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The Creative Thinking Process of Mathematics Education Students Based on the Wallas Thinking Stage in terms of Student Learning Barriers

Lukmanul Akhsani*, Kartono Kartono, Iwan Junaedi, Tri Sri Noor Asih

Universitas Negeri Semarang, Indonesia
*Corresponding Author:lukmanulakhsani@students.unnes.ac.id

Abstract. Numerical methods are a course that studies mathematical problem solving in a systematic way using numbers. Students still have obstacles in learning numerical methods. These obstacles occur in the mental preparation of students in attending lectures, the lecture process carried out by lecturers and students' academic abilities. The purpose of this study is to describe the creative thinking process of students based on the Wallas stage. The method used is qualitative. respondents are students of prospective mathematics teachers. The data was obtained by testing the ability to think creatively. The test results were analyzed by looking at the creative thinking process according to Wallas, namely preparation, incubation, illumination, and verification. Furthermore, an analysis of test answers and in-depth interviews was carried out based on student learning barriers based on the obstacles faced. Interviews were conducted to students who have high, medium and low learning barriers. In general, students have obstacles in the creative thinking process, namely students only use the method of completion without understanding its meaning. This happens because students do not understand the concept well. As a result, students will not be able to solve problems from the lecturer properly if the form or illustration of the questions is changed.

Key words: creative thinking process; learning barriers; student; numerical methods

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INTRODUCTION

Mathematics is a very important subject. Everyone definitely needs Math. They always use mathematics in their life. Mathematics is used by them directly or indirectly. Mathematics can be used in calculations or in the human mind in logical thinking. This is why it is important to learn mathematics at school or university.

Mathematics is studied from kindergarten to university level. Moreover, prospective mathematics teacher students not only learn mathematics, but also learn how to teach it. Students need to pay attention to the essence of each material in mathematics so that when teaching mathematics to students at school it is not wrong. Students also need to have abilities that support them in learning and teaching mathematics Mathematics is a core subject for lifelong learning and understanding for further investment of study and attitudes (Sharif, 2018).

The ability that needs to be possessed by students is the ability to think creatively. The ability to think creatively requires students to answer questions not only correctly. However, students can determine the appropriate solution method and the appropriate answer. Their ideas in working on the problems are also very important to pay attention to. Creative thinking skills are very important in the student learning process.

The creative thinking process according to Wallas has 4 stages, namely preparation, incubation, illumination, and verification (Maharani, 2017; Ratnaningsih, 2021). Sitorus uses 5 stages of creative thinking, namely orientation, preparation, incubation, illumination, and verification (Sitorus, 2016). Furthermore, Sawyer suggests eight steps of creative thinking (Sawyer, 2021), find the problem, acquire knowledge, gather related information, incubation, generated ideas, combine ideas, select the best ideas, and externalize ideas. Furthermore, the creative thinking process according to Mumford is Problem Definition, Information Gathering, Concept/Case Selection, Conceptual Combination, Idea Generation, Idea Evaluation, Implementation Planning, and Adaptive execution (Mumford et al., 2013).

Isaken (Mahmudi, 2010) , defines creative thinking as a process of idea construction that emphasizes aspects of fluency, flexibility, novelty, and detail. In general, creative thinking is triggered by challenging problems. In order for children's creativity to be realized, it is necessary to have encouragement within the individual (intrinsic motivation) and encouragement from the environment (extrinsic motivation).

Furthermore, Munandar (Firdaus et al., 2018) , said that the characteristics of creative thinking abilities related to cognition can be seen from the ability to think fluently, flexible thinking skills, original thinking skills, elaboration skills, and judging skills.

Visual-spatial students show a higher level of creative thinking. This shows that visual-spatial students have better creative thinking skills in learning mathematics, especially geometry (Aini et al., 2020). This shows that there are characteristics of students that need to be considered in learning. These characteristics play an important role in students ' creative thinking skills. Characteristics of children can be viewed from several factors (Janawi, 2019). The main factor can be done through; First, identify the learning characteristics of each student in the class, Second, all students have the same opportunity to actively participate in learning activities, Third, manage the class. Placement of seats will be more meaningful for the creation of good learning, Fourth, knowing the causes of deviations in student behavior. The teacher does not only convey cognitive learning. Sixth, pay attention to students with certain physical weaknesses.

Facts in the field, students are still working on questions from the lecturer according to the example from the lecturer. When the form of the question is changed to another form, students cannot do well. This is important for lecturers to pay attention to. Another problem that arises in learning is lazy learning. The cause of lazy student learning arises from within the student himself (internally) and from outside (externally). Furthermore, another factor that causes laziness to learn among students is that they are no longer confident in their potential and thinking abilities. Therefore, students must be able to change for the better, achieve, be creative, and productive. (Bella & Ratna, 2019). Students' mathematical creative thinking ability in terms of self-efficacy showed various results. This means that students' self-efficacy has no absolute effect on students' mathematical creative thinking abilities. Therefore, the quality of learning remains the focus of learning activities (Ulinnuha et al., 2021).

The results showed that students tended to be silent when asked by the teacher; and students' thinking skills, critical thinking and creativity are still not well developed (Putra, 2020). Research results (Yuli & Siswono, 2011) shows five levels of creative thinking, namely level 0 to level 4 which has different characteristics. This distinction is based on fluency, flexibility, and novelty in mathematical problem solving and problem posing. Students have different creative thinking abilities. Every student faces a problem, they have a unique way of finding a solution. There is a need for greater attention to the practice and teaching of early mathematics teaching as it can enhance early mathematics education and result in long-term improvements in the skills and lives of future generations (Cerezci, 2019).

Based on the explanation above, the creative thinking process is a process that occurs when students work on math problems. Many things hinder students in optimizing their creative thinking skills. These obstacles need to be studied more deeply, both from the external or internal side of the students themselves. Furthermore, it can be determined to what extent the students' creative thinking processes are in accordance with the obstacles they face. The first obstacle is internal, including the student's paradigm that is not right, lack of time to rest/sleep and lack of interest and seriousness in learning. Second, external, including classroom conditions that are not conducive because there are students who are noisy during teaching and learning activities and students are affected by the environment around the house which causes students to often play games (Fernandes et al., 2019).

Research results (Supandi et al., 2021) stated that students' learning barriers did not have a positive effect on students' self-efficacy. When students experience obstacles (internal and external) in carrying out learning activities, student self-efficacy decreases, on the contrary when students do not experience obstacles, student self-efficacy in learning becomes better. While self-efficacy has a positive effect on learning outcomes. This shows that the achievement of student learning outcomes is higher if the efficacy higher self. Student academic achievement is not low when self-efficacy is not low. of the selected subjects, the results of observations on written description tests and interviews showed that students' creativity was influenced by self-efficacy. Subjects with categories that are not very inhibited in solving mathematical problems (differential equations) provide a lot of information about the results of the answers to questions. As for students who are included in the category of less barriers, the information in providing answers is limited. The only solution is to answer the question.

The purpose of this study is to describe the

creative thinking process of students in terms of student learning barriers. According to Broussou (Yusuf et al., 2017), there are 3 factors that cause learning barriers, namely didactic barriers (due to teacher teaching), ontogeny barriers (mental readiness to learn), epistemological barriers (student knowledge that has a limited application context). When viewed at this time learning barriers have been formed systemically for students. Maybe the obstacles arise because students do not come to class, do not study, and it is difficult to digest the material well. It can be concluded that learning barriers are obstacles for students in thinking and understanding something. Therefore, there is a need for an analysis to determine the creative thinking process of students in terms of learning barriers, taking into account the difficulties experienced by students so that student achievement results increase. Furthermore, indicators used for describe the thought process creative (Setiawani et al., 2019) that is preparation (understand problem , identify known and asked elements , sufficient _ required elements , convey _ with method alone), incubation (reflecting) for find solution , write phase solution), illumination (find and write more from one idea), and verification (test the solution obtained).

METHODS

This research is qualitative research. The subjects of this study were 4th semester students of the mathematics education study program, Muhammadiyah University of Purwokerto, in the numerical method course. The sample was taken based on the results of the student learning barriers questionnaire. The test results are described based on students ' creative thinking processes. The extent to which students carry out creative thinking processes on their answers. This study took a sample of three students from the categories of high, medium and low barriers. Furthermore, interviews were conducted to explore related to their creative thinking process.

RESULTS AND DISCUSSION

The results of the questionnaire on student learning barriers show that 75% of students are in the category of moderate learning barriers, 12.5% are in the category of high learning barriers and 12.5% are in the category of low learning barriers. Based on the results of the questionnaire, 3 students with high (HB), moderate (MB) and low (LB) learning disabilities were selected. Of the three subjects, almost all have a dominant learning barrier on epistemological factors. This means that students' knowledge of the concepts and application of the material being studied needs to be the attention of the lecturer when teaching. Then, based on the descriptive analysis of the test, the following results were obtained.

Table 1. The results of the analysis of creative thinking skills

Process	Indicator	Fluency			Flexibility			Originality			Elaboration		
		HB	MB	LB	HB	MB	LB	HB	MB	LB	HB	MB	LB
Preparation	Understanding the problem	√	√	√	√	√	√	√	√	√	√	√	√
	Identify the elements that are known and asked	√	√	√	√	√	√	√	√	√	√	√	√
	Sufficient elements needed	√	√	√	√	√	√	√	√	√	√	√	√
	Deliver in your own way	√	√	√	√	√	√	√	√	√	√	√	√
Incubation	Reflect to find a solution	√	√	√	√	√	√	√	√	√	√	√	√
	Writing solution phase	√	√	√	√	√	√	√	√	√	√	√	√
Illumination	Find and write more than one idea to solve the problem correctly	√	√	√	-	√	√	-	-	-	-	√	√
Verification	Test and retest the validity of the solutions obtained	-	-	-	-	-	√	-	-	-	-	-	-

High Learning Barriers (HB)

The following is a description of the results of the HB test. when working on fluency-related questions, can answer more than one answer. but before HB answered correctly, the answer was inaccurate because it used derivatives to determine the requested procedure, even though only manipulation was enough. However, HB's answer fits the question.

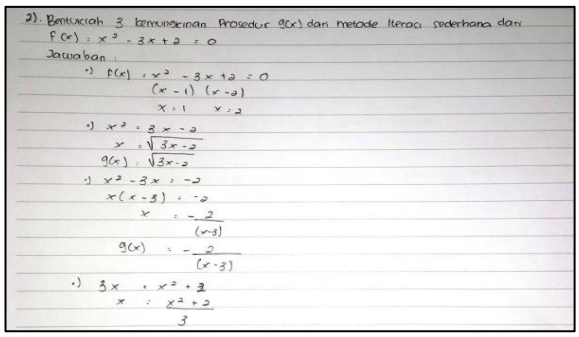

Figure 1. Fluency HB

When answering questions related to flexibility, HB answered with the correct steps. In this question, students are asked to work on iteration questions in two ways. HB uses both methods well. However, there is a small thing that is important not to do, which is to determine the stopping criteria for the iteration. HB's answer so it's not clear when the iteration stops. In the problem it is clear that the error limit (ε) is used in performing calculations, but HB has not determined which value is limited by the . HB also does not write down the reason for the iteration to stop.

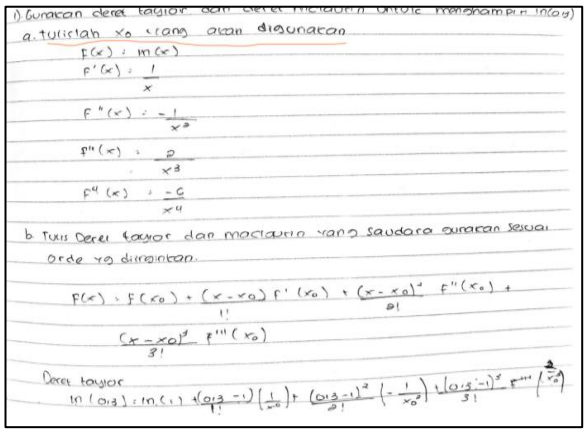

Figure 2. HB fleksibilitas flexibility and elaboration

At the end of the answer, HB did not write the conclusions of the two methods according to the question. Based on the explanation, it shows that HB answers the questions like working on two separate questions. This shows that HB has barriers to illumination and verification. The ideas obtained at the incubation stage are directly applied without the need for consideration of the things that are used to consider the conditions needed for the case at hand. The illumination stage in the answer to this question, HB does not write down the limits or criteria for the iteration to stop properly so that the ideas obtained for solving the questions are not perfect. Furthermore, the verification stage is also not optimal, because the criteria for stopping are not clear. Then a lot of counting errors occur. In such a way that even the conclusions drawn have errors.

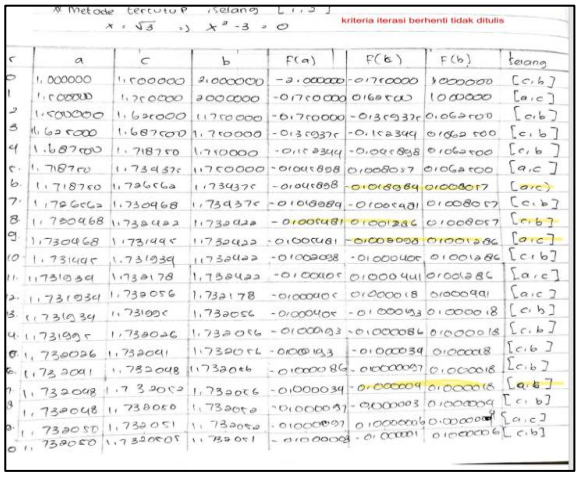

Figure 3. Flexibility and elaboration

HB answers questions related to originality that are not in accordance with the question. In this question, students are asked to make three iteration procedures using a simple iteration method. then students are asked to choose one of the iteration procedures to determine convergence criteria or initial value limits so that iterations converge. However, HB answers by choosing one initial guess and then determining whether the initial value causes convergence or divergence. Answer HB shows the initial guess shows divergent iterations. However, HB continues to the calculation process. This is not appropriate because the iteration requested is a convergent iteration. At the end of the answer there is also no explanation of the results of the calculations. This shows that HB has inhibition at the incubation stage. Lack of knowledge related to the material causes HB to be unable to escape from a problem and think of a solution. HB answers questions according to the understanding he has without adjusting to the questions asked.

Based on the explanation above, students with high learning barriers category have obstacles in the indicator flexibility is at the stage of illumination. The idea or method that has been thought up by students is good, but in the application of the idea it is carried out inappropriately or less than optimally, so that it is not perfect in meeting the indicators. flexibility. This flexibility indicator can be seen clearly because students with high learning difficulties have answered in detail. each method chosen is well written step by step. However, students just use it without paying attention to the consideration of necessary and sufficient conditions in the use of the chosen settlement method and are still wrong in determining the criteria for each stage in the calculation. This shows that students are only still thinking in the subconscious, not thinking with concentration when doing calculations.

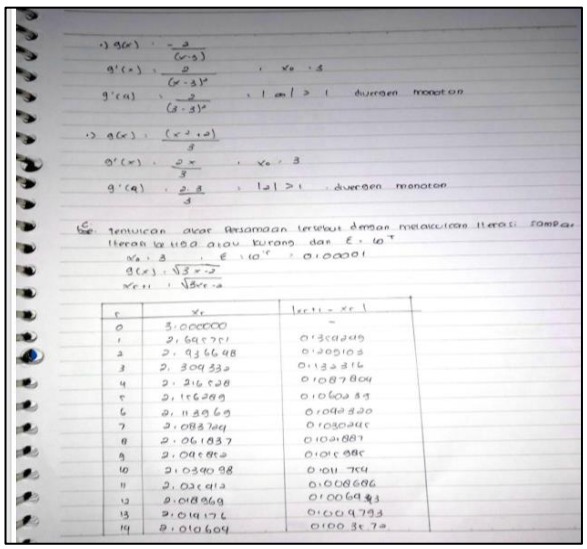

Figure 4. Originality HB

Moderate Learning Barriers (MB)

Students with moderate learning disabilities were selected as the sample, namely MB. MB was chosen because it has a complete and clear answer. In the matter of fluency, MB did well, but there was an error in one of the procedures written. at the stage of creative thinking MB only has obstacles at the verification stage. MB has been good at working on questions so that from the preparation stage to the illumination it looks good.

Furthermore, on the matter of flexibility, MB at the preparation stage has collected information well. The incubation stage is also clear for students. It can be seen from the detailed answers and the parts of the answers that can be read well. However, MB does not write the requested approximation function. MB directly works using numbers. This shows that MB does not understand the Taylor series and the approximation function formed by the Taylor series. The student at the illumination stage only determines the result by focusing on the final result. MB at the end also does not provide a response regarding the two methods used. Like HB, MB also only performs calculation procedures without paying attention to the meaning of what is being done.

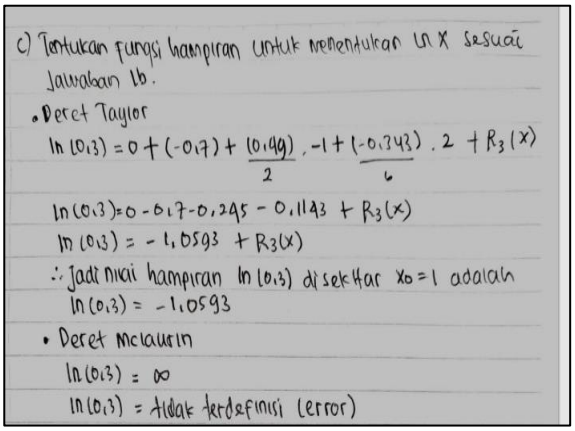

Figure 5. MB Flexibility

Furthermore, at the verification stage, MB does not write down the purpose of calculating the error from the method used. MB does not write down the error calculations for the first or second method. The section should be used to compare the two methods in such a way that the two methods used are not separate.

The elaboration indicator, MB is already doing well. This can be seen clearly from the stages of working on the questions according to the written method, but they do not understand the meaning of the procedures carried out. Just follow the rules and only focus on the results. Based on the explanation above, students with moderate barriers have difficulty in the illumination stage. Where students only work on it, but do not understand the purpose of each stage carried out because students only focus on the results.

Low Learning Barriers (LB)

On fluency questions, LB can mention more than one answer, but immediately answer without any explanation or explanation of the sentence. Then when answering the flexibility question , you can answer but you don't answer directly according to the question . Seen LB only focus on results, not on the process. Students are also quite

detailed in working on the questions. Regarding the originality question, students only guessed the answer, even though what was asked of the question was the limit of convergence. In the matter of fluency, LB, write some answers. In this answer, LB wrote directly without any explanation. Not much is explained or explained in the answer. LB also did not write down the conclusion of the answer.

In the matter of flexibility, LB has many errors in counting. But then LB can figure out where the error is. However, this makes it imprecise in working. This shows that LB has worked with two methods. when there is an error in calculating, LB immediately knows where the calculation error is. However, another thing is shown in the method that LB uses, LB should have stopped at the fourth calculation, but he continues. In terms of originality, LB has worked on clear steps and it can be seen that LB has shown elaboration indicator. However, the answer does not match the question. The question asks to indicate the convergence criteria of the method to be used, not to guess the answer directly. LB only works like any other problem, which is to find a problem and immediately look for a solution.

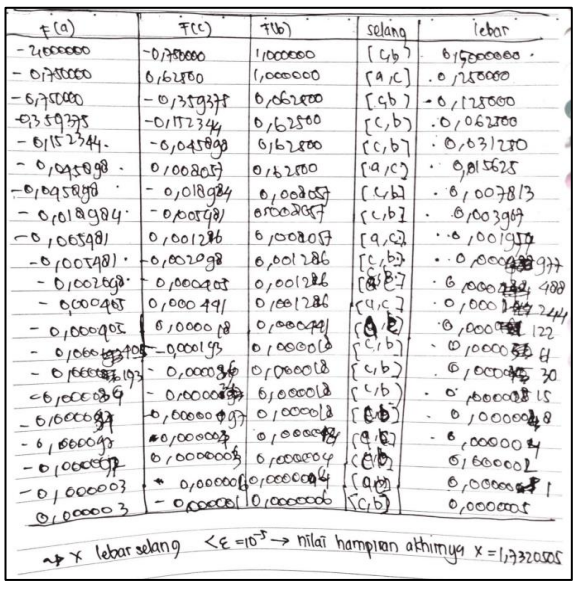

Figure 6. Flexibility of LB

This description is also supported by the results of interviews. The results of the interviews showed that the three students had the same obstacle, namely they did not understand the meaning of each method chosen to solve the problem. They only use the method according to the problem given in the problem. When working students are faced with a choice structure, they cannot make a choice for the next step.

It was conveyed by HB and MB that when working on the problem they did not know that the method used produced an answer, but they still counted the errors of the method used. Then when they work on the command to determine the convergence limit of the solution, they guess the solution.

The explanation above shows that students are able to identify problems and choose the right method. We can say that students have met the minimum standards of this course, namely students can choose the right method for the problem to be solved. However, students need to deepen the meaning of each method studied, so that learning outcomes can be optimal. One of the obstacles to student learning is related to learning difficulties. The results of the study (Lestari, 2015), 5.18% of student learning difficulties are influenced by internal factors which include intelligence, interest, and student motivation and external which includes family and campus, while 94.82% is influenced by other factors such as perception barriers. students, there are parts in the learning sequence that students do not understand, the condition of students who are tired, and the environment where students live.

Seen in the results research, almost all subject study no could reach Step verification. This thing occurs because existence obstacle related understanding student to Theory still less. in line with results research (Setiawani et al., 2019), stated that students who were at low and very low stages did not re-check written answers . Another similar study, namely research (Ratnaningsih, 2021), showed that at the illumination stage, respondents with guardian type did not answer the indicators of originality and elaboration, respondents with artisan and idealistic personality types did not answer only indicators of originality. In the last verification stage, respondents with guardian, artisan, and ideal personality types did not answer the indicators of fluency, originality, and elaboration. Other studies show that most students with moderate abilities only reach the illumination stage, but it takes a long time (Maharani et al., 2017). Furthermore, for student with obstacle tall almost no could reach step illumination on all work done. This thing need attention that the process of expressing ideas Becomes an article is very important.

CONCLUSION

The results and discussion show that students

show obstacles in the verification process. Students only write the conclusion of the calculation results without knowing whether the answer is correct or incorrect. Students apply the method directly without understanding the meaning of each step.

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