

## CREATIVE THINKING ABILITIES OF PROSPECTIVE MATHEMATICS TEACHERS IN SOLVING OPEN-ENDED TRIGONOMETRY PROBLEM

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Received 11 December 2022; Received in revised form 28 January 2023; Accepted 20 February 2023

### Abstract

The current technological developments require students to have creative thinking skills. One of the four thinking skills needed in the 21st century is creative thinking skills which is still lacking in students. The purpose of this study was to describe prospective mathematics teachers' creative thinking skills in solving open-ended trigonometry problems. This research is descriptive qualitative research. This study involved 40 prospective mathematics teachers who were then reduced to four subjects based on high and medium mathematical abilities which were studied in more depth in solving open-ended trigonometry problems. The research instruments used in this study were the researcher, interview guide, and open-ended trigonometry questions. The results of colleges work were analyzed based on aspects and levels of creative thinking skills. In this study, the data analysis phase includes data reduction, data presentation, and conclusion. Then triangulated the data in describing the results of the study. The results of this study are that first collegier with high mathematical abilities meet the aspects of fluency and novelty and the second fulfills the aspects of fluency and flexibility. First collegier with medium abilities fulfill the flexibility aspect and the second fulfills the novelty aspect. So, it can be concluded that collegiers with high and medium mathematical abilities were solving open-ended trigonometry problems have a creative level and quite creative.

**Keywords:** Creative thinking; open-ended problem; trigonometry.

### Abstrak

Perkembangan teknologi saat ini menuntut siswa untuk memiliki kemampuan berpikir kreatif. Salah satu kemampuan berpikir yang dibutuhkan dalam abad ke-21 adalah berpikir kreatif yang masih sangat kurang dimiliki oleh siswa. Tujuan penelitian ini adalah untuk mendeskripsikan kemampuan berpikir kreatif mahasiswa calon guru matematika dalam menyelesaikan soal open-ended trigonometri. Penelitian ini merupakan penelitian kualitatif deskriptif. Penelitian ini melibatkan 40 orang mahasiswa calon guru matematika yang kemudian direduksi menjadi empat subjek berdasarkan kemampuan matematika tinggi dan sedang yang dipelajari secara lebih mendalam dalam menyelesaikan soal-soal open-ended trigonometri. Instrumen penelitian yang digunakan dalam penelitian ini adalah peneliti, pedoman wawancara, dan soal open-ended trigonometri. Hasil pekerjaan mahasiswa dianalisis berdasarkan aspek dan tingkat kemampuan berpikir kreatif. Dalam penelitian ini, tahap analisis data meliputi reduksi data, penyajian data, dan penarikan kesimpulan. Kemudian dilakukan triangulasi data dalam mendeskripsikan hasil penelitian. Hasil dari penelitian ini adalah mahasiswa dengan kemampuan matematika tinggi pertama memenuhi aspek kelancaran dan kebaruan dan yang kedua memenuhi aspek kelancaran dan keluwesan. Mahasiswa calon guru matematika dengan kemampuan sedang pertama memenuhi aspek fleksibilitas dan mahasiswa kedua memenuhi aspek kebaruan. Sehingga dapat disimpulkan bahwa mahasiswa calon guru matematika dengan kemampuan matematika tinggi dan sedang dalam menyelesaikan soal open-ended trigonometri memiliki tingkat kreatif dan cukup kreatif.

**Kata kunci:** Berpikir kreatif; masalah open-ended; trigonometri.



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DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

## INTRODUCTION

The development of current technological advances requires a person to be able to adapt to new environments, and to understand and apply new ideas (Leikin & Elgrably, 2022). This progress is supported by the industrial revolution which requires a person to have four thinking skills, one of the skills needed today is creative thinking skills (Permadi & Zakiyah, 2021). Developing creative thinking skills will produce a creative generation that has the potential to solve complex social and environmental problems (Yusnaeni et al., 2017). The ability to create new ideas or solutions in the problem solving process called creative thinking (Hadar & Tirosh, 2019).

The ability to think creatively can be measured from three aspects, namely fluency, flexibility, and novelty (Fadli, 2022; Fardah, 2012). Creative thinking has five levels, namely not creative, less creative, quite creative, creative, and very creative (Siswono, 2010). Everyone's level of creative thinking is different, so it needs to be analyzed more deeply, not only from basic education but also up to tertiary education. The problem that can measure a person's creative thinking ability is an open-ended problem (Restanto & Mampouw, 2018). One way to bring out mathematical creativity in the classroom is to engage students with open-ended problems (Schoevers et al., 2021). Open-ended problems may have more than one correct final answer in addition to several possible solutions (Levenson et al., 2018). Open-ended problems can also be thought of as different assignments, tasks that lead to fluency, flexibility, and originality (Kattou et al., 2013). So to find out someone's

creativity, you should use open-ended questions. Open-ended problems are often used in learning mathematics.

Trigonometry is one of the oldest mathematical materials, having an important role in the mathematics curriculum (Yorganci, 2022). Trigonometry is a branch of mathematical physics that deals with understanding concepts and their applications (Nabie et al., 2018). Based on this description, this research was focused in students' creative thinking abilities in solving trigonometry problems in more depth. The ability to think creatively is needed by prospective mathematics teacher students to see from various points of view. This research will examine the ability to think creatively at the prospective mathematics teacher level and provide a level of student creativity. With open-ended problems, prospective students of mathematics teachers can provide various possible answers and generate new ideas in solving these problems.

Much research has been done on creative thinking but there are still students who have not fulfilled aspects of creative thinking at all. (Damayanti & Sumardi, 2018; Lusiana, 2017; Murtafiah, 2017; Suripah & Sthephani, 2017). This research will provide a level of student creativity to increasing student creative ability in the future. Therefore, the ability to think creatively needs to be studied more deeply. Based on the explanation above, the researcher aims to conduct research with the title "Creative Thinking Ability of Prospective Mathematics Teachers in Solving Open-Ended Trigonometry Problems".

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

## METHODS

This research is a descriptive qualitative research, namely research that uses qualitative data to describe the results of tests of the creative thinking ability of prospective mathematics teacher students. Data collection in this research involved four types of strategies, namely observation, tests, interviews, documentation in audio-visual form (Creswell & Creswell, 2018). In this study, data was collected through pretest, creative thinking ability test, interviews and audio and visual documentation. In this study the instruments used were the researchers themselves, creative thinking test sheets, creative thinking scoring rubrics, creative thinking ability scoring sheets, and semi-structured interview guidelines. Semi-structured interviews are used as additional data and aim to develop questions according to the results of the work of each subject studied in more depth. The scoring guidelines are contained in the scoring rubric which includes three indicators of creative thinking, namely fluency, flexibility, and novelty (Siswono, 2016).

This research was conducted on undergraduate students in Mathematics Education, Universitas Negeri Malang, class of 2022 in odd semester of the 2022/2023 academic year. The creative thinking ability test was given to 40 students, then four students with high mathematical abilities were selected as many as two people and students with medium mathematical abilities as many as two people. The subjects in this study consisted of four students in the high and medium categories based on the score of the previous assignment (pretest). The selection of subjects with different categories of mathematical abilities was due to the different

mathematical abilities of each prospective mathematics teacher in the class. Besides that, the aims was to find out how the creative thinking skills of prospective mathematics teacher students are based on mathematical abilities in the pretest. The selection of each category is taken based on the pretest that has been done. The categories of mathematic ability of prospective mathematics teacher and their numbers are shown in Table 1.

Table 1. The mathematics ability category of prospective mathematics teacher

Score Range	Category	Total collegers
$N > 90$	High	4
$70 < N \leq 90$	Medium	26
$N \leq 70$	Low	10

Based on Tabel 1, the pretest results of each category, two students were selected to be used as research subjects. It aims to obtain accurate data on each category which will be analyzed further. The creative thinking ability test is administered during the 1st week of lectures in November 2022. The trigonometry problem used is considered suitable for exploring creative thinking skills in this study because it is an open-ended problem so it can be used as a problem with a non-single solution or has many correct answers. The problems was determine the angular speed in real life given as follows: *“One gear wheel turns another gear on the rims. The smaller toothed wheel rotates at 20 rpm (radians per minute). Determine the various possible angular velocities of the larger gear”*.

In this study, prospective mathematics teachers were given a creative thinking ability test for 20 minutes. After determining the subject,

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

the researcher analyzed the creative thinking skills of the mathematics teacher candidate students. Then conducted interviews with the research subjects. The data analysis technique used consisted of three stages, namely data reduction, data presentation, and conclusion. At the data reduction stage, the researcher simplifies, classifies, and removes unnecessary information. The results of the analysis formed in pictures and narrative text. In the final stage, namely the conclusion stage, the researcher concludes all the data and facts that have been obtained based on the theory and previous studies. The validity of the data carried out in this study was data triangulation, namely comparing the results of tests of creative thinking skills and the results of interviews.

Here are presented aspects of creative thinking adapted from (Siswono, 2016) in Table 2 and indicators of the level of ability to think creatively according to (Siswono, 2016) are presented in Table 3.

Table 2. Aspects of creative thinking ability

Aspects	Indicator
Fluency	a) Give lots of ideas or ideas in solving the problem
	b) Give relevant answers correctly and clearly
Flexibility	a) Give many varied ideas or ideas
	b) Give relevant answers more than one answer
	c) Look at the problem from various points of view
Novelty	a) Give ideas or ideas that are different from the others
	b) Solve problems using new ways and generate unusual answers

Table 3. Creative thinking ability level

Levels	Description
4 Very Creative	Fulfills the aspects of creative thinking, namely fluency, flexibility, and novelty or novelty and flexibility.
3 Creative	Fulfills the aspects of creative thinking, namely fluency and flexibility or fluency and novelty.
2 Quite Creative	Fulfills aspects of creative thinking, namely flexibility or novelty.
1 Less Creative	Fulfills the aspect of creative thinking, namely fluency.
0 Not Creative	Does not meet the three aspects of creative thinking, namely fluency, flexibility, and novelty

## RESULT AND DISCUSSION

The subjects in this study consisted of four prospective mathematics teachers who were selected based on the mathematical abilities of the pretest. The selection was based on students' mathematical abilities in solving trigonometry problems by selecting two students with high mathematical abilities and two students with medium mathematical abilities.

After giving the pretest, students were given a creative thinking test about trigometry. Creative thinking skills that are given have three aspects, namely fluency, flexibility, and novelty. The aspect of fluency is an aspect that refers to a person's ability to give as many correct answers as possible. The aspect of flexibility is an aspect that refers to a person's ability to provide answers in various ways and from various points of view. The novelty aspect is an aspect that refers to a person's ability to provide answers that are unique and different from others (Siswono, 2016).

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

The first prospective mathematics teacher with high mathematical ability was given the code SH1, the second prospective mathematics teacher with high mathematical ability was given the code SH2, the first prospective mathematics teacher with medium mathematical ability was given the code SM1, and the second prospective mathematics teacher with medium mathematical ability was given the code SM2. Prospective mathematics teachers with low mathematical ability categories are not described further because students in this dominant category only fulfill one aspect of creative thinking, namely fluency, there are even students who do not fulfill aspects of creative thinking at all or at a non-creative level. So that the data analyzed in this study focused on prospective mathematics teachers with high and medium mathematical abilities. Data and discussion regarding the creative thinking abilities of prospective mathematics teachers are described as follows.

The first prospective mathematics teacher with high mathematical abilities give answers as shown in Figure 1. Based on Figure 1, the results of the work of the first high-mathematics ability prospective mathematics teachers show that SH1 gives the answer to rotation from angular velocity. This is unique because of all student, only SH1 seeks rotation from the gears first. The answer given by SH1 which is able to provide a novelty aspect was a natural thing considering that his mathematical ability was included in the category of high mathematical ability. In addition, SH1 can determine the angular velocity of large gear wheels by doing the example correctly so that SH1 meets the aspects of novelty and fluency but did not meet

the aspects of flexibility. This is because SH1 only provides one possible answer for the angular velocity of the large gear.

$\omega_1 = \omega_A = 20 \text{ rpm (rotasi per Minute)}$   
 Dit.  $\omega_b = ?$   
 Dik.  $\omega_A = \frac{r}{t}$   
 $20 = \frac{r}{60}$   
 $r = 1200$   
 $r_2 = 1200 - (2 \cdot 260)$   
 $= 1200 - 520$   
 $= 680$   
 Dik.  $\omega_b = \frac{r}{t}$  atau  $\omega_b = \frac{1}{2} \cdot \frac{r}{t}$   
 $= \frac{2 \cdot 680}{60}$   
 $= \frac{1360}{60}$   
 $= 22.66$   
 $= 23 \text{ rpm}$   
  
 $v = r \cdot \omega$  maka:  $\omega = \frac{v}{r}$   
 $= 1 \cdot 20$   
 $v = 20 \text{ rpm}$   
 Dik.  $v = \frac{2 \cdot r}{t}$   
 $v = 2 \cdot 20$   
 $= 40$   
 $\omega = \frac{v}{r}$   
 $= \frac{40}{2}$   
 $= 20$   
 $= 20 \text{ rpm}$

Figure 1. The answer of first high-mathematics ability student

This description is also adjusted to the results of the researcher's interview (R) with SH1. Based on the results of the interview with SH1 obtained that subject find difficulty answer the questions. SH1 stated that confused to determine the angular speed of the large cleats. Then SH1 remembered the formula for determining angular velocity. After that SH1 determined the rotation ( $\theta$ ) and the angular velocity of the large wheel. SH1 determined the angular velocity using relationship between linear speed and angular speed.

SH1 supposed that the radii are different and find the angular velocity of the two wheels. Then determined the

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

speed of each cleat. SH1 stated that there were many possible radii of the two cleats and the speed was same. But SH1 just written one answer because his thought that after getting the same speed it was correct. The results of interviews with SH1 show that SH1 does not fulfill the aspect of flexibility because SH1 thinks only one answer is enough to answer the problem. This indicates that SH1 is less careful in understanding the problem given. This could be happened because the subject was accustomed to answering questions with one answer without paying attention to the questions given.

Based on the results of SH1's job description and the results of interviews conducted, SH1 has the ability to think creatively at level 3, namely creative because it fulfills aspects of fluency and novelty. This is different from research (Nugraheni et al., 2021) which found that students with high mathematical abilities fulfill all aspects of creative thinking because SH1 only fulfills aspects of novelty and fluency. The results of the work of prospective mathematics teacher with the second high mathematical ability (SH2) are presented in Figure 2.

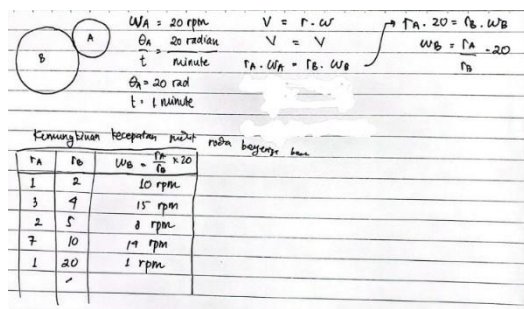


Figure 2. The answer of second high-mathematics ability student

Based on Figure 2, the results of the second high-ability prospective mathematics teachers' work show that SH2 can find new equations from

formulas that are known correctly. It can be said that SH2 fulfills the fluency aspect. In addition, SH2 can determine the angular velocity of the large gear wheel by giving five different correct answers based on the formula that has been obtained so that SH2 fulfills the flexibility aspect. However, SH2 does not meet the novelty aspect. This is because SH2 cannot provide unique answers compared to other prospective mathematics teachers.

This description is also adjusted to the results of the researcher's interview (R) with SH2. Based on the results of the interview with SH2 obtained there was important information from the problem that speed of two wheels was the same. SH2 stated that if there are two circles that intersect, they rotate together, the time to rotate and the linear speed are also the same. SH2 wrote down 5 possible answers because there were many possible answers that can be obtained. When the subject asked where did he get the formula and did this formula apply in general, SH2 answered that he gets those formula based on the linear speed formula in terms of the angular velocity of the two gear wheels by substituting the known angular velocity. The formula applies to this problem only because the angular velocity values of the other cleats have been determined. SH2 didn't know the other solution but believed that there was more than one solution.

The results of interviews with SH2 show that SH2 does not meet the novelty aspect because it does not produce new and unique answers than other prospective mathematics teachers. SH2 states that there is another way to solve it but doesn't know the other way. This could be happened because the subject only solves the question in a way that has been learned and did not

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

want to explore further about other ways that can be used to solve the problem.

Based on the results of SH2's job description and the results of interviews conducted, SH2 has the ability to think creatively at level 3, namely creative. This is because SH2 only fulfills the aspects of fluency and flexibility. The results of the work of the first prospective mathematics teacher with medium mathematical ability (SM1) are presented in Figure 3.

diketahui : $\omega_K$	= 20 rpm	= 120 cps
$r$ roda kecil = 2		
$r$ roda besar = 4		
$\omega_B = \omega_K$		$\omega_B = \omega_K$
$\omega_B \cdot r_B = \omega_K \cdot r_K$		$\omega_B \cdot r_B = \omega_K \cdot r_K$
$\omega_B \cdot 4 = 20 \cdot 2$		$\omega_B \cdot 4 = 20 \cdot 2$
$\omega_B = 40/4$		$\omega_B = 240/4$
$\omega_B = 10 \text{ rpm}$		$\omega_B = 60 \text{ rps}$

Figure 3. The answer of first medium-mathematics ability student

Based on Figure 3, the results of the work of first medium mathematical ability prospective mathematics teacher show that SM1 can determine two angular velocities with different units. It can be said that SM1 fulfills the flexibility aspect. However, SM1 does not meet the aspects of fluency and novelty. This was because SM1 was wrong in giving the initial equation and could not provide a unique answer than other prospective mathematics teachers. Some of the factors that might be influence were students didn't understand the concept well of solving the trigonometric problem and couldn't give another solution.

This description is also adjusted to the results of the researcher's interview (R) with SM1. Based on the results of the interview with SM1 obtained the formula  $\omega_B = \omega_K$  in the first row not the same as in the second row because in the first answer, SM1 answered

according to the units in the question, for the second answer changed the units to  $\frac{rad}{s}$ . SM1 stated that didn't knew another possible answer. SM1 got the spokes of the toothed wheels by made it so that it's easy to find the answer. First subject with medium mathematics ability stated maybe there were another solution but didn't knew it.

The results of the interview with SM1 add to the information related to the answers given by SM1. SM1 did not understand where the formula used in solving the problem came from so it did not meet the fluency aspect. Prospective mathematics teacher with medium mathematical abilities fulfill the aspect of flexibility because they can give two answers with different units. In addition, SM1 does not know whether there is another solution, so it does not fulfill the novelty aspect. Based on the results of SM1's job description and the results of the interviews conducted, SM1 did not really understand the formula used to solve the problem and was able to provide answers with various units. It can be occurred because student didn't pay attention in study or they have misunderstood about the information in the problem given. So, that SM1 has the ability to think creatively at level 2, which is quite creative. This is because SM1 only fulfills the flexibility aspect. The results of the work of prospective mathematics teacher with second medium mathematical ability (SM2) are presented in Figure 4.

$\omega = \frac{v}{r}$	
$\omega = \frac{v}{r}$	
$\omega = \frac{v}{r}$	
10 rpm = $\frac{v}{r}$	misal r, nya a : $\omega = \frac{v}{r} = \frac{v}{a}$ r nya 40 cm
$\omega = \frac{v}{r}$	r, nya 20 : $\omega = \frac{v}{r} = \frac{v}{20}$ r nya 20 cm

Figure 4. The answer of second medium-mathematics ability student

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

Based on Figure 4, the results of the work of prospective mathematics teacher with medium mathematical abilities show that SM2 can create new formulas based on the formulas that have been learned and provide answers that are different from other prospective mathematics teachers. It can be said that SM2 meets the novelty aspect. However, SM2 does not meet the aspects of fluency and flexibility. This is because SM2 does not provide a clear answer regarding the solution to the problem. SM2 also didn't provide the various answers properly and clearly.

It can be happened because some factors like student had some misunderstood about the concepts and didn't read the problem well. This description is also adjusted to the results of the researcher's interview (R) with SM2. Based on the results of the interview with SM2 obtained that there was difficulty to solve the problem. SM2 confused about how many fingers there are. SM2 stated that got the formula by trying to substitute the formulas that that have been learned by using the example  $r_{small} = a$  and  $r_{big} = 2a$ . So that  $s$  and  $t$  are equal. Then the continuation of the formula wasn't finish because SM2 confused about the radius so he just said  $a$ . When SM2 were asked were there definite solution for the speed of the big wheel. SM2 confused and didn't knew the others solution about the problem.

The results of the interview with SM2 added information regarding the answers given by SM2, namely that the student could only make a formula to solve the problem. This means that SM2 fulfills the novelty aspect. But SM2 is confused in determining the spokes of the cog wheels. So that SM2 cannot get the final answer so it does not fulfill the aspects of fluency and flexibility.

Based on the results of SM2's job description and the results of the interviews conducted, SM2 did not understand the problem well. So that SM2 has the ability to think creatively at level 2, which is quite creative. This is because SM2 only fulfills the novelty aspect. Some of the factors that might influence the results of student work are students' lack of understanding of the material and students who are used to working on routine questions that only have a single solution.

Based on the explanation regarding the creative thinking abilities of the first and second high-ability prospective mathematics teacher, they have the same level of creative thinking, namely level 3 which means creative, so that it can be said that high-ability prospective mathematics teachers are creative. Prospective mathematics teachers with the first and second categories of medium mathematical ability have the same level of creative thinking, namely level 2 which means quite creative so that it can be said that prospective mathematics teachers with medium abilities are quite creative. This is different from research (Kattou et al., 2013) which states that students with high mathematical abilities are the most creative. Prospective mathematics teachers with medium mathematical abilities have an average level of creativity and prospective mathematics teachers with low mathematical abilities have a low level of creativity. The results of this study are in line with research (Arilaksmi et al., 2021), namely students with high mathematical abilities have a creative level.

Findings on the results of the students work obtained differences in the creative thinking abilities of students with high mathematical abilities and students with medium

DOI: <https://doi.org/10.24127/ajpm.v12i1.6676>

mathematical abilities, which was from the level of student creativity and the creative thinking aspects of each student are different. But there were similarities, students only fulfill some aspects of creative thinking. Which means not all students can get the fluency, flexibility, and novelty aspects in solving open-ended trigonometric problem.

The advantage of this study is it can determine the creative thinking skills of mathematics students in solving open-ended trigonometry questions by knowing the causative factors and the level of student creativity. But there are still a number of things that need to be improved, like the need to look at students' creative thinking processes in working on these open-ended trigonometry questions. The impact of this research is to be able to find out how students solve an open-ended trigonometry problem by knowing their level of creativity. The contribution of this research is to accustom students to solving non-routine open-ended questions.

## CONCLUSION AND SUGGESTION

Based on the description of the creative thinking abilities of prospective mathematics teachers in solving open-ended trigonometry problems, it can be concluded that in this study prospective mathematics teacher with high mathematical abilities and medium mathematical abilities had some different in solving open-ended trigonometric problem because they had different aspect of creative thinking. Prospective mathematics teacher with high mathematical abilities obtained a creative level. Prospective mathematics teachers with medium mathematical abilities obtained quite creative levels.

In future research, it is suggested to be able to take a deeper look at the factors that influence the creative thinking abilities of prospective mathematics teachers and to be able to provide solutions to improve the creative thinking abilities of prospective teachers in various subjects.

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