Convergent and Divergent Thinking in Mathematical Creative Thinking Processes in terms of Students' Brain Dominance

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Abstract

Convergent and divergent thinking play an essential role in a person's creative thinking process to solve problems, which highlights the significance of this research. Aside from that, these two types of thinking are related to the function of the brain's hemispheres that will affect a person's perspective in processing information. This research aims to get a view of convergent and divergent thinking in the mathematical creative thinking process in terms of brain dominance. The research was conducted using qualitative method with an exploratory descriptive approach. The instruments used are mathematical creative thinking test, brain dominance tests, and unstructured interviews. The research revealed that left-brain dominant students in the creative thinking process are more prominent in convergent thinking; the balance dominant students in the creative thinking process are balanced in divergent and convergent thinking, while right-brain dominant students in the creative thinking process are more adept in divergent thinking.

Keywords: convergent and divergent thinking, mathematical creative thinking process, brain dominance.

Introduction

Guilford (Cropley, 2006) introduced convergent dan divergent thinking concepts in creativity. Divergent thinking is needed in the creative thinking process without eliminating the role of convergent thinking. Divergent thinking can create new ideas, while convergent thinking can choose the necessary concepts and relate these ideas to solve problems. In other words, these two types of thinking complement each other in creative thinking to solve problems. Brophy (1998) explained that creative thinking is about divergent thinking, but it takes convergent thinking to complete it. Hence, convergent and divergent thinking have their own significance in the creative thinking process to solve problems.

Convergent and divergent thinking are needed in preparation, incubation, illumination, and verification stages during the creative thinking process (Cropley, 2006). The preparation stage, incubation stage, illumination stage, and verification stage are the four stages of Wallas (Savic 2016). Indicator's guidelines of the relationship between convergent and divergent thinking with creative thinking process stages, according to Wallas, are combined from two sources namely a thesis written by Sukmaangara (2020) and an article by Cropley (2006). The indicator guidelines are presented in the following table:

Table 1
Indicators of the Creative Thinking Process Stages According to Wallas

No	The Creative Thinking Process Stages	Indicators of the Creative Thinking Process Stage According to Wallas	Activities	Process required
1	Preparation Stage	a. Students prepare themselves to solve problems in various ways such as the following: 1) Students can open books; 2) Ask the teacher or other students; 3) Students learn from the lessons previously taught. b. Students try several ways to solve problems. c. Students are able to understand the problem by writing down what is known and asked;	The activity to understand the problem and activity to identify problem from general knowledge into specific knowledge and produce the knowledge needed to solve problems	Convergent Thinking
2	Incubation Stage	Students seek inspiration by doing various activities such as the following: a. Students take a moment to reflect b. Students read the questions many times. c. Students relate the questions to the material that has been obtained.	the activity of combining two different things to produce something in a new way	Divergent Thinking
3	Illuminatio n Stage	a. Students get ideas. b. Students convey some of their ideas which are used as solutions.	the activity of discovering something new	Divergent Thinking
4	Verification Stage	a. Students run their ideas to get the right answer by: 1) writing the formula; 2) performing arithmetic operations by assigning known data into formulas. b. Students can work on the problem correctly and use many ways. c. Students re-examine the answers and look for other ways to solve the problem	The activity to show about correct solution of the new configuration	Divergent Thinking and Convergent Thinking

Adapted from: (Sukmaangara, 2020; Cropley, 2006)

The convergent and divergent thinking processes are presented in the design of thinking to solve problems. Design thinking is based on convergent and divergent thinking to solve problems both for the definition and solution of a problem (Androutsos & Brinia 2019). According to Lindberg et al. (2010), the basic principles of the flow of design thinking are as follows:

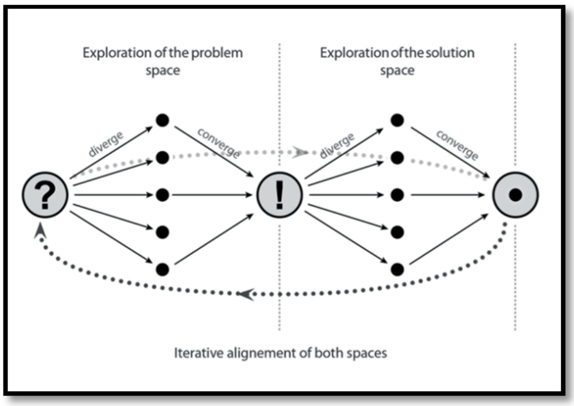


Figure 1. Basic Principles of Design Thinking Flow

The importance of convergent and divergent thinking cannot be separated from the human brain function. The brain consists of two hemispheres, namely the left hemisphere and the right hemisphere. Both of them play different roles. Haryanto (2015) articulated that the source of the left hemisphere function is convergent thinking, and the source of the right hemisphere function is divergent thinking. Geske (1992) stated that brain dominance affects a person's perspective in processing information and directly determines learning styles. The different roles of the brain's hemispheres will affect one's perspective, showing the importance of the hemispheres in convergent and divergent thinking.

Based on the abovementioned description, it is conclusive that convergent and divergent thinking play a vital role in a person's creative thinking process to solve problems. These two types of thinking are related to the function of the cerebral hemispheres, affecting a person's perspective in processing information. Thus, the researchers are interested in examining these two types of thinking in the creative thinking process in terms of brain dominance. This study will investigate how convergent and divergent thinking in the creative thinking process are based on the Wallas stages during problem solving presented in the design of the creative thinking process. The Wallas stage was used because the stages highlight convergent and divergent thinking (Cropley, 2006). Likewise, with design thinking, convergent and divergent thinking could be seen from a way of design thinking (Androutsos & Brinia, 2019).

This research aims to investigate convergent and divergent thinking in the mathematical creative thinking process in terms of brain dominance. The result of the study is expected to help readers, especially teachers, develop convergent and divergent thinking questions adapted to brain dominance so that the students can be more optimal in solving the problems

Methods

This research used a qualitative method with an exploratory, descriptive approach. Researchers deeply explored students' convergent and divergent thinking in the mathematical creative thinking process until they obtained enough data to achieve the research objectives. Then, the collected data were described in written words.

Data were collected using brain dominance tests, mathematical creative thinking questions that met the indicators of fluency and flexibility, and unstructured interviews. The study began by providing 31 students of nine-grade at SMPN 1 Tasikmalaya for the 2019/2020 academic year with a brain dominance test. This study adapted the brain dominance test from Tendero's (2000) dissertation. The results of the brain dominance test were grouped into eighteen students with left-brain dominance, six students with balanced brain dominance, and seven students with right-brain dominance. Furthermore, only one student with left-brain dominance, one with balanced brain dominance, and one with right-brain dominance were selected as research subjects. Subjects were also selected based on their ability to solve problems and ability to provide information orally.

The selected subjects were given two more brain dominance tests at different times so that a total of three brain dominance tests were given. This test was carried out to obtain more valid data to make it more credible (Sugiyono, 2017). The following are the results of the student's brain dominance test:

Table 2

Student Brain Dominance Test Results

Subject	First Test		Second Test		Third Test		Conclusion
	Score	Category	Score	Category	Score	Category	
S1	-5	Left Brain Dominant	-6	Left Brain Dominance	-4	Left Brain Dominance	Left Brain Dominance
S2	0	Balanced Brain Dominance	0	Balanced Brain Dominance	0	Balanced Brain Dominance	Balanced Brain Dominance
S3	3	Right Brain Dominance	4	Right Brain Dominance	4	Right Brain Dominance	Right Brain Dominance

The selected research subjects did the mathematical creative thinking test. This test aims to obtain data about students' convergent and divergent thinking in the mathematical creative thinking process. Unstructured interviews were conducted subsequently after this test to support the data. The given questions for the mathematical creative thinking test is presented as follows:

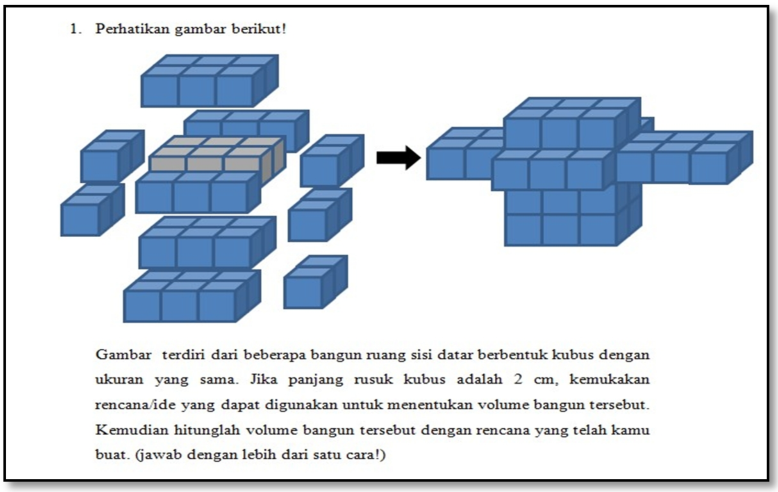


Figure 2. Mathematical Creative Thinking Problem

The data were analyzed using the Miles & Huberman model which consists of data reduction, data presentation, and drawing conclusions (Miles & Huberman, 1994).

Results and Discussion

The convergent and divergent thinking research results in the mathematical creative thinking process will be shown in the design form of students' creative thinking processes. The result of students' thinking process from the mathematical creative thinking test answers in each work step is coded. The design's results of students' thinking processes is presented as follows:

Convergent and Divergent Thinking Processes in the Mathematical Creative Thinking Process of Left-Brain Dominant Students

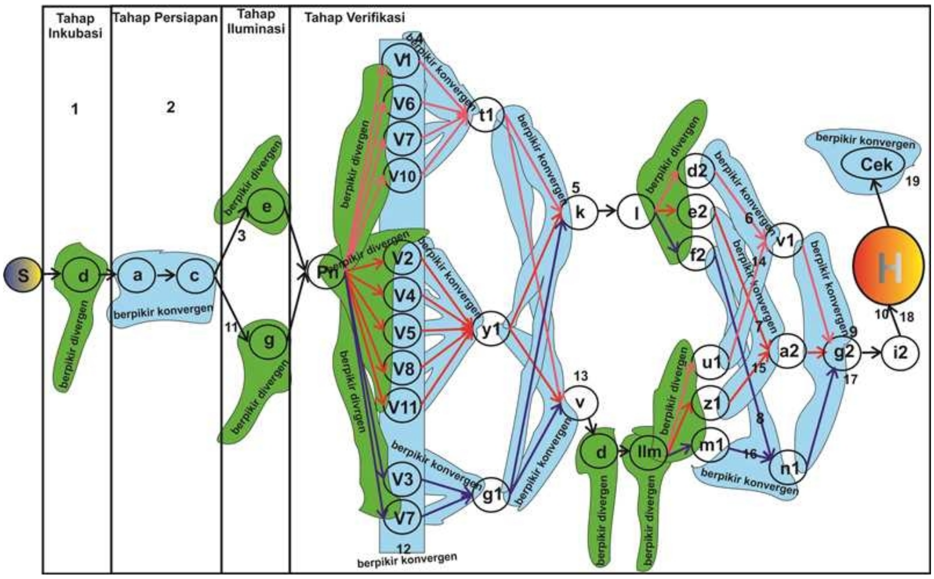
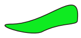
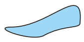


Figure 3 Thinking Process Design of Left-Brain Dominant Students

Information for Figure 3 regarding the thinking process design of left-brain dominance students' is presented in the following table:

Table 3
Description of Mathematical Creative Thinking Process Design of Left-Brain Dominant Students Dominance

Code	Description	Code	Description
S	Question	g1	Solid Figure 3 Cubes
d	Looking for Ideas	L	Volume = 8cm^3
a	rib length 2cm	d2	Volume = 6 x 8cm^3
c	Solid Figure Volume?	v1	Volume = 48cm^3
e	Using the Cube Concept	e2	Volume = 2 x 8cm^3
g	Using the Cuboid Concept	a2	Volume = 16cm^3
Pn	Solid Figure Numbering	f2	Volume = 3 x 8cm^3
V1	Solid Figure Number 1	n1	Volume = 24cm^3
V6	Solid Figure Number 6	g2	Volume = V1 + V2 + V3 + V4 + V5 + V6 + V7 + V8 + V9 + V10 + V11

V7	Solid Figure Number 7	i2	Volume = $48cm^3 + 16cm^3 + 24cm^3 + 16cm^3 + 16cm^3 + 48cm^3 + 24cm^3 + 16cm^3 + 48cm^3 + 48cm^3 + 16cm^3$
V10	Solid Figure Number 10	v	Volume = p x l x t
t1	Solid Figure 6 Cubes	u1	Volume = 6cm x 4cm x 2cm
V2	Solid Figure Number 2	z1	Volume = 4cm x 2cm x 2cm
V4	Solid Figure Number 4	m1	Volume = 6cm x 2cm x 2cm
V5	Solid Figure Number 5	H	The Overall Volume = $320cm^3$
V8	Solid Figure Number 8	Cek	Recheck answer
V11	Solid Figure Number 11	Ilm	Illumination Stage
y1	Solid Figure 2 Cubes	1-19	Student Workflow Number
V3	Solid Figure Number 3		Divergent Thinking Process
V7	Solid Figure Number 7		Convergent Thinking Process
k	Volume = 2cm x 2cm x 2cm		

Based on Figure 3 and Table 3, students started looking for ideas by doing various activities to find inspiration (d code) at the incubation stage. Looking for ideas is an activity to produce something in a new way that requires a divergent thinking process (Cropley, 2006). Students did the preparation stage after the incubation stage. Students read the questions, memorized the lessons, and wrote down what they got from the questions (a and d codes). Activities at the preparation stage aim to identify problems from general knowledge for specific knowledge to produce the required knowledge. These activities require a convergent thinking process (Cropley, 2006). Subsequently, students obtained ideas and conveyed some ideas that would be used, namely using the concept of a cube (e code) and the concept of a cuboid (g code) to solve problems at the illumination stage. Activities at the illumination stage are directed to find something new. These activities require divergent thinking processes (Cropley, 2006). The activities carried out are strengthened by the results of interviews as follows:

P : What did you think for quite a while before working on the questions?
S : I think about materials related to the questions and what the questions need.
P : What did you get?
S : I got the right solution to solve the problem.
P : What solution did you use for the first and second method?
S : I used the cube concept for the first method and the cuboid idea for the second method.

Based on figure 3 and table 3, students gave a number to each solid figure was and divided them into 11 solid figures (V1 – V11 code) at the verification stage. This activity belonged to divergent thinking processes since students used various aspects to find solutions (Linberg et al., 2009). Students solved the problems with the same solid figure for the first and second methods (V1 – V11 code). All of the spatial structures, which consisted of 11 solid figures, were grouped into three parts, namely solid figure with 6 cubes (t1 code), solid figure with 2 cubes (y1 code), and solid figure with 3 cubes (g1 code). The student's activity of grouping into three parts of solid figures is an activity of uniting different aspects. The activity of combining various elements is a convergent thinking process (Linberg et al., 2009).

The first method used the concept of cube volume by calculating the volume of one cube (k - l code). This activity united three different parts of the solid figures using one concept, namely the volume of the cube, which is a convergent thinking process (Linberg et al., 2009). The volume of one cube was multiplied by the number of cubes that made up the solid figure. This caused students to calculate the volume of each solid figure with three parts, namely the volume of solid figures of six cubes (d2 code), the volume of solid figures of two cubes (e2 code), and the volume of solid figure of 3 cubes (f2 code). Finding various aspects to find solutions is a divergent thinking process (Linberg et al., 2009). Likewise, in the second method, students calculated volume by dividing three parts, but students did calculations using the volume of the cuboid (v code). Students calculated in advance the length, width, and height of each solid figure. Next, students calculated using the formula for the volume of the cuboid. This activity resulted in divergent thinking as in the first method shown in Figure 3 (code v – u1, v - a2, v - n1). The results of the three groups of solid figures in both the first and second methods resulted in a volume of $48cm^3$ (v1 code), $16cm^3$ (a2 code), and $24cm^3$ (n1 code). Students calculated the total volume with Vtotal = V1 + V2 + V3 + V4 + V5 + V6 + V7 + V8 + V9 + V10 + V11 (g2-i2 code). The calculation of the total volume obtained the right result; namely, the size of the wake volume of $320cm^3$ (H code). This activity presents the right solution that requires a convergent thinking process (Cropley, 2006). The activities were reinforced by the results of interviews as follows:

P : Can you explain your work?

S : I calculated the volume of the cube first. I multiplied the cube volume by the number of cubes. The calculation resulted in the solid volume of figure number 1, which consisted of six cubes, with $48cm^3$ (students explain the same methods from number 1 to number 11). That was for the first method, while for the second method, I used the concept of the cuboid. The solid figures consisted of 6 cubes, and the length was calculated using 2cm + 2cm + 2cm, which resulted in 6cm. The same method was used to calculate the width and height and yielded 4cm and 2cm, respectively. The product of length, width, and height resulted in the volume of the number 1 solid figure, which was $48cm^3$ (students explained all the same methods from number 1 to number 11)

Students also carried out the incubation stage during the verification stage by looking for ideas (d code) to produce something new and the illumination stage (Ilm code) by finding ideas for something new. These activities require a divergent thinking process (Cropley, 2006). Students also checked the answers (Cek code) which needs a convergent thinking process (Cropley, 2006).

Convergent and Divergent Thinking Processes in the Mathematical Creative Thinking Process of Balanced Brain Dominant Students

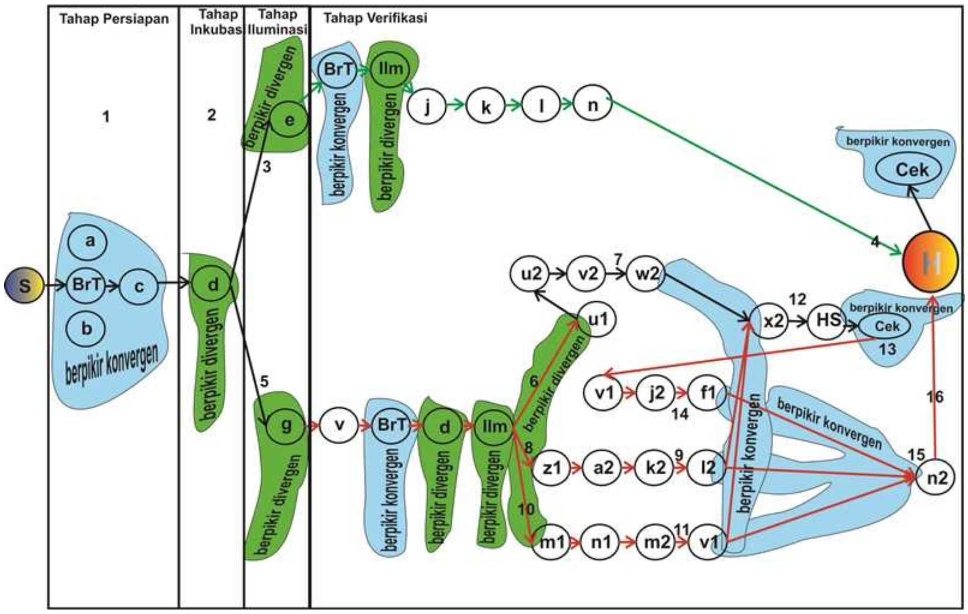


Figure 4. Thinking Process Design of Balanced Brain Dominant Students

Information for Figure 2 regarding the thinking process design of balanced brain dominant students' is presented in the following table:

Table 4

Description of Thinking Process Design of Balanced Brain Dominant Students

Code	Description	Code	Description
b	Many cubes 40	f1	Volume = 192cm^3
j	Volume = s x s x s	k2	Volume = 16cm^3 x 5
n	Volume = 8cm^3 x 40	l2	Volume = 80cm^3
u2	Volume = 40cm^3	m2	Volume = 24cm^3 x 2
v2	Volume = 40cm^3 x 4	n2	V = 192cm^3 + 80cm^3 + 48cm^3
w2	Volume = 160cm^3	H	Volume = 320cm^3
x2	V = 160cm^3 + 80cm^3 + 48cm^3	BrT	Asking
HS	Volume = 288cm^3	1-16	Student Workflow Number
j2	Volume = 48cm^3 x 4		

Based on Figure 4 and Table 4, students did the preparation stage by reading the questions, writing down what they had learned from the questions that have been understood, and then asking questions to better understand the provided questions (a, BrT, b, c codes). Activities at the preparation stage are targeted to identify problems from general knowledge into specific knowledge and produce the required knowledge. These activities require a convergent thinking process (Cropley, 2006). Students looked for ideas (d code) at the incubation stage. Looking for ideas is an activity to produce something in a new way that requires a divergent thinking process (Cropley, 2006). Then, students obtained ideas and conveyed some ideas that will be used, by using the concept of a cube (e code) and the concept of a cuboid (g code) to solve problems at the illumination stage. Activities at the illumination stage are activities to find something new. These activities require divergent thinking processes (Cropley, 2006). The activities carried out were supported by the results of interviews as follows:

P : Why were you silent for a moment, and after that, you asked the question to me?
S : I was looking for a method and also, I convinced myself about the method that I would use. Thus, I asked you, sir! (With a smile)
P : How would you use the first and second methods?
S : I used the concept of the cube for the first method and the idea of the cuboid for the second method.

Based on Figure 4 and Table 4, the first method began with students getting an idea (Ilm code) after asking a question (BrT code). Students multiplied the cube volume of $8cm^3$ by the cube's number to produce a volume of $320cm^3$ (j – H code). The second method started by asking questions (BrT code) to look for ideas (d code), and soon the student got an idea (Ilm code). Students solved problems by calculating the volume of the solid figure of 6 cubes (u1 – f1 code), the volume of solid figure of 2 cubes (z1 – l2 code), and the volume of solid figure of 3 cubes (m1 – v1 code). This activity is directed to find various aspects to find solutions, which is a divergent thinking process (Linberg et al., 2009). In calculating the volume of the solid figure of 6 cubes, the student made a mistake in calculating the multiplication (u2 – x2 code), so that the student re-checked the answer (code checking). After re-checking and knowing the errors, the students started counting again and produced the correct calculations. The total volume of solid figure was calculated by adding the volume calculation of 3 solid figures of different parts, namely V = $192cm^3$ + $80cm^3$ + $48cm^3$ (n2 code) until students produced a total volume of solid figure of $320cm^3$ (H code). This activity to present the right solution requires a convergent thinking process (Cropley, 2009). The activities carried out by the student are supported by the results of interviews as follows:

P : Can you explain your work?
S : The cube formula is s x s x s. The side of the cube is 2cm so the volume of a cube is 2cm x 2cm x 2cm which results in $8cm^3$. I multiplied the volume of one cube by 40 because there are 40 same cubes and the result was $320cm^3$. The second method was conducted using the cuboid formula. The arrangement of these cubes formed a cuboid; then, the cuboids were calculated one by one with the cuboid formula and multiplied by the same number of solid figures to produce $320cm^3$.

During the verification stage, students did the questioning activities to identify problems which require a convergent thinking process (Cropley, 2006). Students also did the incubation stage by looking for ideas (d code) to produce something new and the illumination stage (Ilm code) by finding ideas for something new. These activities require a divergent thinking process (Cropley, 2006). Students also carried out checking activities (Check code) which required a convergent thinking process (Cropley, 2006).

Convergent and Divergent Thinking Processes in the Mathematical Creative Thinking Process of Right Brain Dominant Students

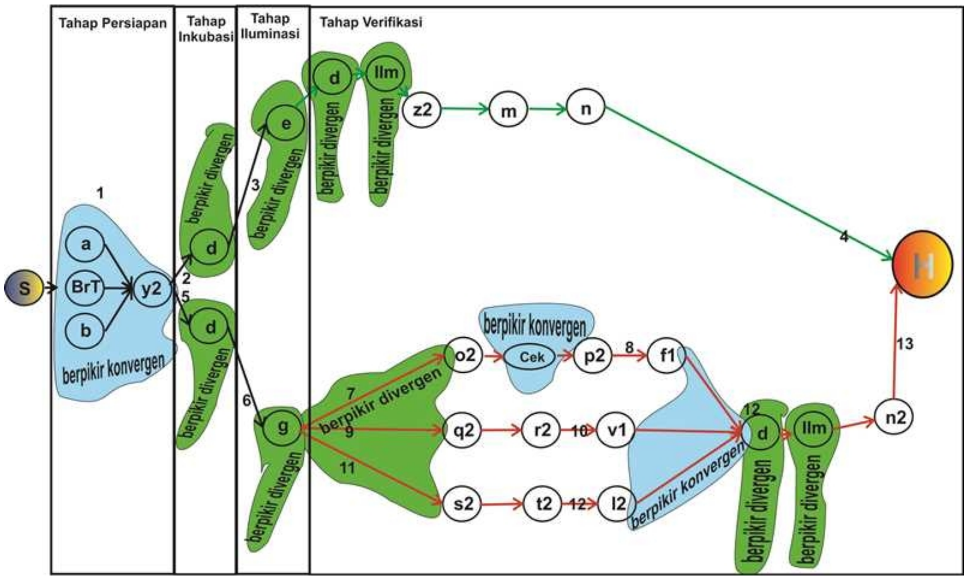


Figure 5 The Thinking Process of Right Brain Dominant Students

Information for Figure 5 regarding the design of the right brain dominant student's thinking process is presented in the following table:

Table 5

Description of Thinking Process Design of Right Brain Dominant Students

Code	Description	Code	Description
y2	Cube Volume?	q2	Volume = 2 x (6cm x 2cm x 2cm)
z2	Volume = $(2cm)^3$ x 40	r2	Volume = 4 x 24cm3
m	Volume = Volume Cube x 40	s2	Volume = 5 x (2cm x 2cm x 4cm)
o2	Volume = 4 x (6cm x 2cm x 4cm)	t2	Volume = 4 x $16cm^3$
p2	Volume = 4 x $48cm^3$	1 – 13	Student Workflow Number

Based on Figure 5 and Table 5, students carried out the preparation stage by reading the questions, writing down what they had learned from the questions they had understood, and asking questions to better understand the provided questions (a, BrT, b, y2 codes). Activities at the preparation stage were to identify problems from general knowledge to specific knowledge to produce the required knowledge. These activities require a convergent thinking process (Cropley, 2006). Students looked for ideas (d code) at the incubation stage. Looking for ideas is an activity to produce something in a new way that requires a divergent thinking process (Cropley, 2006). Afterwards, students obtained ideas and conveyed some ideas they would, namely using the concept of a cube (e code) and the concept of a cuboid (g code) to solve problems at the illumination stage. Activities at the illumination stage are directed to find something new. These activities require divergent thinking processes (Cropley, 2006). The activities carried out are supported by the results of interviews as follows:

P : Why did you ask me?
S : Because I thought this was the length of the cube, but it turned out to be the side length of the cube
P : Have you tried to stay calm for a moment? What did you think?
S : I tried to remember and linked the material to figure out how I wanted to use it.
P : What was the concept used for the first and second methods?
S : I used the cube concept for the first method and the cuboid idea for the second method.

Based on Figure 5 and Table 5, the first method began with students reflecting (d code) to look for ideas. After getting the idea (Ilm code), students could solve the problem. Students multiplied the cube volume of $8cm^3$ by the cube's number to produce a volume of $320cm^3$ (z2 – H code).

The second way, students solved the problem by calculating the solid figure of 6 cubes volume by multiplying the six cubes number directly with the volume of the cube, which is 4 x (6cm x 2cm x 4cm), resulting in a volume of $192cm^3$ (o2 – f1 code). Students did the same calculation to calculate the volume of two cubes (q2 – f1 code) and the volume of three cubes (s2 – l2 code). This activity is an activity to find various aspects to find solutions. This activity is a divergent thinking process (Linberg et al., 2009). Students re-checked (check code) to ensure the method used was correct in calculating the solid figure of 6 cubes volume. After reflecting on it (d code), students obtained an idea (Ilm code) to solve the problem. The total volume of solid figure was calculated by adding volume calculation results of 3 different parts of solid figure, namely $V = 192cm^3 + 80cm^3 + 48cm^3$ (n2 code) so as to produce a total volume of solid figure of $320cm^3$ (H code). This activity aims to present the right solution that requires a convergent thinking process (Cropley, 2009). The students' activities were supported by the results of interviews as follows:

P : Could you explain your work?
S : All right, Sir. In the first method, I wrote the information given and the questions. I calculated the volume of a cube of 2^3 x 40 because there were 40 cubes, resulting in $320cm^3$. In the second method, I calculated this solid figure (pointing to a solid figure consisting of 6 cubes) 6cm for its length, 2cm in height, and 4cm in width. Because there were four solid figures with the same size, I could find 4 x (6cm x 2cm x 4cm) so that it produced $192cm^3$ (students explained all the same methods to solid figure of other cuboids). The total volume was obtained from the summary of the previous volume until I got the volume of $320cm^3$.

Students also did the incubation stage during the verification stage by looking for ideas (d code) to produce something new and the illumination stage (Ilm code) by finding ideas for something new. It required a divergent thinking process (Cropley, 2006). Students also did the answer checking activities (Check codes), which require a convergent thinking process (Cropley, 2006).

Conclusion

Based on the description of Figure 3, Figure 4, and Figure 5 and the results of the interview, we can conclude that convergent and divergent thinking in the mathematical creative thinking process were reviewed by students' with the following brain dominance: 1) Left-brain dominant students in the creative thinking process were more prominent in convergent thinking; 2) balanced brain dominant students had balanced practice of convergent and divergent thinking in creative thinking process, and 3) right-brain dominant students were more dominant in divergent thinking in creative thinking process.

The results showed that students with different brain dominance had different practice of convergent and divergent thinking in the mathematical creative thinking process. It was revealed that students thought divergently or convergently according to the function of the student's brain hemispheres. The results of this study can be used as an illustration for teachers to develop questions related to convergent and divergent thinking in the mathematical creative thinking process by considering the dominance of the student's brain, so that they can solve the problem optimally according to the dominant characteristics of their brain.

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