenting problems more logically.

Next, participant B wrote the following pattern at the pattern recognition stage (see Figure 8). In situations like this, participant B has shown mathematical patterns or relationships that can be communicated in various ways. Based on the main research findings, students with convergent tendencies can identify and express strategies to find optimal solutions. This shows that students' abilities are not only limited to understanding concepts but also involve active involvement in cognitive processes to detail and organize the steps needed to achieve the best solution (Anwar et al., 2023; Jalinus et al., 2020).

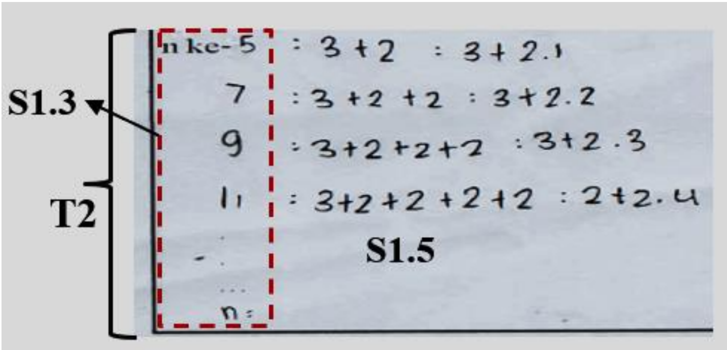


Figure 8. Participant B's stage pattern recognition answer

The participants showed the basic concept of repeatedly adding the number 2 to the initial number 3 (**S1.3**), but they used language in various ways. Although the formulas written in each statement are different, the mathematical core of the statement remains the same. This shows the flexibility in the expression of mathematics, which means that the same concept can be written in different words (**S1.5**) but still have the same mathematical meaning. It shows that there are many ways to show and understand mathematical relationships. It also provides a strong foundation for talking and understanding mathematics. The following interview was conducted to confirm Participant B's answer.

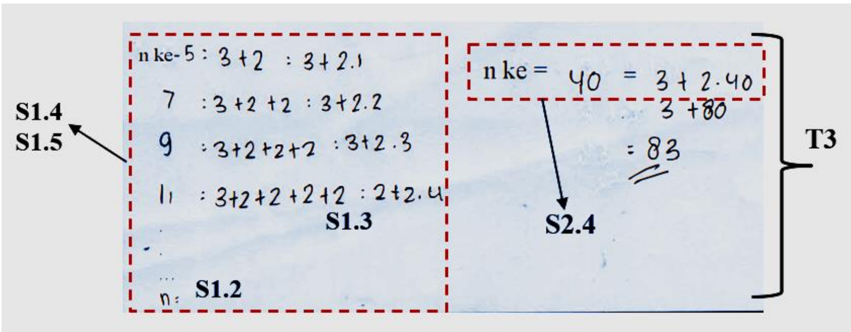


Figure 9. Participant B’s answer for the abstraction and generalization stages

According to Participant B, students represent concepts, operations, variables, or ideas using arithmetic symbols in existing mathematical semiotics at the abstraction and generalization stages (**S1.2**) (see Figure 9). It relates to the student's ability to use mathematical notation and symbols to convey mathematics concepts. For example, in the previous example, the student used a plus mark (+) and an integer, a standard mathematical symbol, to indicate the concept of repetitive addition. (**S1.3**). They made a formula that explains the relationship between these numbers so that readers familiar with mathematical notation can quickly identify and understand them.

A critical aspect of understanding and describing mathematics is the student's ability to use mathematical symbols to indicate pattern relationships or sequences of patterns of numbers. In this case, symbols such as operating signs (+, -, x, ÷), relation signs (such as =, <, >), variables, and numbers are used to show and explain the mathematic relationships underlying pattern or order of pattern of numbers (**S1.5**). They can also describe the relationship between such patterns in a formula or mathematical equation because students with a converger learning style have good mathematical problem-solving and can apply ideas practically (Cavas, 2010; Gooding, 2009).

Participant B could convey mathematical concepts in various languages (**S1.5**), showing a deep understanding of the subject. It shows the student's flexibility and ability to convey mathematical concepts in various ways, which indicates mathematics excellence. However, participant B did not write rules symbolically at the stage," which indicates that the participant did not describe rules or procedures using special symbols or notations in a particular stage or context.

When students can reveal the same concept with various mathematical statements or notations, it shows they have understood the mathematical essence behind the idea, not just memorizing formulas or steps (**S1.4**), presented in Figure 10.

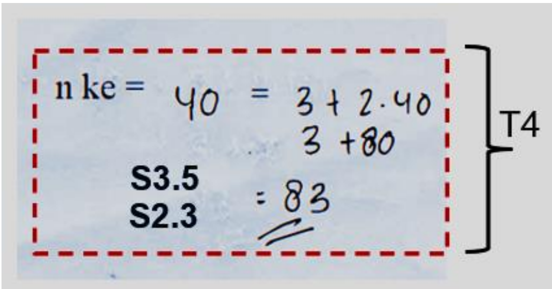


Figure 10. Participant B’s answer in the algorithm stage

Participant B's ability to answer the 40th quarter systematically is a good skill. Participant B seems to understand that the 3+2n rule is a general rule that shows the pattern of the increase of tribes in the arithmetic order in this situation (Handayani & Ratnaningsih, 2019; Winarti et al., 2017). It shows how a strong understanding of mathematical concepts can enable one to answer complex mathematics questions quickly and accurately without having to do long calculations (**S3.4**). However, participant B needs to indicate the general rules of such patterns. Developing a more vital understanding of mathematical concepts and critical thinking skills is finding a formula or general rule of a particular number pattern (**S3.5**).

Based on the description above, students with a converger learning style in computational thinking perform steps of decomposition, pattern introduction, abstraction, and algorithm but still need to perform generalization steps. Students of converger-style learning can see the relationship between different concepts and ideas and find appropriate and practical solutions to problems. In a semiotic context, converger-style students have the following characteristics: Able to understand the relationship between various symbols and mathematical representations. Able to use mathematical symbols and representations to express their ideas clearly and accurately. Able to solve mathematical problems using a systematic and logical approach. The mathematical semiotic analysis scheme for Participant B in computational thinking patterns of numbers is shown in Figure 11.

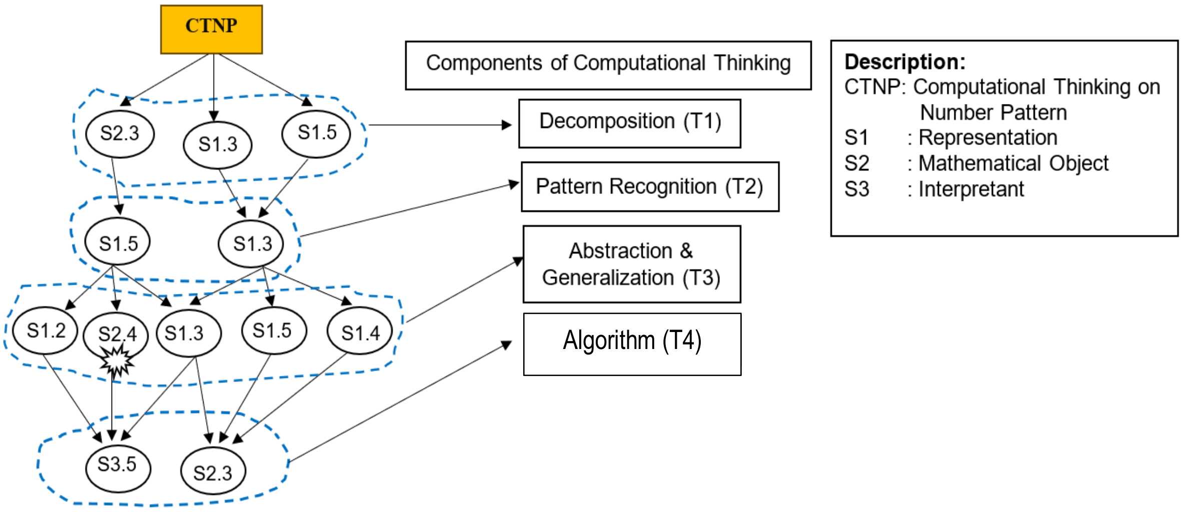


Figure 11. Mathematical semiotic analysis scheme for Participant B

Participant C: An Accommodator Learning Style

The following is a mathematical semiotic analysis of computational thinking concepts of number patterns against Participant C. The decomposition stage, one of the essential phases in understanding concepts, is when students try to break down or disassemble the concepts they learn into smaller parts or simpler sub-concepts. Participant C explains the idea in different words or languages to make it easier to understand, as seen in Figure 12.

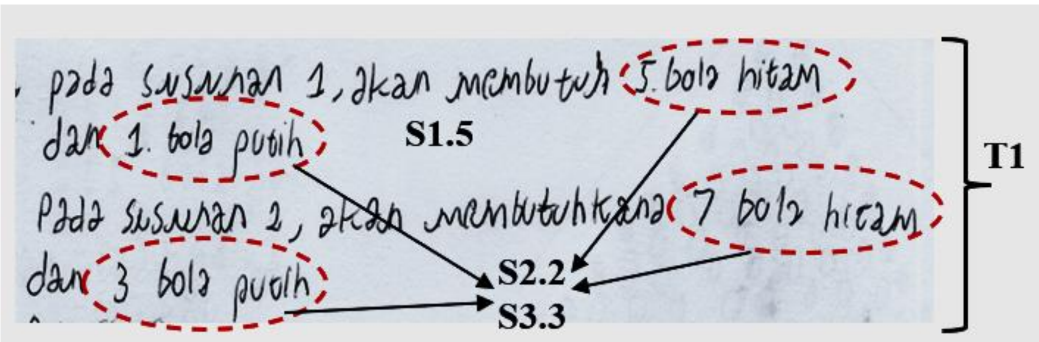


Figure 12. Participant C's answer in the decomposition stage

Translation:

In row 1, It will require five black balls and one white ball.

In row 2, it will require seven black balls and three white balls.

In this case, Participant C tries to communicate the idea of a number pattern in different languages **(S1.5).** Participant C also explained the number patterns that may be present differently. Participant C revealed in the above answer that five black balls and one white ball are required for the first order, and seven black and three white balls are needed for the second order. This is confirmed through the following interview.

P: How do you react to the issue given?

C: My reaction is yes, it's pretty easy to do and doesn't bring too much dizziness or something.

P: Tell me, what information did you get from reading about this?
C: Of course, the information obtained from the matter is the same as the subject. Yes, what's his name known, asked.

Where the number of black and white balls in each order increases in sequence, this concept is similar to the addition pattern (**S3.3**). It shows how Participant C can use different languages and more concrete representations to shape and explain the concept of number patterns. Next is the pattern introduction stage. In the early stages of understanding and identifying patterns in rows or datasets, the student attempted to predict how patterns would change each iteration by looking for the underlying rules or relationships (**S2.2**), as shown in Figure 13.

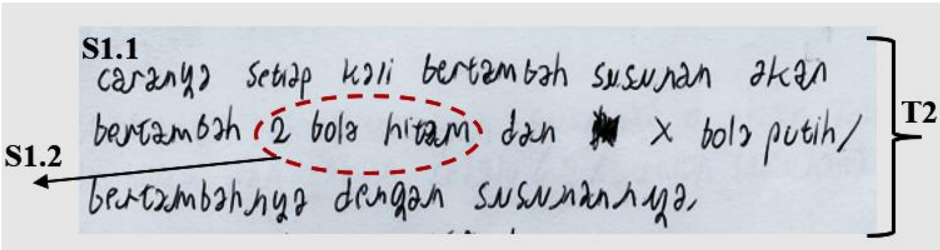


Figure 13. Participant C's answer in the pattern recognition stage

Translation:
Each time you increase the order, you will get two black balls and x white balls/increase with the order.

Participant C sees changes between elements in a row or series, such as certain additions or reductions. Participant C also tried to determine if there was a particular pattern of repetition in the data, which allowed the participant to predict how this pattern would evolve and continue in the next row. **(S1.2**). Pattern introduction is an essential stage in mathematical and logical understanding. It involves the ability to observe, analyze, and predict patterns, which are the basis of many aspects of mathematics, such as problem-solving and decision-making. Participant C could think critically, analyze, and understand patterns in situations or data that can be used in various contexts. It aligns with several research studies that show that students with the accommodation style can determine the right strategy and logic (Fatkhiyyah et al., 2019; Winarti et al., 2017).

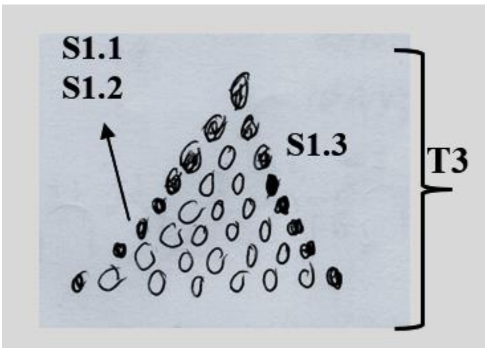


Figure 14. Participant C's answer to the abstraction stage

In this way, participant C used a visual representation in the form of images to give a more precise and more concrete picture of the number pattern. (**S1.1**). It helps strengthen Participant C's understanding of the pattern and enables the participant to communicate with others about it more effectively. Abstraction through pictures or illustrations is a helpful tool in learning mathematics and helps students better recognize patterns and concepts (see Figure 14).

However, Participant C exhibited patterns without identifying or explaining the general rule. Generalization is essential because it enables one to understand the underlying mathematical foundations and apply the patterns in various situations and contexts. Participant C may need to make further efforts to find a general rule or formula that applies to number patterns, enabling the participant to understand the pattern better and use it in various mathematical contexts. It is in agreement with several previous research results that stated that individuals who have an accommodator's learning style do not perform re-examination in terms of solving matters, such as generalizing unwritten number patterns (Kolb & Kolb, 2005; Nezami et al., 2003).

Next is the algorithm stage Participant C with the Accommodator learning style. In problem-solving involving number patterns (**S2.3**), Participant C must not only find a solution to the problem but must also be able to establish the underlying concepts or mathematical principles. (**S3.5**). This means they must understand the formula or rule that applies to the number pattern and then use it for the case they face and present in Figure 15.

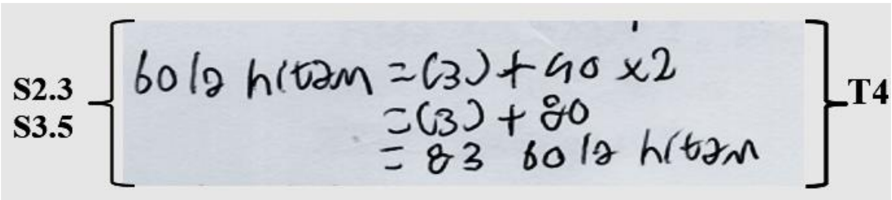


Figure 15. Participant C's answer in the algorithm stage

Translation:
"Bola hitam" means black ball.

Participant C solves a problem involving a number pattern by finding the general rule or formula involved in the pattern and then using the rule to solve the problem. It involves an understanding of the mathematical concepts underlying patterns and the ability to apply them correctly. This process requires an in-depth understanding of mathematics and the ability to apply these ideas (**S3.5**) in concrete problem-solving. This skill is essential for understanding numerical patterns and mathematical problem- solving. This skill is essential for understanding numerical patterns and mathematical problem-solving (**S2.3**), allowing students to apply their knowledge in various situations.

P: From the properties or attributes of the configuration of such objects, can you find a particular pattern?

C: Well, I found a pattern for the black plus three and the white plus one, adding the previous pattern.

The mathematical semiotic analysis scheme for participant C in computational thinking of number patterns is presented in Figure 16.

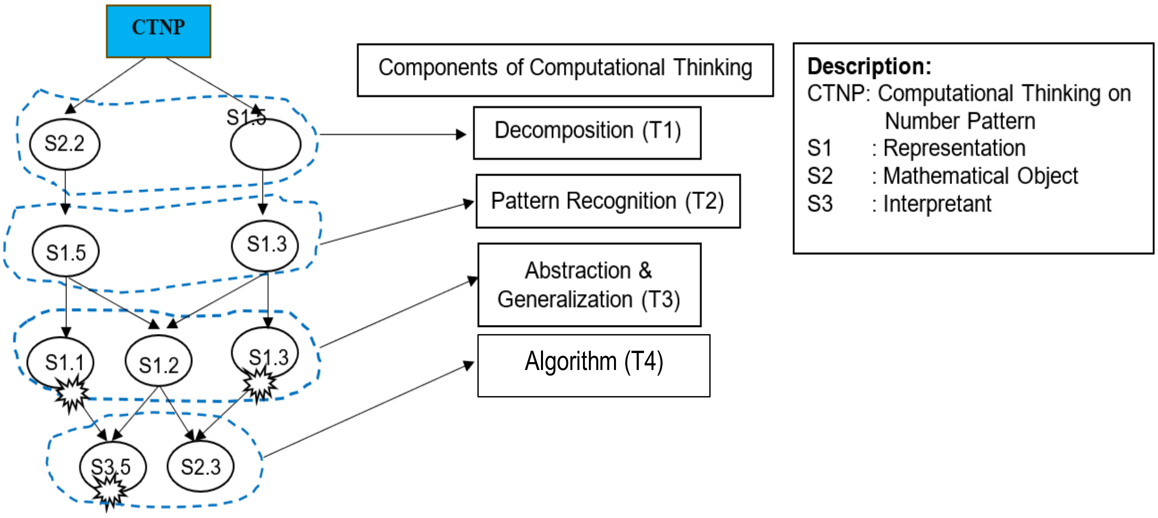


Figure 16. Mathematical semiotic analysis scheme for participant C

Participant D: A Diverger Learning Style

Mathematical semiotic analysis of the concept of number patterns in computational thinking of Participant D, who has a Diverger learning style, was carried out through three stages: representation, mathematical object, and interpretation. The first stage was decomposition. Participant D (Diverger) is an individual who acquires information through concrete experiences and reflective experiences. The study results showed that Participant D created images or diagrams to visualize rows of number patterns, as seen in Figure 17.

Figure 17. Participant C's answer in the decomposition stage

We can confirm this through the following interview.

P: How do you react to the issue given?
D: Hmhmhm, it's tough, but it is actually easy.
P: Please tell me any information you obtained from reading about this.
D: About patterns of numbering and summing

When this learning style is confronted with a string of numbers or a series of number patterns, participant D created a picture that depicts how the numbers change from one step to the next. By using the visualization process, the participant can more clearly see the interaction and movement of numbers from one element to the next (**S2.2**). This method has proven effective in solving mathematical problems, finding relationships between numbers, and identifying possible patterns. Combining visual and analytical elements in the problem-solving process provides an advantage because it actively involves individuals with divergent learning styles in the learning process, which can enhance understanding of specific concepts. The findings align with previous research showing that the ability to express problems in mathematical models or symbols, including visual images, plays an important role (**S1.4**) (Daimaturrohmatin & Rufiana, 2019; Nurmalia et al., 2019). The next stage is pattern recognition, as shown in Figure 18.

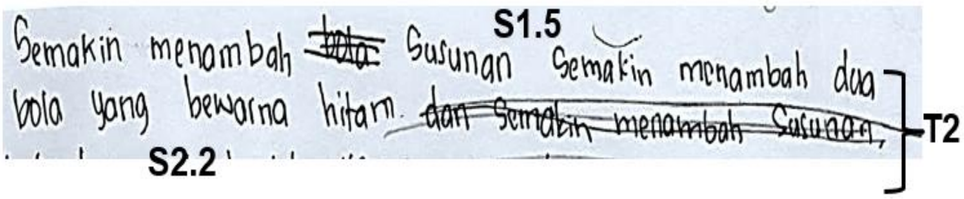


Figure 18. Participant D's answer in the pattern recognition stage

Translation:
The more the arrangement is added, the more the two black balls are added.

Figure 18 shows Participant D's Answers to the Pattern Identification Stage. Participant D was able to predict how pattern elements will evolve, which is a beneficial mathematical ability. Participant D understood the relationship between elements in a row of numbers (**S2.2**) and saw how patterns evolve from step to step by looking at the picture. This ability helps solve various mathematical problems involving analyzing number patterns and predicting the next element in a row. It shows significant progress in understanding mathematical concepts and number patterns. In explaining a number pattern in various languages, participant D performed the process of translating or displaying a pattern with different words or phrases without changing the core meaning of the number patterns themselves; to explain the relationship between numbers in a particular pattern, students must use proper mathematical vocabulary and appropriate sentence structure (**S1.5**). This finding is supported by several research results that found that individuals with a diverger learning style recount what is understood in the subject (Daimaturrohmatin & Rufiana, 2019; Syaputra et al., 2022; Anwar et al., 2023).

P: How many ways did you use to answer this?
C: For a black ball, I used two ways, and for a white ball, I used two ways.

Students can represent mathematical concepts, operations, variables, or ideas in this abstraction phase using arithmetic symbols. Students transform mathematical ideas and concepts into more structured mathematics symbols or expressions (see Figure 19).

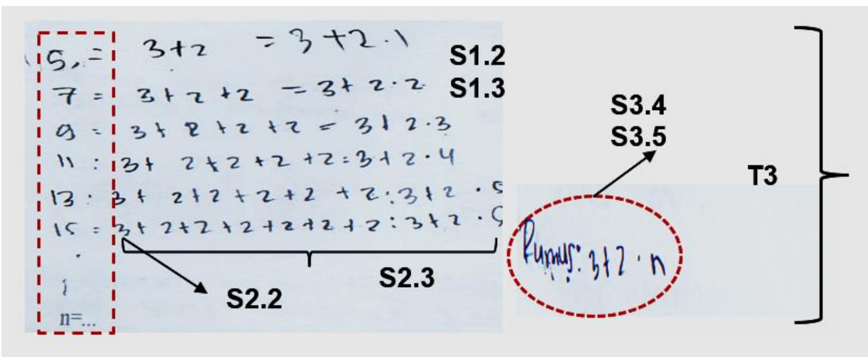


Figure 19. Participant D's answer in the abstraction and generalization stage

This stage of abstraction helps students better internalize mathematical concepts. By representing concepts in arithmetic symbols, students can more easily think about mathematics systematically, identify patterns, and solve mathematical problems (**S1.2 & S1.3**). It also helps them communicate and share their understanding of mathematics with others because these symbols are universal mathematical languages. Overall, the abstraction phase is an essential foundation in the mathematical learning process that allows students to connect the real world with mathematical symbols to apply these concepts in various contexts and build a solid mathematical understanding.

Participant D was also able to use predictive abilities to look ahead and predict how the pattern will develop in the future. Participant D used their understanding of the rules found in the previous analysis to predict numbers or data that may appear in the next iteration (**S2.2**). These skills not only serve to solve mathematical problems but also to develop a deeper understanding of mathematics concepts and enhance the ability to think critically (**S2.3**). By analyzing and predicting the relationship of symbols in mathematical patterns, students can become more skilled problem solvers and apply their mathematical understanding in various situations.

When Participant D implemented number patterns in a broader mathematical context, Participant D saw how the concept of the pattern can be used in a variety of problems and applications of mathematics. In addition, student D could also define the ideas that were discovered. This means the participant could draw up rules or formulas that describe the models of numbers studied and apply them in different mathematic situations. By establishing these concepts, participants D can broaden their understanding of math and use them in real-world problem-solving.

In this way, participant D acquired more profound skills in mathematical thinking and connecting mathematics concepts in a broader context. It also helped the participants apply math in everyday life and other disciplines, thus enabling them to become more skilled and competent learners in various fields of Mathematics. Next, participant D works the 40th tribe using the previously found rule of Un=3+2n, as shown in Figure 20.

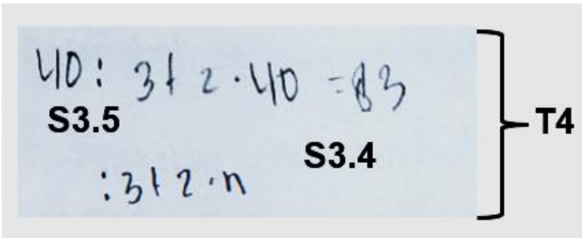


Figure 20. Participant D's answer in the algorithm stage

Participant D applied the formula Un = 3 + 2n to count the 40th quarter by replacing "n" with 40. This calculation gave the final value for the 40h quarter in the row. This action shows how students with divergent learning styles can use the mathematical formula they have previously learned to execute more complex calculations and apply their mathematical understanding in a concrete context. A step that includes the 40th quarter calculation in a mathematic row with a rule of Un = 3 + 2n is highly relevant to the characteristics of students with diverse learning styles. It is associated with some of the characteristics of students with a divergence of learning styles: Students with a divergent learning style tend to have the ability to understand mathematical concepts abstractly and see the relationship between the elements in a row or pattern of mathematics. Besides, students with a diverging learning style in problem-solving can be swiftly bored if the solution is not found. Students with divergent learning styles can usually take the mathematical concepts they learn and apply them in various mathematics contexts (Jalinus et al., 2020;

Kolb, 2014). In this case, they apply the formula Un = 3 + 2n in a concrete situation to count the 40th tribe. With divergent learning styles, Participant D tends to have less logical ability, which makes them unable to express themselves adequately (Anwar & Susanto, 2020). The mathematical semiotic analysis scheme for Participant D in computational thinking of number patterns is shown in Figure 21.

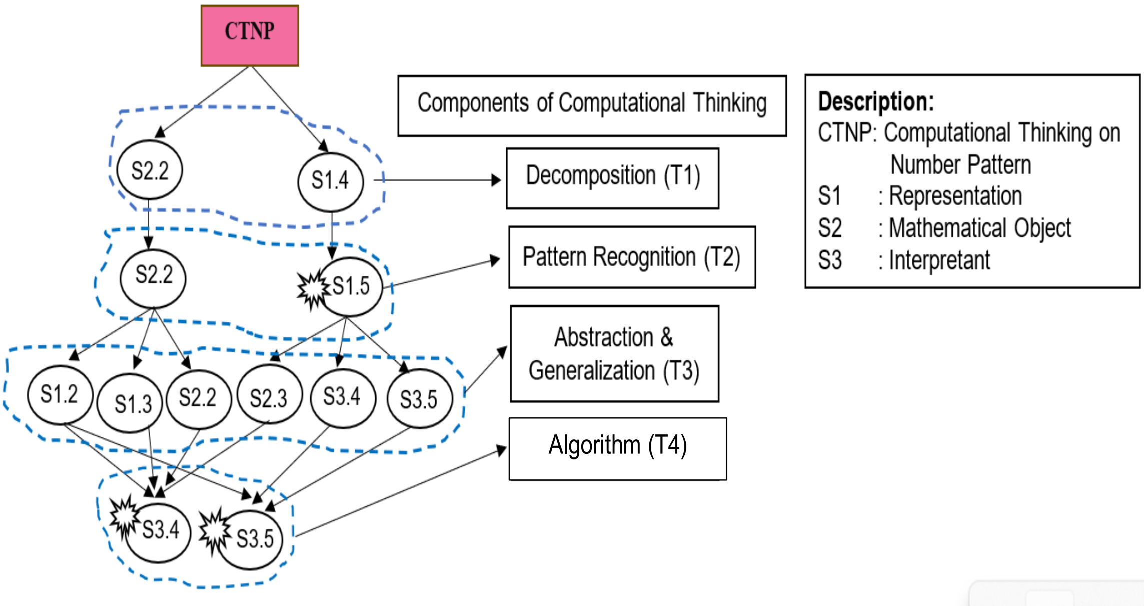


Figure 21. Mathematical semiotic analysis scheme for participant D

CONCLUSION

The study aims to explore the various responses of students with the learning styles of assimilator, converger, accommodator, and diverger when faced with computational thinking patterns of numbers. The findings of this study reveal that the characteristics of the Kolb model's learning style play an important role in solving the problem of number patterns. The mathematical semiotic analysis of computational thinking on number patterns significantly correlates with the Kolb Learning Style Model. These findings provide important insights into how Kolb's learning style characteristics affect students' ability to face problem-solving challenges in the context of number patterns.

This research highlights the close relationship between Kolb's learning styles and students' computational thinking and provides a strong foundation for developing more effective mathematical teaching materials. By understanding how students with a particular learning style can be more successful in solving number patterns problems, educators can adapt their teaching strategies to create a more personal and relevant learning experience.

Some limitations need to be considered in interpreting the results of this integrative literary review research, such as the need for external translators and the limited demographic of students involved in this research subject, only four people from one educated school. This restriction may involuntarily introduce the bias of the subject into the findings. The research team has thoroughly confirmed this interpretation by carefully examining possible alternatives and possible contradictory evidence. Future research efforts involve the participation of diverse participants, covering a variety of demographic backgrounds. The study may examine the impact of specially designed teaching interventions on the development of computational thinking among students categorized as accommodators and convergers.

The findings underline the importance of understanding and paying attention to student learning styles, using the Kolb Learning Style Model, in the context of developing computational thinking skills in mathematics. Thus, this research provides a solid foundation for developing mathematical education that is more responsive to students' individual learning needs. In addition, this knowledge serves as a concrete basis for guiding curriculum development, evaluation methods, and future learning approaches in mathematical education, especially in the algebraic sphere. This research has contributed to improving education practices and policies more broadly.

The recommendation from the results of this research is that teachers design activities that involve concrete experience, reflection, observation, and experimentation so that all students can develop computational thinking. In addition, teachers provide learning materials in various formats according to Kolb's learning style preferences. Learning allows students to understand concepts through visual media, group discussions, simulations, and practical projects to present computational thinking concepts in various ways. Furthermore, they provide additional training to teachers to increase their understanding of the Kolb model and how to integrate it into learning to improve computational thinking.

Acknowledgments

We thank Edi Irawan for his help finalizing, discussing, and checking this similarity paper. We also thank the leadership and the entire range of Universitas Pendidikan Indonesia and IKIP Siliwangi postgraduate mathematics education programs for providing guidance and support. Finally, we would like to express our gratitude to Izur, the ninth-grade teacher, and all the academic civitas in the 15th grade in Bandung who have supported and granted permission for this research.

Declarations

Author Contribution	:	RP	: Conceptualization, Writing - Original Draft, Editing and Visualization.
		T	: Validation, Supervision & Editing, Formal analysis, review and Methodology.
		JAD	: Validation and Supervision
Funding Statement	:	This research was not funded.	
Conflict of Interest	:	The authors declare no conflict of interest.	

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