Mathematical creative thinking process of the students: an analysis of Wallas stages and personality types

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Abstract. The process of creative thinking and personality types are two important things that must be considered but often overlooked. The purpose of this study to the investigated mathematical creative thinking process seen the stages of Wallas and personality types of Keirsey. This research is in junior high school in Indonesia with survey research methods. Participants 4 students with the guardian, artisan, rational, and idealist personality types. Data were collected with the Myers-Briggs Type Indicator (MBTI) tests, mathematical creative thinking tests, and interviews. The conclusion shows that mathematical creative thinking process of guardian and artisan type: the preparation stage tends to long to understand the problem and in the illumination, a phase is more focused on the ways that have been taught by teachers and less able to develop an idea. While the process of mathematical creative thinking rational type: the preparation phase tends to be faster in understanding the problem, the illumination stage can find ideas and build an idea to develop ideas and ideas unusually. The creative thinking process of idealistic type: in the preparation stage tends to be quick in understanding the problem, the illumination stage is more attached to the ways that teachers have taught.

1. Introduction
Thinking is a cognitive process that is a mental activity that emphasizes reasoning, critical, and creative. Thinking is closely related to what happens to the human brain that can be visualized, observed and communicated [1]. The process of thinking in mathematics is very important to note, not just see the final result [2]. Linking the two opinions that the process of creative thinking [3] is very important to be trained to students, creative thinking is one of the mathematical skills which is a higher-order thinking skill [4], [5]. Creative thinking is an important issue that needs to be analyzed, creative thinking is the ability of individuals to produce creative works, new ideas, processes or products [6]. Creative thinking as a dynamic mental process includes convergent and divergent thinking. Convergent thinking leads to a single solution, whereas divergent thinking includes fluency, flexibility, novelty, and elaboration [6]. Fluency generates various ideas in solving problems, flexibility is several ways, novelty uses methods that are not common or not standard [3], while elaboration ability to develop, add to be complete and easy to understand. Creative thinking in mathematics combines concepts in mathematics to produce new concepts. At the school level, creativity in mathematics is usually associated with problem solving or problem posing. Students must be allowed to engage in struggling to solve challenging mathematical problems so students think creatively by reflecting and linking their ideas. Mathematical creative thinking at the school level, students solve problems in ways not previously known.

Various studies on mathematical creative thinking have been carried out, research [7] about mathematical creative thinking is associated with intelligence. Also, research [8] on the support of
mathematical creative thinking towards mathematics education, other research [9] development of mathematical creative thinking through experimental studies. Research [10] says that the mathematical creative thinking process plays a very important role in mathematics education, thus the thought process is an important thing to consider. One of the creative thinking processes developed by [11] is used to determine the stages of the creative thinking process which consists of 4 stages known as Wallas stages, namely: preparation, incubation, illumination, and verification. Indicators of each stage [12], the preparation stage is writing down what is known and asked of the problem, think of alternative solutions by linking to the knowledge possessed. The incubation stage involves pausing while working on the problem, and linking what is known to the problem with prior knowledge. The illumination stage applies ways or ideas to solve problems. The verification phase is to re-examine the solution using another way to solve the problem [13].

Creative thinking is also influenced by the type of personality that is characteristic of a person in behavior. Personality types are grouped based on certain rules, one personality type according to David Keirsey is Guardian, Artisan, Rational, and Idealist. This classification is based on how a person gets his energy (extroverted or introverted), how someone takes information (sensing or intuitive), how someone makes a decision (thinking or feeling), and how their basic lifestyle (judging or perceiving). Of course, each personality type will have a different character in solving problems. Keirsey classifies his personality as the Keirsey Temperament Sorter (KTS) [14].

Noting the research that has been done, no one has examined the creative thinking process, even though the creative thinking process is very important to note. Likewise, there has been no research on creative thinking processes in terms of personality types. Therefore, this research is focused on studying the mathematical creative thinking process in terms of personality types. The thought processes are analyzed according to Wallas' stages, and his personality type according to David Keirsey. The study was conducted at a junior high school in Tasikmalaya Indonesia, on the material to build flat side spaces. The purpose of this study is to investigate and analyze mathematical creative thinking processes at the Wallas stage in terms of David Keirsey's personality type. It is expected that the results of this study obtain a pattern of thought processes according to the stages of Wallas in each personality type.

2. Research Method
This is qualitative research using survey methods. Personality type data were collected using the Myers Briggs Type Indicator (MBTI) test and mathematical creative thinking tests using mathematical creative thinking tests, mathematical creative thinking processes at each stage of Wallas using observations of student answers. Myers Briggs Type Indicator test results, students are grouped into personality types Guardian, Artisan, Rational, and Idealist. Participants were selected from each type of personality with a purposive meaning that the students chose the most statements according to their type, thus 4 participants were involved in this study. Then given a test of mathematical creative thinking in turns using think aloud, then the answers of students are observed and analyzed at each stage of Wallas so that the thinking process of each participant is obtained. Doubtful student answers were explored more deeply by using interviews. The MBTI instrument was adopted from [15], the mathematical creative thinking test instrument has been tested for face validity and content validity by two mathematics education experts. Data analysis techniques include data reduction, data display, and conclusion drawing.

3. Results and Discussion
This research was conducted at one of the junior high schools in Tasikmalaya Indonesia of 4 participants who had the Guardian, Artisan, Rational, and Idealist personality types, analyzed mathematical creative thinking processes on indicators of fluency, flexibility, originality, elaboration, based on Wallas stages, namely preparation, incubation, illumination, and verification. Data collection was started from personality type tests on 35 students using the MBTI test, then grouped into Guardian, Artisan, Rational, and Idealist. From each group of personality types, one participant was selected using a purposive method, which is to choose the most statements from personality type and given code like in Table 1.
Table 1. MBTI test results

| Personality Types | Many | Participant Code |
|-------------------|------|------------------|
| Guardian          | 11   | PG               |
| Artisan           | 10   | PA               |
| Rational          | 6    | PR               |
| Idealist          | 8    | PI               |

Mathematical creative thinking test was given to 4 participants (PG, PA, PR, PI) in turns using the think-aloud technique. Four test questions with indicators of fluency, flexibility, originality, elaboration. Participants' answers were observed and analyzed, dubious answers were explored deeper by interview. The results of the analysis and interviews of PG's answers, the mathematical creative thinking process at the Wallas stage can be seen in Table 2.

Table 2. Mathematical creative thinking process at PG Wallas stages

| Personality Type | Indicator of mathematical creative thinking | Fluency                  | Flexibility             | Originality             | Elaboration             |
|------------------|---------------------------------------------|--------------------------|-------------------------|-------------------------|-------------------------|
| Preparation      | Understand problem information by writing down what is known and asked | Write down what is known and asked | Understand the problem by writing down what is known and asked | Write the known and asked clearly |
| Incubation       | Stop for a moment to think of a solution | Stop for a moment to think about some ideas | Stop for a moment to associate with prior knowledge | Stop for a moment to think of some solutions |
| Illumination     | Find a solution and apply it to answer | Writing solutions is linked to prior knowledge | There is a solution but it is wrong | Answering but counting wrong |
| Verification     | Not using other ways to answer | Can answer in other ways | No answer | Do not answer in other ways |

Noting Table 2 PG participants the mathematical creative thinking process is incomplete, there are Wallas stages that are not answered or answered but are wrong. The stages of preparation and incubation are filled completely and correctly in each indicator of mathematical creative thinking. At the illumination stage, answer but wrong on the originality and elaboration indicators. Whereas at the verification stage, indicators of fluency, flexibility, elaboration answer but not in other ways so it is considered wrong, the originality indicator does not answer. The PG mathematical creative thinking process is illustrated in Figure 1 by coding.
Participants with the Artisan PA personality type, the results of the analysis of mathematical creative thinking test answers at each stage of Wallas, obtained the thought process can be seen in Table 3.

Table 3. Mathematical creative thinking process at PA Wallas stages

| Personality Type | Indicator of mathematical creative thinking | Fluency | Flexibility | Originality | Elaboration |
|------------------|---------------------------------------------|---------|-------------|-------------|-------------|
| Preparation      | Formulate the problem by writing down what is known and asked | Understand the problem by writing down what is known and asked | Write down what is known and asked | Understand the problem by writing down what is known and asked |
| Incubation       | Write solutions that are related to prior knowledge | Write down various ways to answer | Write down ways of solving it by relating it to previous knowledge | Stop for a moment to think of a solution |
| Illumination     | Write a solution and apply it correctly | Apply formulas that have been written correctly | Answered but wrong | Perform calculations correctly |
| Verification     | Do not apply other ways of answering | Answering using other methods correctly | Answering does not use any other method | Answered but wrong |

Based on Table 3 PA thinking process according to Wallas stages in each indicator of creative thinking is incomplete, some stages are not answered. At the verification stage the answer is wrong but the indicators are fluency, originality, and elaboration. Likewise at the illumination stage, answer but wrong on the originality indicator. The PA mathematical creative thinking process at the Wallas stage, illustrated by using coding can be seen in Figure 2.

Participants with the Rational PR personality type, mathematical creative thinking processes at the Wallas stage are complete, clear, and correct. At each stage of Wallas on each indicator, the PR thinking process can be seen in Table 4.

Table 4. Mathematical creative thinking process at PR Wallas stages

| Personality Type | Indicator of mathematical creative thinking | Fluency | Flexibility | Originality | Elaboration |
|------------------|---------------------------------------------|---------|-------------|-------------|-------------|
| Preparation      | Write down what is known and asked | Formulate the problem by writing down what is known and asked | Write the known and asked clearly | Write down what is known and asked |
| Incubation       | Write down various ways to answer | Stop for a moment to think of a solution | Answering by linking prior knowledge | Write solutions that are related to prior knowledge |
| Illumination     | Apply formulas that have been written correctly | Perform calculations correctly | Write a solution and apply it correctly | Apply formulas that have been written correctly |
| Verification     | Answering using other methods correctly | Answering the other way correctly | Count other ways correctly | Use other methods completely and correctly |

From Table 4 it is found that the participant's thought process with the rational personality type of PR, each Wallas stage and each indicator of mathematical creative thinking the answer is complete. The process of thinking public relations using coding can be seen in Figure 3.

Observation and analysis of participants' answers with Idealist PI personality types, mathematical creative thinking processes on the indicators of Wallas fluency, flexibility, originality, and elaboration stages consist of preparation, incubation, illumination, and verification can be seen in Table 5.

Table 5. Mathematical creative thinking process at PI Wallas stages
Personality Type | Indicator of mathematical creative thinking | Fluency | Flexibility | Originality | Elaboration |
|-----------------|---------------------------------------------|---------|-------------|-------------|-------------|
| Preparation     | Write the known and asked clearly           |         | Formulate the problem by writing down what is known and asked | Write down what is known and asked | Formulate the problem by writing down what is known and asked |
| Incubation      | Stop for a moment to think of a solution    |         | Answering by linking prior knowledge | Write solutions that are related to prior knowledge | Write down various ways to answer |
| Illumination    | Perform calculations correctly              |         | Apply formulas that have been written correctly | Applying formula but wrong | Write a solution and apply it correctly |
| Verification    | Using other methods but wrong               |         | Count other ways correctly | No answer | Answering but not using other methods |

The mathematical creative thinking process of students with the idealist personality type PI, at the preparation and incubation stages answered completely and correctly, but at the illumination stage the formula was applied but was wrong. Furthermore, at the verification stage, the fluency indicator uses another method but is wrong, as well as the elaboration indicator, it does not answer the originality indicator. The PI creative mathematical thinking process is illustrated using coding can be seen in Figure 4.

Mathematical creative thinking processes based on the stages of Wallas from PG, PA, PR, and PI have different thought processes. The PG participants thought the process was the least compared to the others, while the PA and PI thought processes were relatively the same, and the most superior was the PR thought process. All participants in the preparation and incubation stages had no problems, all answered correctly and completely. Whereas in the illumination and verification stage, only PR can answer correctly, PG, PA, and PI experience obstacles. In each indicator of mathematical creative thinking ability, only the indicator of flexibility all participants can go through the process of thinking properly. In the indicator of fluency and originality, PG, PA, and PI experience a lot of errors, while in the elaboration indicator only PG is experiencing deficiencies in the thought process. Participants are weak on the originality indicator, this is because students must answer in their way or in a way that was never given by the teacher, or in a unique way. Answering questions like this are generally never given at school. Weak on the fluency indicator, on this indicator students make mathematical questions or write down ideas and then answer them themselves. Questions like this are also rarely given by teachers in schools, so students are not accustomed to difficulties. Elaboration indicators, participants before answering questions must complete the data first, because the questions given are incomplete data. Solving problems like this has also never been given by the teacher, in general the teacher gives a complete problem, all the data is known (well-structure problem).

4. Conclusions
The results of the study concluded that students who have the rational personality type (PR), a complete mathematical creative thinking process based on Wallas stages on indicators of fluency, flexibility, originality, and elaboration include: 1) at the preparation stage to understand the problem, can reveal information both verbally and in writing, 2) at the incubation stage students stop for a moment thinking about the solution of the problem and relate it to the previous material, 3) at the illumination stage students can answer questions on indicators mathematical creative thinking, 4) at the verification stage students evaluate answers by using another way. Students with Guardian (PG), Artisan (PA), and Idealist (PI) personality types, mathematical creative thinking processes based on Wallas stages are only at the preparation and incubation stages. At the illumination stage, PG does not answer the originality and elaboration indicators, PA and PI do not answer only the originality indicator. At the last stage of verification, PG, PA, and PI did not answer the indicators of fluency, originality, and elaboration. The PR mathematical creative thinking process is based on the Wallas stages of each indicator, most
complete from beginning to end. The PA and PI mathematical creative thinking processes are relatively the same at each of the Wallas stages, while PG is the most incomplete thought process.

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References
[1] T. Montag-Smit and C. P. Maertz, “Searching outside the box in creative problem solving: The role of creative thinking skills and domain knowledge,” *J. Bus. Res.*, vol. 81, no. November 2016, pp. 1–10, 2017.
[2] H. R. Maharani, S. Sukestiyarno, and B. Waluya, “Creative Thinking Process Based on Wallas Model in Solving Mathematics Problem,” *Int. J. Emerg. Math. Educ.*, vol. 1, no. 2, p. 177, 2017.
[3] S. Y. Chen, C. F. Lai, Y. H. Lai, and Y. S. Su, “Effect of project-based learning on development of students’ creative thinking,” *Int. J. Electr. Eng. Educ.*, vol. 0, no. 0, pp. 1–19, 2019.
[4] N. Ratnaningsih, R. R. El Akbar, and E. Hidayat, “Effect of chronotype and student learning time on mathematical ability based on self-regulated learning,” *J. Phys. Conf. Ser.*, vol. 1013, p. 12141, May 2018.
[5] N. Ratnaningsih, R. Hermanto, and N. S. Kurniati, “Mathematical communication and social skills of the students through learning assurance relevance interest assessment and satisfaction,” *J. Phys. Conf. Ser.*, vol. 1360, p. 12032, Oct. 2019.
[6] Y. Noh, “A study of the effects of library creative zone programs on creative thinking abilities,” *J. Librariansh. Inf. Sci.*, vol. 49, no. 4, pp. 380–396, 2017.
[7] T. K. Tyagi, “Mathematical Intelligence and Mathematical Creativity: A Causal Relationship,” *Creat. Res. J.*, vol. 29, no. 2, pp. 212–217, 2017.
[8] V. Švecová, L. Rumanová, and G. Pavlovičová, “Support of Pupil’s Creative Thinking in Mathematical Education,” *Procedia - Soc. Behav. Sci.*, vol. 116, pp. 1715–1719, 2014.
[9] R. Massyrova, I. Nur gul, B. Saktaganov, Z. Issayeva, and S. Udarzeva, “Theoretical and Experimental Study of the Concept of the Students Creative Thinking Development,” *Procedia - Soc. Behav. Sci.*, vol. 177, no. July 2014, pp. 445–448, 2015.
[10] N. Yaftian, “The Outlook of the Mathematicians’ Creative Processes,” *Procedia - Soc. Behav. Sci.*, vol. 191, pp. 2519–2525, 2015.
[11] M. Savic, “Mathematical problem-solving via wallas’ four stages of creativity: Implications for the undergraduate classroom,” *Math. Enthus.*, vol. 13, no. 3, pp. 255–278, 2016.
[12] E. Sadler-Smith, “Wallas’ Four-Stage Model of the Creative Process: More Than Meets the Eye?,” *Creat. Res. J.*, vol. 27, no. 4, pp. 342–352, 2015.
[13] M. A. Nuha, S. B. Waluya, and I. Junaedi, “Mathematical creative process wallas model in students problem posing with lesson study approach,” *Int. J. Instr.*, vol. 11, no. 2, pp. 527–538, 2018.
[14] F. Gungör, H. Kurt, and G. Ekici, “The Relationship between Personality Types and Self-efficacy Perceptions of Student Teachers,” *Procedia - Soc. Behav. Sci.*, vol. 116, pp. 786–790, 2014.
[15] O. Mazni, S. L. Syed-Abdullah, and N. M. Hussin, “Analyzing personality types to predict team performance,” *CSSR 2010 - 2010 Int. Conf. Sci. Soc. Res.*, no. Cssr, pp. 624–628, 2010.