Learning barriers and student creativity in solving math problems

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Abstract. Innovation and creativity are essential for all disciplines and learning activities. Creative processes, such as imagination, are a crucial component in understanding the learning experience of mathematics. Approaches in teaching and learning are considered in this study to foster student creativity and innovation in understanding cases of implementing differential equations. The objects of this research were 154 students. Subjects were selected based on barriers to learning and academic achievement. The selected subjects represent the categories of students with very not inhibiting, not inhibit, pretty inhibit, and inhibit. Selected subjects were given two different types of problems (ordinary mathematical problems and word problems). The results showed that the way students work in getting answers to word questions was more varied than routine mathematical problems. Students' imagination of understanding the questions and answers provides a different perspective. These results conclude that the approach to learning and evaluation using story questions increases students' mathematical imagination in education.

1. Introduction

Barriers to learning occur at various levels such as attitude, organization, and contextual [1]. For this reason, it is important that education professionals are aware of their existence, know how to identify them, and can propose changes and improvements that eliminate them to offer students an inclusive response. Student learning barriers are categorized as external barriers and internal barriers [2]. The first obstacles include lack of equipment, the unreliability of equipment, lack of technical support and other resource-related problems. Second-level barriers include school-level factors, such as organizational culture and teacher-level factors, such as beliefs about teaching and technology and openness to change. Internal learning barriers come from students' psychology, how to learn, and how to organize learning.

Most of the students and teachers also indicated that they face some learning barriers (visual and auditory impairment, low concentration, lack of English language skills and socio-economic challenges that might prevent them from achieving academic success [3]. Also, many students showed that they experience more than one learning barrier so that the education centre has an important role in developing the competencies needed in the future of teachers to develop quality and inclusive education. One of the key competencies will identify barriers to learning and participation that are present in different educational contexts to remove barriers and build change and improvement.

Boles [4] provides students' views on several aspects of learning barriers. The first view is to respond to problems from today's sample group of students. Second, they provide clues about possible interventions to overcome at least some of the learning barriers. In this way, they relate the past
(works published in literature), current addressing contemporary problems (what students face today) and the future (as they provide valuable clues about possible future interventions). These investigations have highlighted that despite many complex factors that enable or hinder student success, teachers have the power to create a teaching-learning environment that supports more students to stick with their studies and make the best of their abilities.

Imagination is the ability to think to facilitate the growth of ideas [5], apart from the challenges posed to the imagination by the emergence of algebraic methods. If stories are a product of imagination, then imagination plays a very active role in self-talk which occurs when we are involved with problem-solving actions. The use of symbols is part of making the possibility against empirical evidence [6].

The stages of students' mathematical imagination include displaying sensory mathematical imagination (first stage), then creative mathematical imagination (second stage) and then creative mathematical imagination (third stage). Students who can display creative mathematical imagination will first display sensory and creative mathematical imaginations. But not the other way around, students can show sensory mathematical imagination but they cannot immediately bring out creative and recreational mathematical imagination [7]. Sensory imagination is perception, which is the experience obtained from a stimulus. Creative imagination is the emergence of ideas in unusual and unexpected ways. Meanwhile, recreational imagination is the ability to construct ideas from different perspectives from an experience [8].

Creativity is a dynamic property of the human mind that can be enhanced and often occurs when one can connect seemingly different ideas [9], and creativity can be cultivated daily [10]. People's beliefs about creativity may differ from the underlying structure of creativity. Conception and self-perception related to the structure of creativity may not fit well with actual cognitive mechanisms. Creativity theory is important in supporting teaching and learning, as well as learning design [11]. Creativity is an imaginative activity and aims to produce original and valuable results concerning students. Students can make some of these connections on their own as they recognize the relationships between juggling, mathematics, and other disciplines [12].

The creative process is at the core of innovation in learning. Mathematical creativity is based on expertise, it requires a deep understanding of mathematical concepts and procedures. Like all creative behaviour, mathematical creativity is rooted in the intellectual abilities and personality traits of each individual. So that in the learning process in the classroom, apart from stimulating original thinking, the barriers to creativity must be removed (epistemological barriers) [13]. The factors associated with the emphasis on creativity include teaching and learning action [14]. On the other hand, the freedom of creativity in various mathematical approaches is confusing [15]. In this case, the presentation of mathematical problems is very important to stimulate students' mathematical imagination and creative thinking. This paper tries to explore students' mathematical thinking using a contextual form.

2. Methods
This study uses a qualitative method. The population of this study were 154 seventh semester students majoring in Mathematics Education, University of PGRI Semarang, with the course material for differential equations. All students were given a questionnaire about learning barriers. A total of four students were selected based on their academic achievements and learning barriers they experienced. Subject 1 (S1) is a very unobstructed category and S2 is an unobstructed category. The subjects of S3 were students in the moderately obstructed category, and S4, namely students in the obstructed category. Selected students are given the same questions, namely mathematical problems in the form of word problems. The results of the answers from students were analyzed qualitatively and discussed based on their imagination and creativity. The mathematical creativity indicator used in this analysis is the flexibility of students in solving problems. For each subject is there a difference in how to identify problems, translate problems into a mathematical model (differential equation model).
3. Results and Discussion
The problem in this research is mathematical problems in the topic of differential equations. The problems are presented in the word problem, as shown in Figure 1.

The annual population growth rate of a country is 0.2 times its current population.  

a. Suppose the current population is 100 inhabitants, what will be the population after 80 years?  

b. If the current population is 150 inhabitants, then in 2060 a disease outbreak occurs so that 6000 people die, what will the population be in 2080?

Figure 1. Mathematical contextual problems.

The results of the answers from the first subject (S1) students with the category of not being hampered by participating in learning activities are shown in Figure 2. For question (a), the S1 subject was able to identify the initial time and population at the beginning of the year, namely \( N(t_0) = 100 \) and the constant \( k=0.2 \). Undergraduate students can determine the differential equation model from the question. The mathematical model in question is \( \frac{dN}{dt} = kN(t) \). The S1 model subject resolves the model to be \( N(t) = N(t_0) \exp(kt+c) \), for a constant \( c \). Subject S1 can substitute the model obtained with \( t=80 \) and for \( c=0 \) the equation \( N(80) = 100 \exp(0.2 \times 80) \) is obtained. S1 Subject's answer to question (b) Able to use the projected model from the question (a), and solve for \( t_1=40 \) for 2060 and \( t_2=80 \) in 2080. The subject can determine the population in 2060. Population in 2060 after minus the number of people who died, which is 6000. This calculation is used as the initial condition in 2060 to determine the population in 2080.

Figure 2. Results of S1.

The second subject (S2) is a subject with the category not obstructed. This student can define the initial population, namely \( P(0)=100 \), and the growth constant is 0.2. The answer to the first question S2 immediately wrote down the formula, namely \( \frac{dP}{dt} = 0.2 \times P \). From this model, the students did the integration, and the result was \( P = C \exp(t/5) \), with \( C=P(0) \). Students do the substitution for \( t=80 \) on the
model obtained, and the result is \( P(80) = 100 \times \exp(16) \). This result is a statement of the total population after 80 years. The second question, S2 can write the population in \( t_1 \) (the year 2060), namely \( P(t_1) = 150 \times \exp(80) - 6000 \). When answering the population in 2080, S2 uses the formula \( P(t_2) = (150 \times \exp(8) - 6000) \times \exp(4) \). The calculation result shows the number of \( 441,143 \times \exp(4) \).

Subject 3 (S3) directly determines the mode of the differential equation \( \frac{dN}{dt} = 0.2 \times N \). Subject S (3) makes steps in solving the question point a. The next stage S3 integrates and the result is \( N = \exp(0.2 \times t + c) \). By substituting for an initial population of 100, S3 writes the model to be \( 100 = A \times \exp(0) \), and we obtain \( A = 100 \). This result is summarized as \( N(0) = A = 100 \). The solution to questions a, S3 uses the model \( N(80) = 100 \times \exp(0.2 \times 80) = 888,612 \) inhabitants. Answering the question, the two subjects wrote down the steps to determine \( t_1 \), \( t_2 \) and made substitutions. Subjects do not experience difficulties in making substitutions, including when the year 2060 an epidemic occurs which causes the death of 6000 residents. By performing mathematical operations, the initial condition is obtained at the end of 2020 the population is \( N(t_1) = 150 \times \exp(8) - 6000 \). This population of \( N(t_1) \) is used as the initial population, so S3 writes the total occupation for 2080 to be \( N(t_2) = (150 \times \exp(8) - 6000) \times \exp(0.2 \times 20) \).

The fourth subject (S4) identifies information from the questions and finds questions from the problem, as shown in Figure 3. This subject can write a differential equation model, namely \( \frac{dN}{dt} = 0.2 \times N \). This model is solved through an integration process, and the result is \( N = \exp(0.2 \times t + c) \). By performing mathematical operations, the mathematical model is \( N = A \times \exp(0.2 \times t) \), where \( A = \exp(c) \). This model is used to determine the population size for the next 80 years. With the initial condition \( t=0 \) and \( N(t_0) = 100 \) the population in 2080, it is obtained that \( N = 100 \times \exp(0.2 \times 80) = 100 \times \exp(16) \).

Answering the second question, S4 determines the initial conditions in early 2060 and the death cases due to the plague as many as 6000 people. Early models in 2060 are written as \( N(t_1) = 150 \times \exp(0.2 \times 40) - 6000 \). The value of \( N(t_1) \) is the initial amount for determining the number of populations in 2080. The written model was \( N(t_2) = N(t_1) \times \exp(0.2 \times 20) \), with \( N(t_1) = 441,143 \) people.

![Figure 3. Results of S4.](image)

S1 subjects determine the answer to the problem using mathematical steps. The mathematical imaginations that appear are presented in the form of a differential equation model and the steps for
the solution. The information provided from the questions and their solutions is many and communicative in presenting the information. In contrast to other subjects, they are more interested in trying directly to find answers to given mathematical problems. The idea of answering the problem of almost all subjects can do it well. Apart from S2 subjects, all final answers are translated into numerical form as a result of calculations. While the S2 subject only wrote in mathematical form the final result. This result is interesting, because the result of the last number for each calculation is different for each subject, even though with the same initial value $e$. S1 explicitly determines the value of $e=2.72$, while the other subjects do not. The process of doing it is mathematically correct, but the final calculation as a result of the numbers is different. This shows that students' counting skills are still not good, and they are in a hurry. Accuracy in evaluating the answer results is not optimal, especially in cutting and determining decimals. This final result makes the number of populations incorrect in $t+80$ (a problem a), and $t_1$, and $t_2$ (in problem b). The researchers suspected that the subjects did the calculations not using the right tools.

All subjects provide answers in the same way and provide one alternative answer. S1 subjects provide a background to mathematical problems in general. Subsequently developed into a mathematical model of differential equations. Subjects S1, S3, and S4 explain the stages in solving the problem. Meanwhile, S2 performs mathematical operations to determine the final model directly. Subjects S3 and S4 explained the stages of work but did not provide a complete description and narrative as in the S1 subject. Information for each stage is more operational and mathematical in performing calculations. Students are more focused on doing calculations to determine the final answer. Meanwhile, information related to problems and solutions is not completely conveyed. So that the explanation of the calculation results is a mathematical narrative. The form of mathematical problems and the presentation of questions will determine the students' answers. Students are more challenged to provide a lot of information when the question form is contextual [16]. Each student's imagination differs according to their understanding [17-18]. This results in different information conveyed from student work. Good student imaginations (S1) provide more creative answer descriptions [19]. Students with the unobstructed category have a good interaction between the educational environment, intellectual abilities and individual personality traits. So that it can have a major influence on three important components of creativity: expertise, original thinking, and intrinsic motivation which are part of creative potential [20]. Serious math problems keep students from just giving up. Thus, the presentation of the form of open questions and/or story questions gives students a challenge in providing illustrations and answers.

4. Conclusion
Presentation of problems in mathematics provides imagination to students' thinking. Students illustrate problem content and models based on their point of view. The four subjects in this study gave different completion steps (the final results have similarities). Differences in how to convey information from the process and the results of calculations indicate the freedom of students in describing the results of their work. Open mathematical problems are very helpful for students in developing creative attitudes. Students provide information on the results of their work based on experience. The form of presenting mathematical problems stimulates students to develop creative ideas, independent of the final results of the questions from the problem.

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