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Mathematical Creative Thinking Process of Prospective Teachers with Visual, Auditory and Kinesthetic Learning Styles Based On Wallas' Stages

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Abstract. This descriptive qualitative research aims to describe the mathematical creative thinking process of prospective teachers with visual, auditory, and kinesthetic learning styles based on Wallas' stages. Wallas' stages include preparation, incubation, illumination, and verification. This research was conducted on fourth semester students of STKIP Gotong Royong Masohi who have high abilities. The research subjects consisted of three prospective teachers, each with Visual, Auditory, and Kinesthetic learning styles. Data collection was done with tests and interviews. The data validity test was carried out by triangulating the test results and interviews. The data were analyzed with the stages of data reduction, data presentation, and verification. Each research subject was interviewed regarding the results of work on group material questions. The results showed that prospective teachers with Visual learning styles tend to be faster in the preparation stage because they can visualize abstract concepts more easily. Prospective teachers with Auditory learning styles are more prominent in the incubation stage, where they process information through discussions and listening to explanations. Meanwhile, prospective teachers with Kinesthetic learning styles show high creativity at the illumination stage, where they are better able to find innovative solutions through physical activity or object manipulation. However, all learning styles show similarities in the verification stage where they check and ensure that the solution found is in accordance with the rules and properties of algebraic structure groups. These findings imply that an understanding of learning styles can help in designing more effective and varied teaching methods to develop prospective teachers' mathematical creative thinking skills. This research also emphasizes the importance of different approaches in teaching abstract concepts such as algebraic structure to maximize the potential of each individual.

Key Words: visual; auditory; kinesthetic; mathematical creative thinking process; Wallas stages.

INTRODUCTION

Creative thinking can be stated as a mental activity in generating ideas, concepts, problem solving, or finding certain patterns that are interrelated with each other in finding meaning (1). This activity is not only about producing answers, but also includes the ability to connect various information and create new meanings from what exists. In mathematics, it is called the ability to think mathematically creatively. The ability to think mathematically creatively is one of the needs in mathematics education to solve problems in order to find many new ideas and solutions so that the right solution to the problem can be obtained (2,3)

The creative thinking process is a combination of logical thinking and divergent thinking (4). Logical thinking emphasizes more on students' ability to draw conclusions according to logical rules and can be proven with correct conclusions based on previous knowledge according to what is known (5), while divergent thinking emphasizes students' ability to find various alternative answers to a problem (6). The mathematical creative thinking process is a process used in solving problems by developing a structured mindset with reference to the logical, didactic nature of the knowledge area and adapting connections to mathematical content (7). The student's creative thinking process is a real picture of how student creativity emerges in solving problems (8).

Eventhough much research has been done on the mathematical creative thinking process, there is a significant GAP when we focus on prospective teachers and group material in algebraic structures. Previous studies have more often explored students' mathematical creative thinking abilities ((9–12), without separating the specific context of prospective mathematics teachers who will later teach (13–16). Prospective mathematics teachers have a very important role in shaping students' creative mindsets (17), so a deep understanding of their mathematical creative thinking processes on complex materials such as algebraic structure groups is very significant. Groups are one of the fundamental concepts in abstract algebra that have broad applications in various fields of mathematics and science. However, struggle in understanding groups is often a significant impediment for many prospective mathematics teachers. More in-depth research on how creative thinking processes play a role in comprehending and teaching the concept of groups will be very helpful in developing more effective teaching methods.

In addition, the evaluation system used only measures learning achievement, as if mathematics learning only looks at the results, not the process (18). In growing and developing the mathematical creative thinking process, prospective teachers require to be introduced to complex and varied mathematical problems. By facing these problems, they will learn how to question existing assumptions, identify patterns, and develop new strategies in solving problems. Only with a comprehensive evaluation can we ensure that prospective teachers have superior pedagogical and mathematical competencies to educate the nation's next generation.

Open-ended problems in mathematics learning have great potential to escalate the level of mathematical creativity of prospective teachers. (19) stated that open-ended questions provide challenges to demonstrate the depth of understanding of each material that has been obtained, have a lot of experience in interpreting problems, and allow for generating different ideas when connected with different interpretations. By presenting problems that do not have a single correct answer, but allowing for various approaches and solutions, prospective teachers can develop divergent thinking skills. They acquire to explore various methods, connect different concepts, and formulate strong arguments to support their solutions. This is very significant considering that creativity in mathematics is not only about figuring out the right answer, but also about innovative ways to achieve that answer. Thus, prospective teachers who are accustomed to open-ended problems tend to be more adaptive and innovative educators, able to inspire students to explore mathematics in a deeper and more meaningful way.

Mathematical creativity indicators are very essential to assess the extent of the mathematical creativity abilities of prospective teachers. These indicators consist of fluency, flexibility, originality, and elaboration (20). Other versions related to mathematical creativity indicators are fluency, flexibility, and novelty (19,21). According to (22) indicators of mathematical creativity include fluency, flexibility, novelty, and elaboration. There are also mathematical creativity indicators, namely fluency, novelty, and elaboration (23). Sensitivity indicators are also added so that they become sensitivity, fluency, flexibility, originality (24). Based on the indicators above, in this study, the mathematical creative abilities of prospective teachers are assessed based on the indicators of sensitivity, fluency, flexibility, originality, and detail, abbreviated as 5K.

The guidelines developed by Wallas in measuring the creative thinking process of prospective teachers include four stages, namely the 4 stages of Wallas thinking, namely: 1) preparation; 2) incubation; 3) illumination; 4) verification (25). First, the preparation stage in solving problems by collecting data, looking for approaches and solutions. The second stage of incubation is the beginning of the process of emerging new inspiration and discovery. The third stage of illumination is producing a problem based on new ideas and concepts. The fourth stage of verification is testing and checking the results of problem solving that has been carried out (26).

The creative thinking process in mathematics can be influenced by the individual learning style, including prospective teachers. When prospective mathematics teachers learn according to their learning style, they can more easily engage information, comprehend complex concepts, and apply theories in practice. This is because learning methods that are in line with their learning style maximize the brain's potential in processing information. On the other hand, if prospective mathematics teachers are forced to learn in a way that does not suit their learning style, they may have difficulty understanding the material and tend to feel frustrated. This can obsctruct their development and make the learning process ineffective. Therefore, it is important for prospective mathematics teachers to identify and understand their own learning style in order to optimize the learning process and achieve maximum results (27).

Learning style is a combination of how a person absorbs, organizes, and processes information (28). Each prospective teacher has a unique learning style, which can affect the way they understand mathematical concepts and apply creative thinking in teaching. Visual, auditory, and kinesthetic learning styles are some common types of learning styles. Prospective teachers with a visual learning style are neat and orderly in learning mathematics, careful, able to remember visual associations well in learning mathematics, either through writing on the board,

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graphs, and pictures, prefer reading rather than reading aloud. Characteristics of auditory type mathematics learning; easily distracted by noise, auditory type people learn by listening, therefore they usually need an atmosphere away from noise to learn mathematics well, can repeat what the math teacher explains verbally, and like to discuss. Characteristics of kinesthetic type mathematics learning styles; learning through manipulation and practice or practice questions (29,30). By understanding and applying their own learning styles, prospective teachers can develop a more effective creative thinking approach to teaching mathematics. This not only helps them solve mathematical problems in more innovative ways, but also allows them to create a more dynamic and inclusive learning environment for their students.

Based on the background that has been described, this study aims to describe the mathematical creative thinking process of prospective teachers with visual, auditory, and kinesthetic learning styles based on Wallas stages.

LITERATURE REVIEW

A. Mathematical Creative Thinking Process

The creative thinking process of prospective teachers is a real picture of how mathematical problem solving occurs. The creative thinking process is defined as a process that combines logical thinking and divergent thinking (4). Prospective mathematics teachers who are able to think divergently will be able to help students find various ways to understand mathematical concepts. This can include alternative methods for solving problems, creative ways to teach material, or new ideas to attract students' interest in learning mathematics. The following are aspects that can be measured in the creative thinking aspect presented in Table 1.

Table 1. Aspects of Creative Thinking and their Indicators

Aspects of Creative Thinking	Indicator
Sensitivity	1. Understand the existence of a mathematical problem to be solved. 2. Generate problems in response to a situation.
Fluency	1. Generating many ideas, many answers, many solutions, many questions fluently. 2. Providing many ways or suggestions to do things. 3. Thinking of more than one answer.
Flexibility	1. Producing varied ideas, answers, or questions. 2. Seeing a problem from different perspectives. 3. Looking for different alternatives or directions. 4. Being able to change the approach or solution.
Originality	1. Able to produce new expressions or ways of solving mathematics and for. 2. Thinking of unusual ways of solving mathematical problems. 3. Able to make unusual combinations of its parts.
Detail	1. Able to enrich and develop an idea. 2. Add or detail the details of an object, idea, or situation to make it more interesting.

B. Creative Thinking Process According to Wallas

Wallas in his book The Art of Thought as quoted by (22) stated that the creative thinking process included four stages, namely: preparation, incubation, illumination, and verification. Indicators of the mathematical thinking process based on Wallas' stages are presented in Table 2.

Table 2. Indicators of Mathematical Creative Thinking Process Based on Wallas Stages

Wallas Stages	Characteristics of Mathematical Creative Thinking	Mathematical Creative Thinking Process Indicators

Preparation	Sensitivity	The ability to understand a problem or situation that requires a solution.
	Fluency	The ability to generate many ideas or solutions in a short period of time.
	Flexibility	The ability to generate many different types of ideas or solutions.
	Originality	The ability to find unique or unusual solutions.
	Detail	The ability to develop ideas or solutions in great detail.
Incubation	Sensitivity	The ability to remain aware of a problem even when not actively thinking about it.
	Fluency	The ability to maintain a flow of ideas even when not directly focused on the problem.
	Flexibility	The ability to develop ideas or solutions from multiple perspectives when not directly thinking about the problem.
	Originality	The ability to discover new connections and unexpected solutions during downtime.
	Detail	The ability to elaborate on ideas that emerge during downtime.
Illumination	Sensitivity	The ability to quickly recognize a solution or idea that suddenly appears as the right answer.
	Fluency	The ability to channel ideas that emerge suddenly into concrete solutions.
	Flexibility	The ability to adapt and develop ideas that emerge suddenly.
	Originality	The ability to see innovative and original solutions that emerge unexpectedly.
	Detail	The ability to develop and describe new ideas in clear detail.
Verification	Sensitivity	The ability to evaluate the effectiveness of solutions generated.
	Fluency	The ability to test multiple solutions quickly and effectively.
	Flexibility	The ability to adjust ideas or solutions based on feedback and evaluation results.
	Originality	Ability to identify new elements that can improve the solution.
	Detail	Ability to develop the solution further with accurate and precise details.

C. Learning Styles

The learning styles of prospective teachers in this study (28,31,32) are divided into three parts, namely Visual, Auditory, and Kinesthetic.

Visual learning style is a learning style where someone learns best when they see the pictures they are studying, a small part of them is oriented towards printed text and can learn through reading. Prospective teachers who have a visual learning style tend to have good/more dominant visual intelligence than other intelligences. Visual intelligence includes a collection of interrelated abilities, including visual differentiation, visual recognition, projection, mental imagery, spatial considerations, manipulation of internal or external images, any or all of which can be expressed.

Auditory people learn by using their hearing and tend to be interdependent. They also use a lot of interpersonal intelligence. When studying they prefer a quiet environment. They speak a little slower than visual people and use a lot of words related to hearing. For example: "this story sounds very interesting", "this still doesn't sound clear", "it doesn't sound right. From this explanation, it can be concluded that the auditory learning style is a learning style where someone learns best when they hear what they are learning.

The kinesthetic learning style is a learning style where prospective teachers do physical activities. Two important things that are very much liked by those with a kinesthetic learning style are often moving or moving during learning. Physically, they use their physical more than seeing and listening through the lecture method. They speak through body movements and give a lot of responses when learning is demonstrated. The kinesthetic learning style also likes to write by hand and the most important thing for them is to use their body parts in learning. When learning takes place, they like to move, shake their legs, hands, head, or maybe occasionally play with their hair with their heads.

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METHODOLOGY

The type of research used was descriptive qualitative research. This study described the process of mathematical creative thinking in solving problems for fourth-semester prospective teachers with high mathematical abilities based on Visual, Auditory, and Kinesthetic learning styles.

The determination of the research subjects was reserved based on certain criteria so that this study used a purposive sampling technique (33). The subjects in this study were three prospective fourth-semester prospective teachers of STKIP Gotong Royong Masohi who had received group material, had high abilities considering the 2023/2024 Mid-Semester Exam scores, and in accordance with the predetermined criteria, namely having a Visual, Auditory, Kinesthetic learning style. Determination of this learning style used Bobbi De Porter learning style questionnaire.

In qualitative research, the main instrument was the researchers themselves and used supporting instruments in the form of written test questions that had been validated by experts, interview guide sheets based on Wallas' thinking stages, along with documentation. Research data were in the form of test results, interview results and documentation results. The test results of prospective mathematics teachers were used for interview material. The results of the documentation were used to analyze qualitative data in the form of images, subject expressions and words both verbally and in writing. Research data in the form of test results, interviews and documentation were analyzed based on Wallas' 4 stages of thinking, namely: 1) preparation; 2) incubation; 3) illumination; 4) verification. The data analysis process was carried out by: 1) Data Reduction; 2) Data Display and 3) Verification. Data reduction in this study was the process of selecting basic data, presented in a short form such as graphs, flowcharts and the like, then conclusions were drawn. The data validity test carried out in this study was triangulation. Triangulation was checking data from various sources in various ways and times. The triangulation used is time triangulation. In order to test the credibility of the data, repeating the test and interviews could be done with different times and situations to obtain consistent data.

RESULTS AND DISCUSSION

RESULTS

The results of the mid-semester exam assessment for the Algebra Structure 1 course and the completion of the Visual, Auditory, and Kinesthetic learning style questionnaires conducted on fourth semester students of the education study program at STKIP Gotong Royong Masohi, 3 subjects were obtained who met the criteria for selecting subjects, namely AR has a Visual learning style, DED has an Auditory learning style, and AV has a Kinesthetic learning style.

Table 1. Name of Research Subjects

Initials	Category	Mid-term exam scores	Score			Learning styles
			Visual	Auditory	Kinesthetic	
AR	Tall	89	13	10	7	Visual
DED	Tall	91	8	14	8	Auditory
AV	Tall	84	11	6	13	Kinesthetic

The material in this study is the concept of groups, where prospective teachers are given mathematical creative thinking story problems using indicators of sensitivity, fluency, flexibility, novelty, and detail (Figure 1). The questions have been validated by 2 lecturers of mathematics education at STKIP Gotong Royong Masohi. Where instrument validation includes validation, content, face, and construct.

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1. Title: **Adventures in the World of Algebra**

One day, a group of Mathematics students from STKIP Gotong Royong Masohi received a very challenging assignment from their lecturer. They had to find a way out of an algebraic maze filled with group puzzles and other algebraic structures. In this maze, each crossroads is represented by a group operation that they must complete in order to continue their journey.

a. At one intersection, they find an equation. $(a * b) * c = a * (b * c)$. Students must explain what is meant by the associative property in groups, and why this property is important in algebraic structures.
b. At the next junction, they encounter a simple group equation: $(a * b = b * a)$. Students must identify what type of group has this commutative property and give two examples of suitable groups.
c. They then come to a crossroads that requires an understanding of subgroups. Given a group (G) with an element (e) as the identity, and a subset $H \subseteq G$ that is also a group with the same operation, students must show that $(H)$is a subgroup of (G) by giving different examples of subgroups in the group (G).
d. At one intersection, they must create a new group from two known groups. If the group $\left(G_1\right)$ is a cyclic group of order 3 and the group $\left(G_2\right)$is a cyclic group of order 4, they must show how to form a direct product $\left(G_1 \times G_2\right)$ and give a *Cayley table* for this new group.
e. Having almost reached the end of the maze, they encounter the final puzzle that requires a proof of a theorem. If (G) is a finite group of order n, the students must prove that for every element a in (G), the element has an order that divides n. Provide a complete and detailed proof of this theorem.

Figure 1. Mathematical Creative Thinking Story Questions

The mathematical creative thinking process of prospective teachers who have Visual, Auditory, and Kinesthetic learning styles in solving story problems about finding a way out of an algebraic labyrinth full of group puzzles and other algebraic structures .

A. The mathematical creative thinking process of prospective high-ability Visual teachers

Based on the results of the work that has been done by the AR subject and continued with interviews regarding the results of the work, it has fulfilled all stages of the mathematical creative thinking process consisting of 1) preparation stage, 2) incubation stage, 3) illumination stage, 4) verification stage.

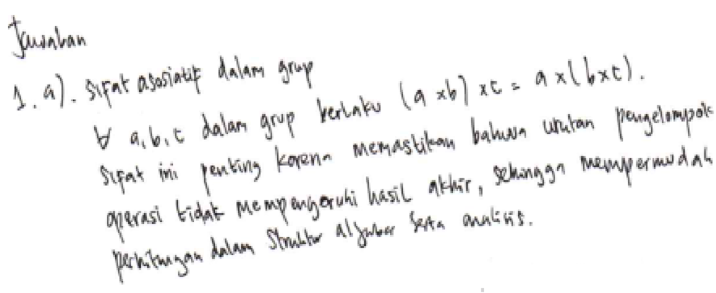

Figure 2 Completion of point a AR subject

In the preparation stage, AR subjects recall the definition of the associative property in groups. The associative property states that in binary operations, the grouping of elements does not affect the final result. In the incubation stage, AR subjects consider the importance of this property in various mathematical operations. After understanding the definition, AR subjects enter the incubation phase, where AR subjects reflect on the importance of the associative property in various mathematical operations. Here, AR subjects may think about how this property functions in addition and multiplication operations, and how it affects the way we solve everyday mathematical problems. In the illumination stage, AR subjects realize that the associative property ensures that the order of operations does not affect the final result. This allows AR subjects to perform calculations more flexibly, without

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having to worry about how they group numbers or elements. In the verification stage, AR subjects explain by giving examples and reasons the importance of this property in maintaining the consistency of operations.

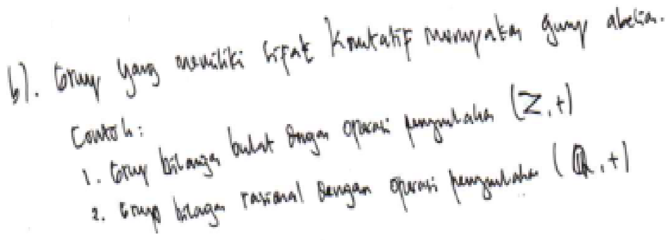
b). Group yang memiliki sifat Komutatif merupakan grup abelian.
Contoh:
1. Group bilangan bulat dengan operasi penjumlahan (Z,+)
2. Group bilangan rasional dengan operasi penjumlahan (Q,+)

Figure 3 Completion of point b of AR subject

In the preparation stage, AR subjects begin by recalling the basic concepts of groups, especially the types of groups that have commutative properties. At this stage, AR subjects begin by recalling the basic concepts of groups in mathematics. AR focuses on the types of groups that have commutative properties, namely groups where the order of operations does not affect the results. In the incubation stage, AR subjects reflect on various examples of groups that have been studied, remembering that groups that have this property are called Abelian groups. At this stage, AR subjects let their minds reflect and wander among various examples of groups that have been studied. AR subjects' minds may seem passive, but they are unconsciously processing the information that has been collected. In the illumination stage, AR subjects realize that Abelian groups have properties $(a * b = b * a)$. This is the moment when a new solution or idea clearly appears in AR's mind. In the verification stage, AR subjects verify by providing two examples of Abelian groups, namely the group of integers with the addition operation $(Z, +)$and the group of rational numbers with the addition operation $(Q, +)$. Finally, in the verification stage, AR subjects ensure that their understanding is correct by testing the idea. AR subjects verify the concept of Abelian groups by providing two examples.

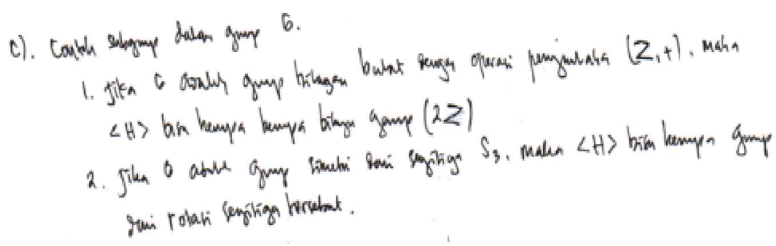
c). Contoh subgrup dalam grup G.
1. Jika G adalah grup bilangan bulat dengan operasi penjumlahan (Z,+), maka
<H> bisa hanya banyak bilangan genap (2Z)
2. Jika G adalah grup simetri dari segitiga S_3, maka <H> bisa hanya grup
dari rotasi segitiga tersebut.

Figure 3 Completion of point b of AR subject

At the preparation stage, the AR subject remembers the definition of subgroups and the conditions that must be met for a subgroup to be created. *A subset* of a group can be called a subgroup. The incubation stage of AR subjects considers various groups and subgroups that they have learned. AR subjects remember the rotation group in the plane, the symmetry group in geometric objects, or the group of integers with the addition operation. The illumination stage of AR subjects realizes that The subset (H) must satisfy the identity, inverse, and closed conditions under group operations. It is the moment when previously learned concepts become clearer and more structured. The AR subject verification stage provides examples such as subgroups of rotation groups in the plane or symmetry groups.

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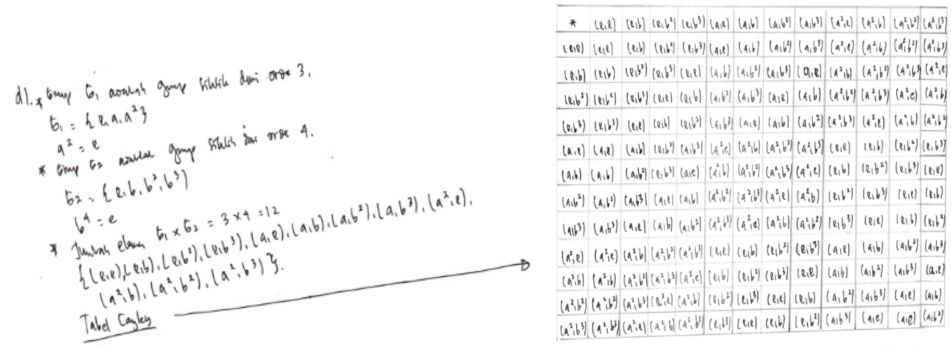

Figure 4 Completion of point d AR subject

In the preparation stage, AR subjects recall the concept of the direct or Cartesian product of two groups. The direct product, in this context, involves two groups $\left(G_1\right)$and $\left(G_2\right)$. AR subjects study how the elements of each group relate and how the group operations work on the direct product. In the incubation stage, AR subjects think about how to combine the elements of G_1 and G_2. This is the phase where the AR subject ponders and explores various possibilities without performing any concrete calculations directly. This thought process allows the AR subject to understand the relationships and operations required to form a direct product. In the illumination stage, the AR subject realizes that the direct product $\left(G_1 \times G_2\right)$ can be formed by ordered pairs of elements of both groups. For example, if (a) is an element of $\left(G_1\right)$ and (b) is an element of $\left(G_2\right)$, then the ordered pair (a, b) is an element of the direct product $\left(G_1 \times G_2\right)$. The AR subject realizes that operations on the direct product are performed component-by-component, that is $(a, b).(c, d) = (a.c, b.d)$, , where $a, c \in G_1$ and $b, d \in G_2$.In the verification stage, the AR subject constructs a Cayley table for $\left(G_1 \times G_2\right)$. This Cayley table is a tool used to visualize and verify group operations on direct products. By constructing a Cayley table, the AR subject ensures that all operations performed are in accordance with the group rules and that the direct product does indeed form a group.

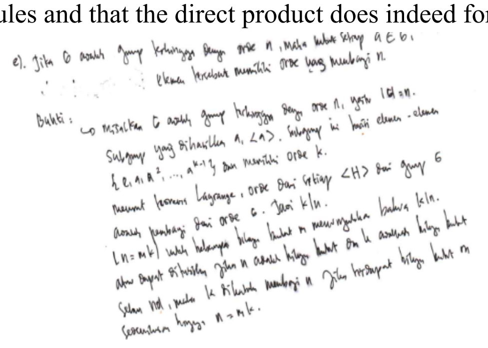

Figure 5 Completion of AR subject point e

In the preparation stage, AR subjects recall some basic concepts in group theory, namely the definition of element order and Lagrange's theorem. In the incubation stage, AR subjects think about the application of Lagrange's theorem to elements (a)in the group (G). This involves deep thinking about the relationship between individual elements and the structure of the group as a whole. In the illumination stage, AR subjects experience enlightenment or deep insight. AR subjects realize that based on Lagrange's theorem, the order of an element (a) must divide the order of the group. (G). That is, if the order of the group $(G)$is (n),then the order of the element (a) (for example (m)) must be a divisor of (n). In the verification stage, AR subjects compile complete and detailed evidence to ensure that the understanding and conclusions reached are correct.

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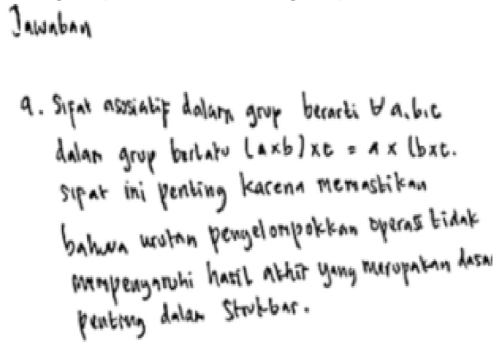
B. The mathematical creative thinking process of high-ability auditory teacher candidates

Based on the results of the work that has been done by the DED subjects and continued with interviews regarding the results of the work, it has fulfilled all stages of the mathematical creative thinking process consisting of 1) preparation stage, 2) incubation stage, 3) illumination stage, 4) verification stage.


Jawaban

a. Sifat asosiatif dalam grup berarti $\forall a,b,c$ dalam grup berlaku $(a \times b) \times c = a \times (b \times c$. sifat ini penting karena memastikan bahwa urutan pengelompokkan operasi tidak mempengaruhi hasil akhir yang merupakan dasar penting dalam Struktur.

Figure 6 Completion of point a DED subject

In the preparation stage, DED subjects remember that one of the basic properties of groups is associativity because they have listened to lecturers' explanations and noted down definitions and examples. In mathematics, the associative property means that the grouping of operations does not affect the final result. In the incubation stage, DED subjects consider how this property applies to various operations they are familiar with, such as addition and multiplication. DED subjects think of simple examples such as adding integers. The DED subject's illumination stage discovered that the associative property means that the order of operations does not affect the final result, as in adding integers: $(2 + 3) + 4 = 2 + (3 + 4)$.This shows that no matter how we group the numbers, the final result remains the same. The verification stage of DED subjects examines several operations in groups they are familiar with to ensure that the associative property does hold and understands its importance in maintaining consistency of operations in algebraic structures.

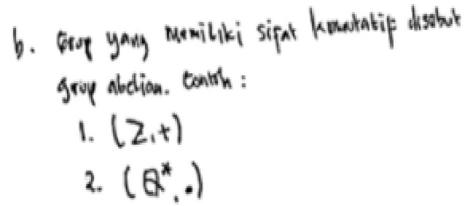

b. Grup yang memiliki sifat komutatif disebut grup abelian. contoh :
1. $(Z,+)$
2. $(Q^{*},.)$

Figure 7 Completion of point b for DED subjects

In the preparation stage of the DED subject, the lecturer explains the basic properties of groups, including the commutative property. The commutative property is a property where $a * b = b * a$ for all $a$and $b$in a group. The incubation stage of the DED subject thinks about commutative properties such as addition and multiplication of a number. Addition and multiplication of numbers have commutative properties for example $a + b = b + a$and The subject DED's $a \times b = b \times a$. illumination stage hears his friend's conversation that "A group that has the property $(a * b = b * a)$is called an abelian group!". The subject DED remembers that the group of integers with the addition operation $(Z, +)$and the group of rational numbers without the multiplication operation $\left(Q^{*},.\right)$ are examples of abelian groups. The subject DED's verification stage re-examines these operations to ensure that the commutative property is satisfied in both examples of given groups. For all $a$and b in Zor Q, $a + b = b + a$so the commutative property is satisfied.

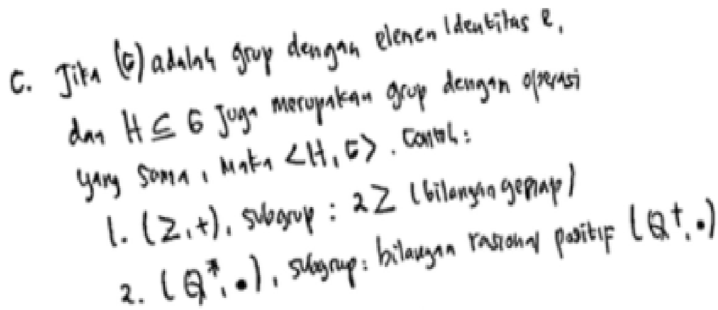


Figure 8 Completion of point c subject DED

In the preparation stage, the DED subjects listened to the lecturer's explanation of the definition of subgroups and the conditions that must be met. The conditions for a subgroup are having an identity element, having an inverse, and fulfilling the closed property. In the incubation stage , the DED subjects thought about examples of different groups and subgroups that they had previously learned. This process helped the subjects relate the concepts they had learned to real examples, preparing them for the next stage. In the illumination stage, the DED subjects began to connect their thoughts that in the group of integers with the addition operation $(Z, +)$, the subgroup consisting of even numbers $(2Z)$is also a group with the same addition operation. This is an important enlightenment, because it shows that even numbers fulfill the subgroup requirements. An explanation was added by the DED subjects that in the group of rational numbers there is no zero $\left(Q^*,.\right)$. In the verification stage, the DED subjects checked whether the subset of even numbers fulfilled all the subgroup requirements: identity, inverse, and closed under the group operation but did not write it on the answer sheet.

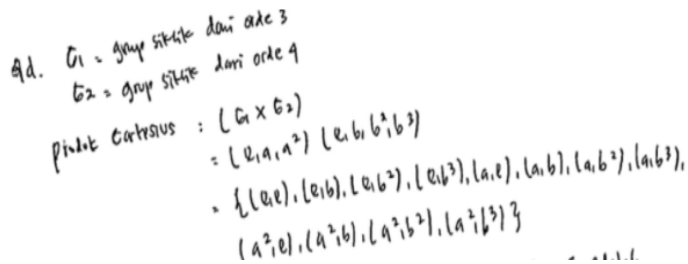


Figure 9 Completion of point d for DED subjects

In the preparation stage, the DED subject recalls the explanation of the direct product of two groups and how the Cayley table is constructed. The Cayley table is a representation of a group operation that shows the results of operations between each pair of elements in the group. In the incubation stage, the DED subject thinks about how to combine the two cyclic groups and construct the Cayley table. The Cayley table for the group will include all combinations of the elements present, and each element in the direct product is a pair of elements from each group. In the illumination stage , the DED subject memorizes by speaking out the direct product or *Cartesian product* . The DED subject concludes that the Cayley table for the group will include all combinations of the elements present, and each element in the direct product is a pair of elements from each group. In the verification stage, the DED subject does not construct the Cayley table for the new group .$\left(G_1 \times G_2\right)$ in checking operations on each pair of elements of cyclic groups of orders 3 and 4. Although the subject of DED did not construct a *Cayley table* for the new group $\left(G_1 \times G_2\right)$, he understood that in order to verify operations on each pair of elements of cyclic groups of orders 3 and 4, it was necessary to construct such a table.

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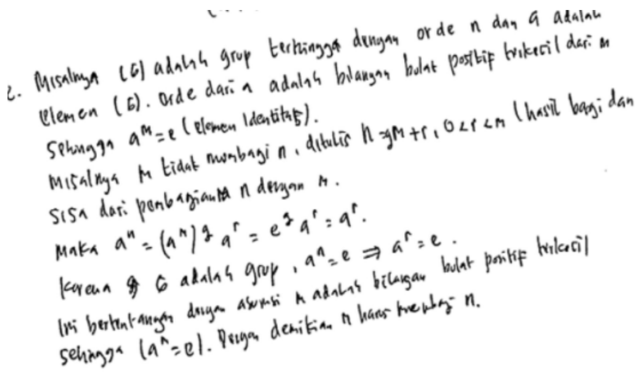
c. Misalnya (G) adalah grup terhingga dengan orde n dan a adalah
elemen (G). Orde dari a adalah bilangan bulat positif terkecil dari m
sehingga $a^m = e$ (elemen identitas).
Misalnya m tidak membagi n, ditulis $n = qm + r$, $0 < r < m$ (hasil bagi dan
sisa dari pembagian n dengan m.
Maka $a^n = (a^m)^q a^r = e^q a^r = a^r$.
Karena G adalah grup, $a^n = e \Rightarrow a^r = e$.
Ini bertentangan dengan asumsi m adalah bilangan bulat positif terkecil
sehingga $(a^m = e)$. Dengan demikian m harus membagi n.

Figure 10 Completion of point e on DED subject

In the preparation stage, the DED subject recalls his friend's explanation of Lagrange's theorem and the concept of the order of elements in a group. Lagrange's theorem states that the order of each subgroup of a group G divides the order of the group G. In addition, the subject also understands that the order of an element in a group is the length of the cycle generated by the element. In the incubation stage, the DED subject ponders the relationship between group elements and group order. The subject thinks about how elements in a group behave and how they form different subgroups. The subject may also consider various examples and special cases to gain a better intuition about this theory. In the illumination stage , the DED subject gets enlightenment that based on Lagrange's Theorem, the order of each subgroup (including the order of the generated element) must divide the order of the group. This means that if we have a group G of order n, and an element a in G that generates a subgroup , then the order of element a (i.e. the length of the cycle generated by a) must divide n. In the verification stage, the DED subject writes a complete proof.

C. The mathematical creative thinking process of high-ability kinesthetic prospective teachers

Based on the results of the work that has been done by the AV subject and continued with an interview on the results of the work, it has fulfilled all stages of the mathematical creative thinking process consisting of 1) preparation stage, 2) incubation stage, 3) illumination stage, 4) verification stage.

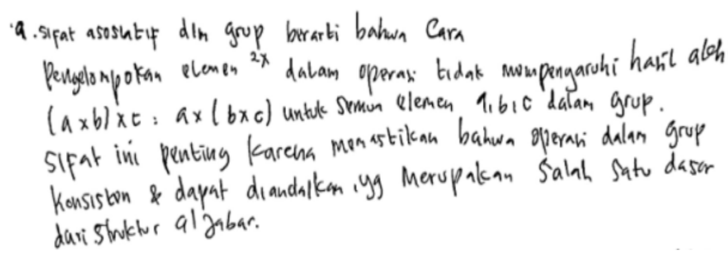
a. Sifat asosiatif dlm grup berarti bahwa cara
pengelompokan elemen 2x dalam operasi tidak mempengaruhi hasil akhir.
$(a \times b) \times c = a \times (b \times c)$ untuk semua elemen a, b, c dalam grup.
Sifat ini penting karena memastikan bahwa operasi dalam grup
konsisten & dapat diandalkan, yg merupakan salah satu dasar
dari struktur aljabar.

Figure 11 Completion of point a subject AV

In the preparation stage, AV subjects, while moving their pens, examine the associative property and its importance in groups. AV subjects remember that in groups, operations must be associative. This property states that in a group, the operations performed must be consistent and independent of how the elements are grouped. In the incubation stage , AV subjects think of familiar commutative groups, such as the group of integers with the operation of addition or the group of real numbers with the operation of addition. In the illumination stage , AV subjects realize that the associative property ensures that the order of grouping does not affect the results of operations within the group, which is important for consistency in calculations. AV subjects realize that this property ensures consistency in calculations, which is very important in various applications of mathematics and other sciences. For example, in computer programming and algorithms, the associative property ensures that repeated operations give

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consistent results regardless of how the elements are grouped. In the verification stage, AV subjects check examples to make sure their understanding is correct, such as using the group of integers with addition.

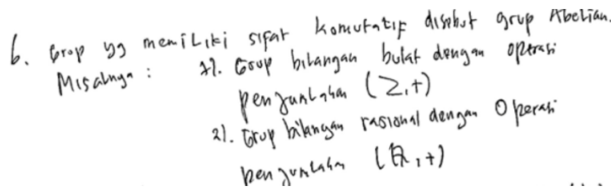


Figure 12 Completion of point b subject AV

In the preparation stage, the AV subject begins by understanding the basic concept of commutative or abelian groups. The AV subject remembers that in an abelian group, binary operations are commutative. In the incubation stage, the AV subject begins to think of examples of Abelian groups while moving his feet. During the incubation stage, the AV subject begins to think of real examples of abelian groups. This thought process may take place subconsciously, while the AV subject is doing other activities such as moving his feet. This is a period where ideas begin to form but are not yet fully realized. In the illumination stage, the AV subject finds that the group of integers with the addition operation $(Z, +)$and the group of rational numbers without zero with the addition operation $(Q. +)$ are examples of Abelian groups. In the verification stage, the AV subject rechecks these examples by performing operations to ensure that the commutative property is met.

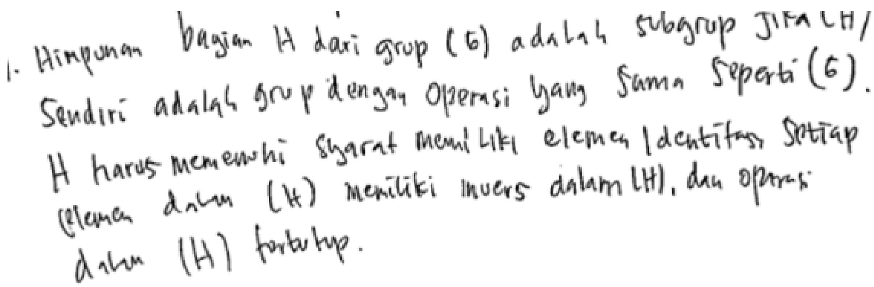
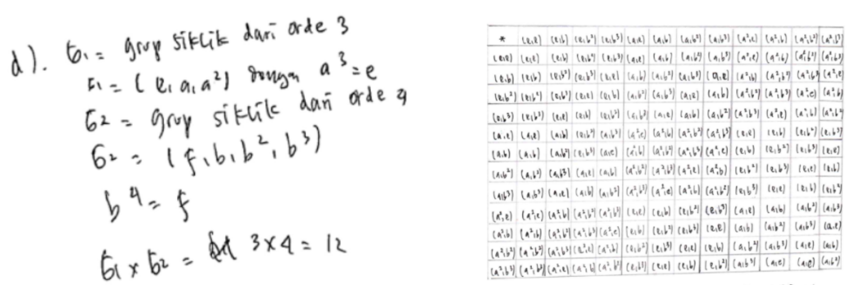


Figure 13 Completion of point c subject AV

In the preparation stage, the AV subject remembers the definition and properties of subgroups. And thinks about how to show that a subset $(H⊆G)$is a subgroup. To (H)be a subgroup, (G), a subset (H) must meet three main properties: meet the closed properties under the group, have an identity element, and be closed under the inverse. In the incubation stage, the AV subject plays with a pen and scribbles on paper in search of a group to form a subgroup. This can involve trying various combinations of elements and group operations to see if the subset meets the properties of a subgroup. In the illumination stage, the AV subject understands that to (H) be a subgroup, (H) it must be closed under the group operation, have an identity element, and each element must have an inverse in(H)**.** The AV subject verification stage AV subject checks to ensure that the subset (H) does indeed meet all subgroup criteria. This is done by performing relevant operations and ensuring that the results are in accordance with the three subgroup properties.



*	(e,e)	(e,b)	(e,b²)	(e,b³)	(a,e)	(a,b)	(a,b²)	(a,b³)	(a²,e)	(a²,b)	(a²,b²)	(a²,b³)
(e,e)	(e,e)	(e,b)	(e,b²)	(e,b³)	(a,e)	(a,b)	(a,b²)	(a,b³)	(a²,e)	(a²,b)	(a²,b²)	(a²,b³)
(e,b)	(e,b)	(e,b²)	(e,b³)	(e,e)	(a,b)	(a,b²)	(a,b³)	(a,e)	(a²,b)	(a²,b²)	(a²,b³)	(a²,e)
(e,b²)	(e,b²)	(e,b³)	(e,e)	(e,b)	(a,b²)	(a,b³)	(a,e)	(a,b)	(a²,b²)	(a²,b³)	(a²,e)	(a²,b)
(e,b³)	(e,b³)	(e,e)	(e,b)	(e,b²)	(a,b³)	(a,e)	(a,b)	(a,b²)	(a²,b³)	(a²,e)	(a²,b)	(a²,b²)
(a,e)	(a,e)	(a,b)	(e,b²)	(a,b³)	(a²,e)	(a²,b)	(a²,b²)	(a²,b³)	(e,e)	(e,b)	(e,b²)	(e,b³)
(a,b)	(a,b)	(a,b²)	(e,b³)	(a,e)	(a²,b)	(a²,b²)	(a²,b³)	(a²,e)	(e,b)	(e,b²)	(e,b³)	(e,e)
(a,b²)	(a,b²)	(a,b³)	(a,e)	(a,b)	(a²,b²)	(a²,b³)	(a²,e)	(a²,b)	(e,b²)	(e,b³)	(e,e)	(e,b)
(a,b³)	(a,b³)	(a,e)	(a,b)	(a,b²)	(a²,b³)	(a²,e)	(a²,b)	(a²,b²)	(e,b³)	(e,e)	(e,b)	(e,b²)
(a²,e)	(a²,e)	(a²,b)	(a²,b²)	(a²,b³)	(e,e)	(e,b)	(e,b²)	(e,b³)	(a,e)	(a,b)	(a,b²)	(a,b³)
(a²,b)	(a²,b)	(a²,b²)	(a²,b³)	(a²,e)	(e,b)	(e,b²)	(e,b³)	(e,e)	(a,b)	(a,b²)	(a,b³)	(a,e)
(a²,b²)	(a²,b²)	(a²,b³)	(a²,e)	(a²,b)	(e,b²)	(e,b³)	(e,e)	(e,b)	(a,b²)	(a,b³)	(a,e)	(a,b)
(a²,b³)	(a²,b³)	(a²,e)	(a²,b)	(a²,b²)	(e,b³)	(e,e)	(e,b)	(e,b²)	(a,b³)	(a,e)	(a,e)	(a,b²)

Figure 14 Completion of point d subject AV

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In the preparation stage, the AV subject remembers the concept of the direct product of two groups. The direct product of two groups $G_1$and $G_2$is a group whose elements are ordered pairs. $\left(g_{1,}g_2\right)$. Incubation stage , the AV subject tries to create a table containing all combinations of elements from $G_1$and G_2. Illumination stage , the AV subject realizes how the elements of the direct product operate by creating a Cayley table of $G_1 \times G_2$. The Cayley table shows the results of operations on each pair of elements in the group. For example, if multiplying $(a, b)$by (a, e)then the result is In $(a.a,\ b.e) = (a, b)$.verification stage , the AV subject ensures that the Cayley table that has been created is correct by checking the properties of the groups in the table.

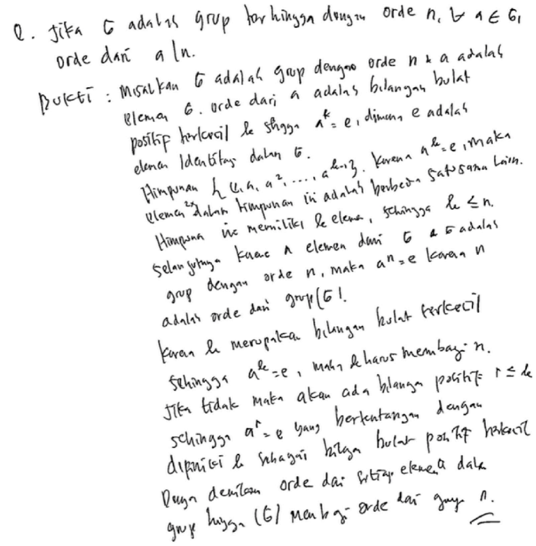
Q. Jika G adalah grup berhingga dengan orde n, ∀ a ∈ G, orde dari a | n.
Bukti : Misalkan G adalah grup dengan orde n & a adalah elemen G. orde dari a adalah bilangan bulat positif terkecil k sehingga $a^k = e$, dimana e adalah elemen identitas dalam G.
Himpunan {e, a, a^2, ..., a^{k-1}}. Karena $a^k = e$, maka elemen² dalam himpunan ini adalah berbeda satu sama lain. Himpunan ini memiliki k elemen, sehingga $k \le n$.
Selanjutnya karena a elemen dari G & G adalah grup dengan orde n, maka $a^n = e$ karena n adalah orde dari grup |G|.
Karena k merupakan bilangan bulat terkecil sehingga $a^k = e$, maka k harus membagi n.
Jika tidak maka akan ada bilangan positif $r \le k$ sehingga $a^r = e$ yang bertentangan dengan dipilihnya k sebagai bilangan bulat positif terkecil.
Dengan demikian orde dari setiap elemen a dalam grup hingga |G| membagi orde dari grup n.

Figure 15 Completion of point e subject AV

In the preparation stage, AV subjects memorize the theorem and the necessary proofs, understand the concept of the order of elements in a group. In the incubation stage, AV subjects try to prove this theorem by writing down the proof steps and pondering them while walking around the room. In the illumination stage, AV subjects realize that using Lagrange's Theorem, which states that the order of each subgroup divides the order of the group, can help prove this theorem. In the verification stage, AV subjects recheck each step in the proof to ensure accuracy and consistency.

DISCUSSION

Research on prospective teachers with a visual learning style is able to fulfill all indicators of the mathematical creative thinking process according to Wallas' stages, especially in solving open-ended problems well (32). Research findings show that the preparation stage carried out by prospective teachers, namely reading questions calmly, understanding problems in depth, and visualizing abstract concepts, has been proven to accelerate their preparation process in dealing with a problem. This is because they can focus better, understand problems better, and find more effective solutions in a shorter time. Research findings show that the incubation stage is a crucial phase in the learning process, especially for subjects with a visual learning style. By letting their minds rest for a moment, they give their brains the opportunity to process and associate information in a deeper way. This not only improves understanding but also strengthens long-term memory of the material that has been learned. The illumination stage is a "eureka" moment where a creative solution or idea suddenly appears. For prospective teachers who have a visual learning style, this moment often comes when they see a pattern or image that helps them understand the problem.

For example, they may suddenly see how elements in a group interact through visual representation, which helps them find a solution to a particular problem. The final stage is verification, where prospective teachers will test and validate the solutions they have found. They will use the mathematical methods they have learned to ensure that the solution is correct. Visual learning styles will help them re-check the steps they have taken through diagrams or graphs they have previously created. By understanding and applying these four stages, prospective teachers can develop effective mathematical creative thinking skills, especially for students with visual learning styles. This process not only improves students' understanding of mathematics, but also prepares them to face more complex challenges in the future (32–34).

The mathematical creative thinking process of prospective teachers with high ability using Wallas stages based on auditory learning styles at the preparation stage will begin to gather information and understand the mathematical problems faced. They listen to explanations from a mentor, group discussions, or listen to audio recordings on the topic. They will explore relevant mathematical concepts while trying to identify existing relationships. And read the questions by moving their lips. The incubation stage of prospective teachers will allow the information they have obtained to process subconsciously. They do not actively think about the problem, but remain engaged in activities that allow their brains to continue processing information, such as listening to music, podcasts, or even discussing with colleagues about other topics. The illumination stage occurs when prospective teachers get enlightenment or "aha moments." For someone with an auditory learning style, this moment can occur when they listen to a re-explanation, listen to a discussion, or even when they hear sounds around them that trigger new ideas. This is the moment where a new solution or way to understand a mathematical problem suddenly becomes clear. At the verification stage The prospective teachers will test and verify the solutions or ideas they have discovered. They will discuss the solutions with peers, listen to feedback, and perhaps record their own explanations to ensure that the solutions are correct and applicable. The auditory learning style allows them to listen back to their explanations and ensure that all the steps are logical and correct. By following these steps and utilizing the auditory learning style, highly capable prospective teachers can develop a deep understanding of the concept of groups in algebraic structures. This process not only strengthens their own understanding but also prepares them to be more effective and inspiring teachers in the future.

The mathematical creative thinking process of high-ability prospective teachers uses the Wallas stages based on the kinesthetic learning style at the preparation stage for prospective teachers to gather information and understand existing problems. For kinesthetic learning styles, this can be done with activities such as using teaching aids, physical mathematical models, or games that involve movement. The incubation stage involves taking a break from active thinking about the problem and letting the subconscious mind work. For kinesthetic learners, this can involve physical activities such as walking, playing light sports, or other physical activities that allow their brains to work in the background while their bodies remain active. The illumination stage is when prospective teachers get creative ideas or solutions. In the context of kinesthetic learning, this can happen when they re-interact with physical objects. For example, they might find a new way to visualize group structures through object manipulation or develop a game that helps explain the concept. Illumination can occur when they realize patterns or connections that were previously invisible. In the verification stage, prospective teachers will test and validate their creative ideas. They can do presentations or demonstrations using physical props to explain group concepts to colleagues or lecturers. Feedback from these activities helps them refine and strengthen their understanding. In addition, they can make notes or diagrams summarizing their findings so they can use them as future references. By implementing an approach that suits the kinesthetic learning style, the mathematical creative thinking process of prospective teachers can be enhanced, allowing them to develop better abilities in teaching and solving mathematical problems.

CONCLUSION

1. Prospective teachers with visual learning styles tend to be faster in the preparation stage. They have the ability to visualize abstract concepts more easily, thus accelerating their initial understanding of the material being taught.

2. Teacher candidates with auditory learning styles excel in the incubation stage. They are more effective in processing information through discussions and listening to explanations. This allows them to develop deep understanding through verbal interaction and listening.
3. Prospective teachers with a kinesthetic learning style demonstrate high creativity at the illumination stage. They are better able to find innovative solutions through physical activity or object manipulation, which helps in developing new and creative ideas.

These findings underscore the importance of understanding and accommodating different learning styles in preservice teacher education. By recognizing the unique strengths that each learning style brings, educational institutions can design more effective and inclusive learning programs. Additionally, preservice teachers who are aware of their own learning styles can utilize appropriate strategies to optimize their learning process and, ultimately, become better educators.

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