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Students Activities in Solving Pythagoras Theorems Using Desmos Application

Hilaria Yesieka Ayu Wulandari [1], Tatag Yuli Eko Siswono[2]

[1,2] Universitas Negeri Surabaya, Kampus Ketintang Surabaya 60231, Indonesia
Email: hilariayesieka.20026@mhs.unesa.ac.id

Abstract

This study aims to describe the creative thinking skills of students in solving problems related to the Pythagorean Theorem using Desmos application. This descriptive research involved 3 Junior High School students in grade 9 in Sidoarjo (Indonesia) who each had high, medium, and low ability backgrounds. The task in the form of questions consisted of two questions asking students to create two different triangles. The results of the analysis showed that high-ability students were able to create two different triangles if they were given sides 3 and 4 in the form of a right triangle and an equilateral triangle. Students with moderate and low abilities were able to draw right triangles with Desmos, but had difficulty drawing isosceles triangles. Both of them drew an isosceles triangle, but with side lengths of 3, 4, and 6. These results illustrate that the use of Desmos helps students' ideas in finding answers in drawing triangles, but the basic abilities that students have can be an obstacle in completing the given tasks.
Keywords: learning activity, Pythagoras Theorem, Desmos

Abstrak

Penelitian ini bertujuan untuk mendeskripsikan kemampuan berpikir kreatif siswa menyelesaikan soal terkait teorema phytagoras menggunakan aplikasi desmos. Penelitian deskriptif ini melibatkan 3 siswa Sekolah Menengah Pertama kelas 9 di Sidoarjo (Indonesia) yang masing-masing memiliki latar belakang kemampuan tinggi, sedang, dan rendah. Tugas berupa soal terdiri dua pertanyaan yang meminta siswa membuat dua buah segitiga yang berbeda. Hasil analisis menunjukkan siswa kelompok tinggi dapat membuat dua segitiga berbeda jika diketahui sisinya 3 dan 4 berupa segitiga siku-siku dan segitiga sama sisi. Siswa kemampuan sedang dan rendah dapat menggambarkan segitiga siku-siku dengan desmos, tetapi kesulitan dalam menggambar segitiga sama kaki. Keduanya menggambarkan segitiga sama kaki, tetapi ukuran sisinya, 3, 4, dan 6. Hasil ini menggambarkan penggunaan desmos membantu ide siswa menemukan jawaban dalam menggambar segitiga tetapi kemampuan dasar yang dimiliki siswa dapat menjadi kendala menyelesaikan tugas yang diberikan.
Kata kunci: aktivitas belajar, Teorema Phytagoras, desmos

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Introduction

Creative thinking is a crucial element in modern education (Fadlilah et al, 2021). It plays a significant role in the advancement of science, technology, and social activities and in resolving conflicts (Dilekçi & Karatay, 2023). Creative thinking enables individuals to view situations from multiple perspectives, communicate effectively, and collaborate with different stakeholders with diverse interests. This fosters a positive work environment and enhances productivity in daily work(Qadri et al., 2019). Creative thinking is a series of cognitive activities carried out by individuals related to problem solving on certain objects and conditions using their own abilities. Creative thinking can also be interpreted as an effort toward solving certain events and problems based on individual capacity(Aurelia, 2021). In addition, creative thinking is the ability to generate new ideas or solutions to a problem (Hadar & Tirosh, 2019). The process of creative thinking ability is carried out by their efforts to use and optimize their imagination, knowledge, and skills when they face a particular problem (Jagom et al., 2021).

Creative thinking can also be described as the ability to generate new ideas or solutions in the problem-solving process(Suherman & Vidákovich, 2022). This creative thinking ability becomes important when facing a problem, especially in mathematical problems. Currently, mathematical problems are not just about memorizing multiplication or formulas but also emphasize students' understanding of the mathematical problems given (Asriningsih et al., 2018). Therefore, in solving problem, critical, creative, and logical thinking skills are needed to solve the given problems. One of the mathematical learning materials that can test creative thinking ability is the Pythagorean Theorem. The Pythagorean Theorem states that in a Right-angle triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides. To master the Pythagorean Theorem, it requires ideas about angles and trigonometry (Dwi et al., 2022). Therefore, to solve it requires the ability to process and analyze problems and solve them with their own abilities. Several aspects measured in creative thinking behavior can be seen in Table 1.

Tabel 1. Indicators of Creative Thinking Ability

No.	Aspects	Indicators
1.	Fluency	• Able to generate/express several relevant ideas/answers • Smooth flow of thought.
2.	Flexibility	• Generating diverse ideas • Ability to change ways or approaches • Different directions of thought.
3.	Novelty	• Providing a logical answer that is different from others

However, the conditions in the field indicate that students' creative thinking abilities in Indonesia are still relatively low, which is less than 50% (OECD, 2023).These results are also supported by research findings that state that some Indonesian students still find it difficult to complete PISA (Programme for International Student Assessment) questions. Students are still not accustomed to facing questions that require creative thinking skills, so the answers produced often do not show success in fulfilling the indicators of creative thinking ability(Yuniarti et al., 2021). Another factor is the lack of understanding of teachers regarding the forms of mathematical problems that require creative thinking skills, so the questions given tend to be closed-ended (Gisbtarani & Rianasari, 2021). To stimulate and develop students' creative thinking abilities, interesting learning methods need to be designed and developed for students, one of which is by using technology (Samura et al., 2021).

Desmos is a web-based software or application that is an innovation in mathematics learning today. Desmos can be easily and freely accessed by visiting the website https://www.desmos.com on a search engine. Desmos has various features that can be accessed by both teachers and students to support learning activities in the classroom (Ramadani et al., 2023). The flagship feature of Desmos is the classroom activity, which provides facilities for teachers to organize how learning activities in the classroom will run because they can add material, questions, or display media that support learning (Nuri et al., 2023). Using Desmos allows interactive visualization of triangles and the relationships between their sides, aiding

understanding of the Pythagorean theorem. Students can change the value of a triangle's side and immediately see changes in the length of the other side and the Pythagorean value, making exploration and experimentation easier(Simanungkalit & Rajagukguk, 2022).

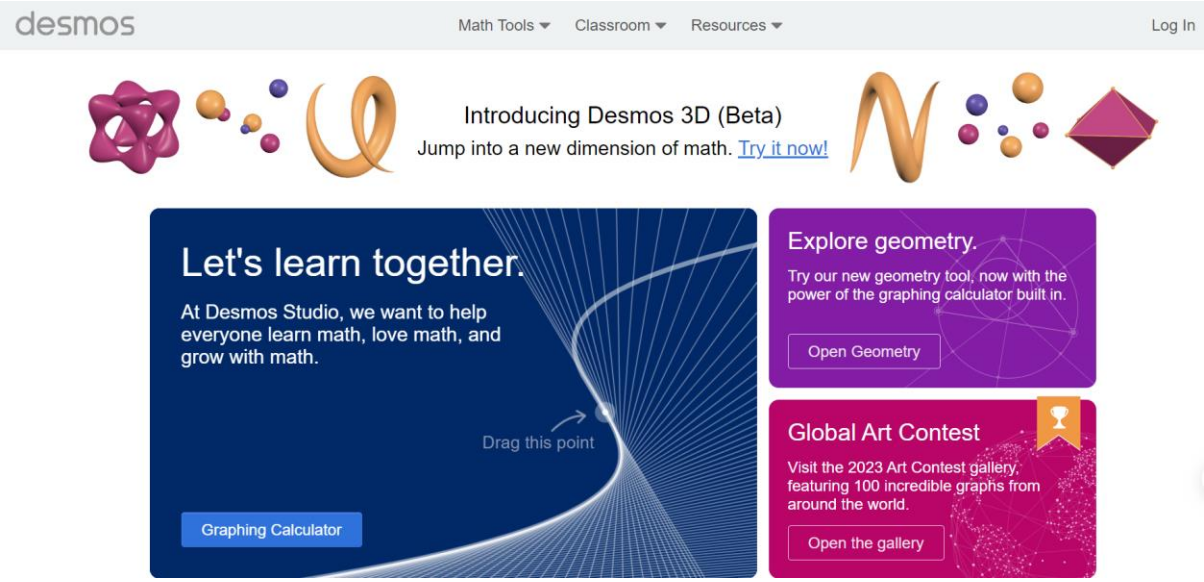

Figure 1. Front Page of Desmos

Therefore, this study aims to conduct an in-depth investigation of student activities in learning Pythagoras using Desmos applications related to creative thinking ability.

Method

This research uses a case study method where the researcher presents systematic and accurate research results in presenting phenomena and facts. Additionally, the researcher also used qualitative research methods that tend to focus on the process rather than the results. Before selecting the students, who will participate in the interview session, a test was conducted on 34 ninth-grade students from a junior high school in Sidoarjo. The students had different backgrounds in terms of gender and mathematical ability. The test consisted of five items that examined their mathematical ability, specifically related to the concept Pythagoras Theorem. The students were given 45 min to complete the test and were informed that their work would not be graded so that they could use their own methods to solve the tasks.

The results of the test indicated that mostly all of them were in the group of moderate achievers (score >70 out of 100), others in the group of high achievers (score >85 out of 100), and some students in the group of low achievers (score <65 out of 100) based on their written test performance. Afterward, the scores obtained by students from the initial ability test were collected to select three subjects. Additionally, to ensure the selection of appropriate subjects, we also verified their mathematics performance data. The subjects consisted of three students, each of whom came from the high, medium, and low categories based on the results of the initial ability test. The subjects were then given a creative thinking ability test, which was designed and consulted with by the supervisor. In the first stage, the students will first work on the creative thinking ability test, and then the results of the test will be

analyzed and compared with the results of the initial ability test. In this research, desmos is used as a medium that can help students to solve problems regarding the Pythagorean Theorem related to students' creative thinking abilities. After the three students have completed the creative thinking ability test, the researcher will conduct interviews to gather information about their learning experiences while working on the creative thinking ability test using Desmos software.

Result and Discussion

Research on students' creative thinking abilities was conducted on Tuesday, November 22, 2022, with a population of 30 students in the ninth grade. As an initial assessment, students will be given a sheet containing 4 questions to measure their understanding of Pythagorean theorem. After the 30 students complete the assessment, the collected scores will be analyzed to determine the high, medium, and low categories. The data obtained is as shown in Table 4.

Table 2. Initial Ability Test Category Grouping Results

Interval	Category	Students
$x \geq (\bar{x} + SD)$	High	3
$(\bar{x} - SD) < x < (\bar{x} + SD)$	Medium	20
$x \leq (\bar{x} - SD)$	Low	7

Therefore, based on these results, 3 subjects were selected for further research on creative thinking abilities using the Desmos software.

Table 3. Selected subjects

Subject Code	Score	Category
S31	90	High
S14	80	Medium
S17	57	Low

The three selected subjects were then given a creative thinking test and an interview. The test administered consisted of creative thinking questions related to Pythagorean theorem. Below are the questions in the creative thinking test:

> It is known that the length of the two sides of the ABC triangle is 3 cm and 4 cm.
> 1.Specify the type of triangle that can be formed!
> 2.Make at least two answers to solve the problem!

This results obtained and the corresponding explanations as per the creative thinking test using Desmos:

1. Analysis of the results from S31

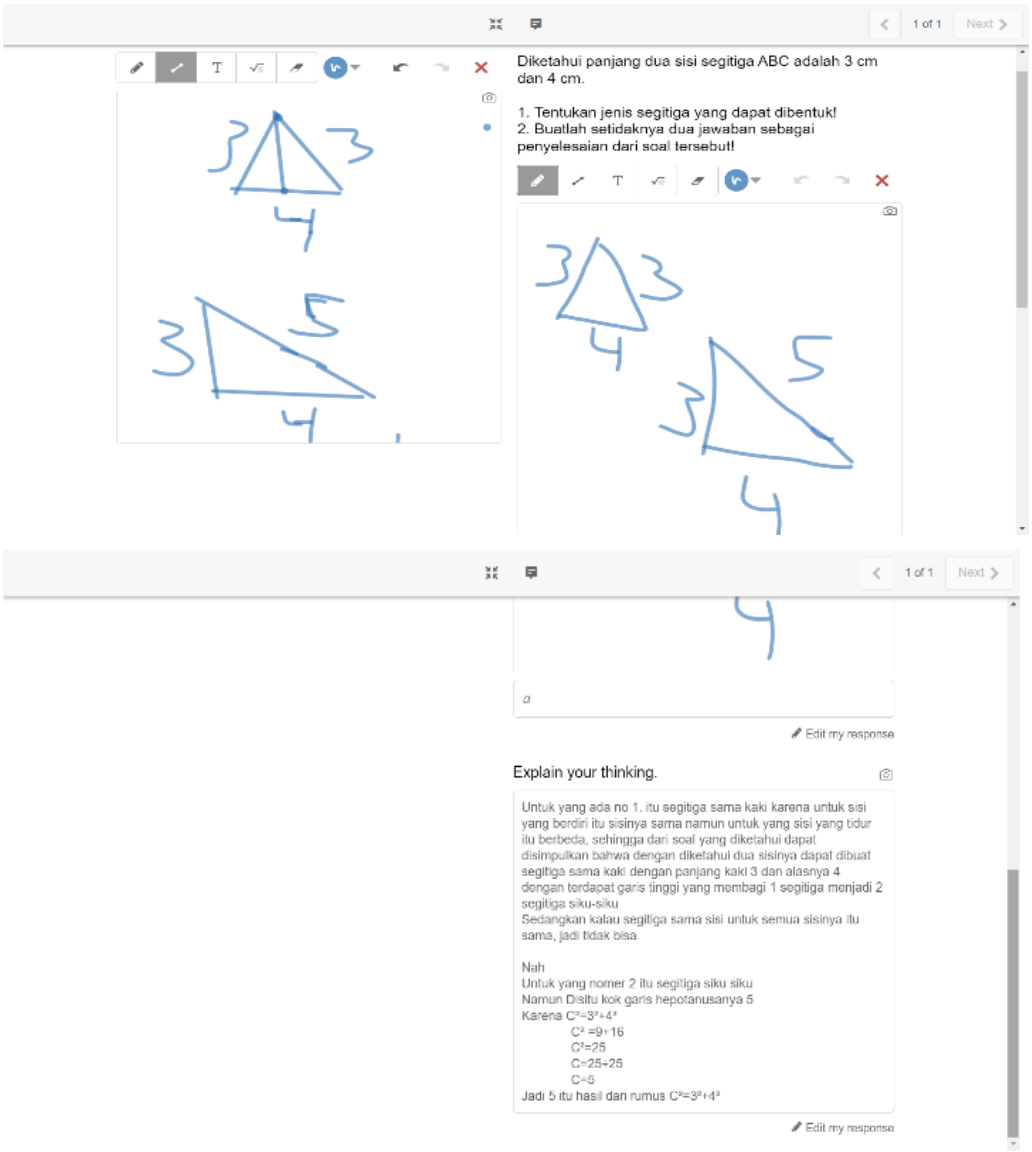

Figure 2. Work Results of S31 in Desmos

In accordance with the results obtained, S31 subjects can solve problems and can explain the process carried out to obtain answers very clearly. Table 4 is the result of interviews with subject S31 to identify the creative thinking process of subject S31.

Table 4. Results of Interviews with S31

Indicator	Question	Answer
Fluency	From the statement given, what can you understand?	There is a triangle, namely ABC which has a side length of 3 cm and 4 cm
Fluency	If you understand, try to explain what was instructed in the first question!	So, from the statement of triangles with a length of 3 cm and 4 cm we have to determine what triangles can be made of the length of the known side earlier

Flexibility	What triangles can you create?	Right angle triangles and isosceles triangles
Flexibility and Novelty	Why do you think that right and isosceles triangles can be formed from the statements given?	So, the first thing I tried was for this isosceles triangle I think it can be if you use the 3 cm and 4 cm sides and if the Right-angle triangles you can because you have been taught about Pythagoras
Fluency and Novelty	Okay, explain your steps to obtaining an isosceles triangle!	So, for the isosceles triangle, I use the notion of an isosceles triangle, which is the same leg length, so in my opinion it can be formed an isosceles triangle from side lengths of 3 cm and 4 cm, with a leg length of 3 cm and a base of 4 cm. Then, I thought about making an equilateral triangle, but it didn't happen because the definition of an equilateral triangle is that the sides must be equal in length.
Fluency	Okay, good. Then for the Right-angle triangles, how do you get it?	This is the side length of 3 cm and 4 cm, now as I remember it is 3 and 4 that can be used as Pythagorean triple. Well, after I tried to enter it using the Pythagorean formula, it turned out to be correct. So, the sides are 3 cm, 4 cm, and 5 cm as the hypotenuse

Based on the analysis of the results of answers and the results of interviews conducted with S31 which were adjusted to the achievement of the indicators of creative thinking ability, subjects were able to achieve the three indicators that had been set, namely thinking fluently, thinking flexibly, and thinking originally very well. In the indicator of fluent thinking, S31 subjects are able to express ideas that are relevant to the given problem.

Similarly, at the beginning the subject is able to understand and grasp the meaning of the available statements and questions given. Students can quickly understand and look for ideas on how to solve the problem. In the indicator of flexible thinking, the subject is able to think of diverse ideas and change the direction of approach in solving problems very well. The resulting ideas listed in the answer description can also be explained well. The subject can also explain in detail about how to get the answers given and still remember the material that has been taught about flat building so that they can apply it to work on existing problems.

In the answer sheet, the subject only describes simply, but when interviewed, Subject S31 can explain in detail and precisely according to what he understands and no misconceptions occur. In the initial aspect, the subject was able to provide a logical answer that had never been thought of by other subjects regarding how subject S31 obtained an isosceles triangle using height lines. The subject can also explain his reasons why he uses the high line in his attempt to prove that from a given statement an isosceles triangle can be formed. Despite there were doubts regarding the use of the height line, after receiving reinforcement from the researcher, the subjects were finally convinced that they could use the height line in an isosceles triangle.

2. Analysis of Results from S14

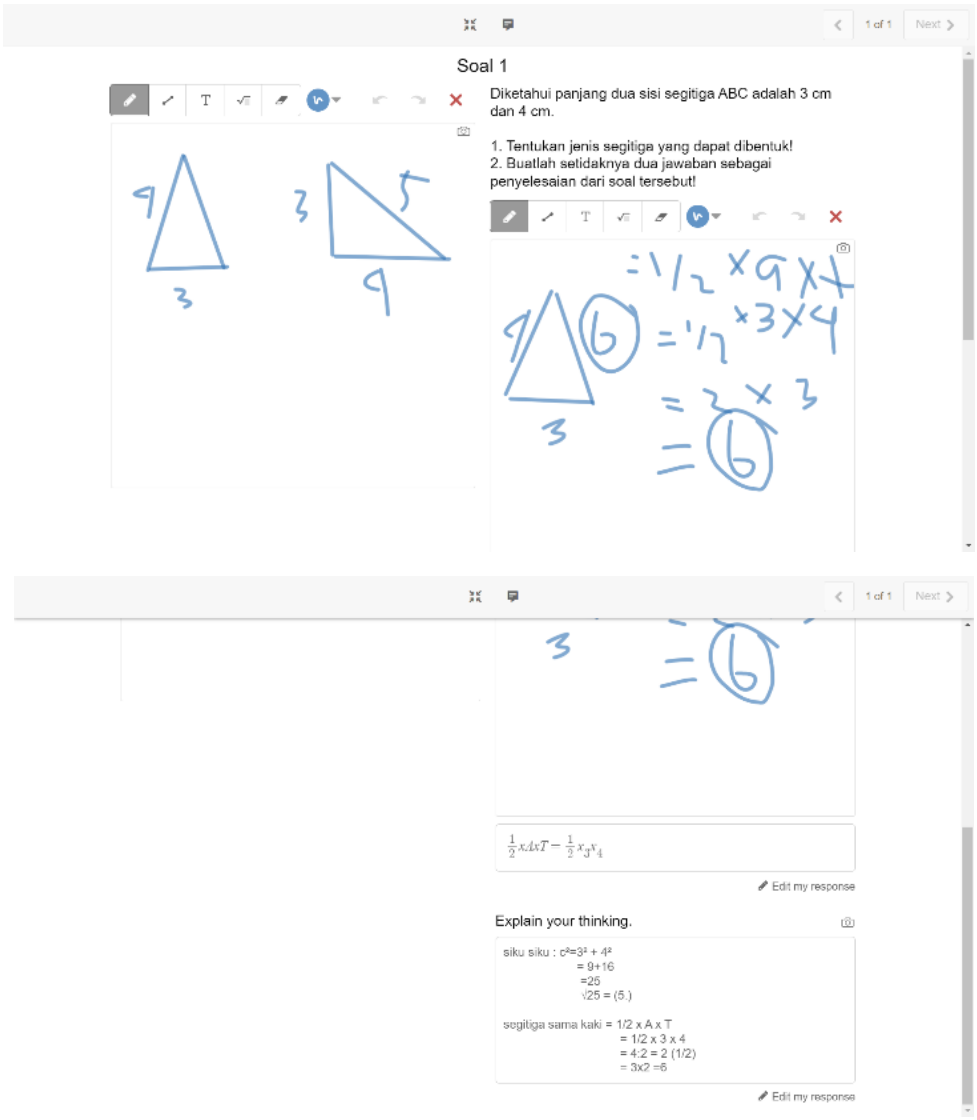

Figure 3. Work Results of S14 in Desmos

In accordance with the results obtained, S14 subjects can solve problems and can explain the process carried out to obtain answers clearly. Table 5 is the result of interviews with subject S 14 to identify the creative thinking process of subject S14.

Table 5. Results of Interviews with S14

Indicator	Question	Answer
Fluency	From the statement given, what can you understand?	So, basically there is a triangle whose side length is 3 cm and 4 cm
Fluency	If you understand, try to explain what was instructed in the first question!	From the known side of 3 cm and 4 cm, what triangle can be formed
Flexibility	What triangles can you create?	Right-angle triangles and isosceles triangles
Flexibility and Novelty	Are you sure from what is known that 3 cm and 4 cm can be made Right-angle triangles and isosceles triangles?	Sure brother, I tried and found that isosceles triangles and Right-angle triangles can be formed.

Fluency and Novelty	Okay, explain your steps to obtaining an isosceles triangle!	For those isosceles triangles I tried to draw a regular triangle first, then insert the sides. The left one is 4 cm and the lower one is 3 cm. Well then, for the other side I use the formula that $\frac{1}{2}\ x\ a\ x\ t$. So a is 3 then t is 4 and meet 6. So, the sides 3, 4, and 6
Fluency	Why do you use the area formula to find the length of one side?	Because I am confused about what way to use the other side and what I know is that triangles use formulas $\frac{1}{2}\ x\ a\ x\ t$.
Fluency	Okay, if it's for a right-angle triangle, how do you get it?	I once remembered that 3 and 4 could be calculated using the Pythagorean formula. So, I tried to use the usual Pythagorean formula. After calculation, it turns out that the Right-angle triangles formed has 3 cm, 4 cm, and 5 cm sides obtained from calculations with the formula.

Based on the analysis of the results of the answers and the results of interviews conducted with S14 which were adjusted to the achievement of the indicators of creative thinking ability, subjects were able to achieve the three indicators that had been set, namely thinking fluently, thinking flexibly, and thinking originally well even though there were still some notes that had to be straightened out. In the indicator of fluent thinking, the subject can show his ability in terms of expressing ideas that he considers relevant to the given problem.

After reading the statements and questions asked, the subject can understand what the intention conveyed, but to jump into the work step, the subject needs to validate first to the researcher regarding his understanding. After getting further validation and explanation from the researcher, the subject then began to try to do the given problem by drawing sketches on the Desmos answer sheet. On indicators of flexible thinking, the subject can reasonably think about diverse ideas. The subject is able to determine that from the given statements can be formed isosceles triangles and Right-angle triangles. However, when researchers tried to ask and examine the written answers, it turned out that the subject experienced a misconception when looking for one side of the isosceles triangle.

The subject uses the area formula when finding the length of the side of an isosceles triangle. When asked the reason why using the formula, the subject assumed that it could be used to find the length of the side of an isosceles triangle. On indicators of original thinking, the subject has not demonstrated his ability to express logical answers that are different from others. When asked questions related to the difficulties experienced, the subject initially doubted whether there were other triangles formed and after experimentation, finally the subject was able to find out that there were other triangles that could be formed.

3. Analysis of Results from S17

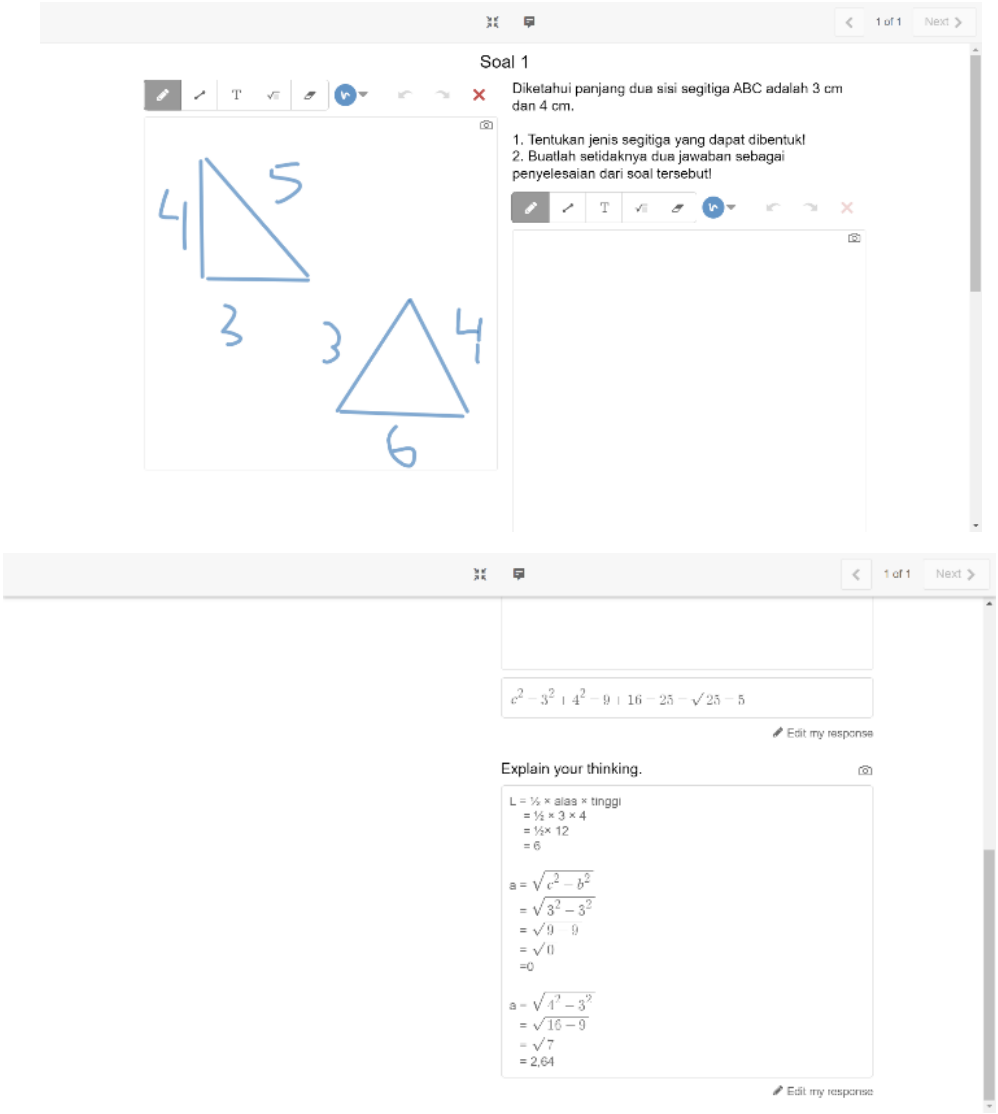

Figure 4. Work Results of S17 in Desmos

In accordance with the results obtained, the subject of S17 is quite able to solve the problem and explain the process carried out to obtain answers quite clearly. However, in the process the subject of S17 suffered from related misconceptions. Table 6 is the result of interviews with subject S17 to identify the creative thinking process of subject S17.

Table 6. Results of Interviews with S17

Indicator	Question	Answer
Fluency	From the statement given, what can you understand?	It is known that the length of the two sides of the ABC triangle is 3 cm and 4 cm.
Fluency	If you understand, try to explain what was instructed in the first question!	The first question asks what triangles can be formed from what is already known
Flexibility	What triangles can you create?	Right-angle triangles and isosceles triangles
Flexibility and Novelty	Why do you believe that Right-angle triangles and isosceles	If it is a Right-angle triangle, I believe the problem can be calculated using the Pythagorean formula. Well, if the Right-angle

	triangles can form? What about equilateral triangles?	triangles was actually confused earlier, this also became an isosceles triangle or equilateral triangle.
Fluency	Okay. Now explain in advance how you got these Right-angle triangles!	I use the direct Pythagorean formula which $c^2 = a^2 + b^2$. First, I draw the triangle using sides 3 cm and 4 cm. Then the hypotenuse is entered into the Pythagorean formula and meets the hypotenuse 5 cm.
Fluency and Novelty	Okay, then what about the isosceles triangle ones? Try to explain the results of your calculations as well!	For the isosceles triangle, I first drew the triangle. Then you have to know the other side and I calculate it using the formula $\frac{1}{2}\ x\ a\ x\ t$ and found the result 6.
Fluency	Then, on the answer sheet you write that a = 0 and there is also a = 2.47. What does it mean?	That was I thought the 6 was the bottom side and could be divided into 2, so it was 3 cm and 3 cm. Then I tried that in the middle a line can be drawn so there are 2 Right-angle triangles. Well, then I calculated using the Pythagorean formula for the other size and the results were 0 and 2.47.

Based on the analysis of the results of answers and the results of interviews conducted with S17 which were adjusted to the achievement of the indicators of creative thinking ability, the subject was still lacking in achieving the three indicators that had been set, namely fluent thinking, flexible thinking, and original thinking and needed further guidance. In the indicator of fluent thinking, the subject is able to understand the intent of the statements and questions asked. However, several times the subject feels unsure of the answers that have been made, so they often delete the sketches that have been made and feel confused.

The researcher then tried to provide scaffolding to the subject related to how to do the given problem. After trial and error, the subject was then able to find the solution to the first problem by drawing a Right-angle triangle and an isosceles triangle. In the flexible thinking indicator, the subject has been able to draw isosceles triangles and Right-angle triangles, but has not been able to determine where to place the side view on the formed triangle. The subject is less able to explain the way he does the problem. The subject expresses relevant ideas, but has not demonstrated a given level of creative thinking. In addition, the subject also experienced the same misconception as subject S14 who used the triangle area formula to find the length of the other side of a Right-angle triangle.

The subject was able to use high lines on isosceles triangles despite still not understanding the concept. This is evidenced by the subject experiencing a misconception by using the Pythagorean concept to find the length of the side of a Right-angle triangle, but the subject entered the wrong number. On the indicators of original thinking, the subject was able to show answers that S14 did not think of, but still misunderstood in their concept of use. When asked about the difficulties experienced, the subject admitted that he still did not understand the concept of triangles and Pythagoreans so he still often felt confused.

Discussion

This study aims to explore information about students' mathematical creative thinking abilities in solving problems related to the Pythagorean theorem using Desmos software. The research involved three subjects representing students with high, moderate, and low initial mathematical abilities. S31 represents a student with high initial mathematical ability, S14 represents a student with moderate initial mathematical ability, and S17 represents a student with low initial mathematical ability.

Both S31, S14, and S17 were able to understand and articulate the meaning of the given problems well. Therefore, all three demonstrated good fluency in thinking. For S31, there were many ideas, and they actively built their knowledge related to the Pythagorean theorem from the given problems. Additionally, S31 was able to express relevant and logical ideas when asked about the results of their work (Flexibility). S31 also had an alternative solution method that the other two subjects did not consider, which involved using an altitude. Although there was confusion during the execution, after explanation and reinforcement, the subject regained confidence in their answer. Thus, S31 successfully met the novelty indicator.

Next, S14 was able to provide diverse ideas and generate solutions to the given problems (Flexibility). However, S14 sometimes needed validation for the ideas or concepts they expressed to ensure their correctness, leading to occasional uncertainty in their answers. Misconceptions related to triangle sides were occasionally found in S14, requiring further explanation. Regarding the novelty indicator, S14 did not meet it because they did not present different ideas or problem-solving approaches.

Subsequently, S17 was able to articulate ideas and solutions for the problem. The given ideas were relevant but did not reach the desired level of creative thinking. Additionally, the subject could understand triangles but still felt confused about the sides within a triangle (Flexibility). The subject occasionally lacked confidence in their written answers, leading the researcher to provide scaffolding in the problem-solving process. For the novelty indicator, although the subject had ideas, the basic concepts were not precise, resulting in less accurate solutions.

All three subjects were capable of providing accurate solutions to the given problems. This is in line with the research conducted by Apriansyah, D., & Ramdani, M. (2018), which states that mathematical abilities in students influence their creative thinking skills. S31 demonstrated higher levels of creativity, meeting the novelty indicator. S14 showed flexibility in thinking but did not exhibit novelty, while S17 had relevant ideas but fell short of achieving the desired level of creative thinking.

Conclusion

Based on the results of research on students' creative thinking ability in solving mathematical problems of Pythagorean material, it was concluded that subjects who have high creative thinking abilities are able to solve problems related to Pythagoras correctly and can fulfill the creative thinking

indicators that have been determined very well. Students are able to quickly and accurately understand the meaning of the statements and questions given and work on the questions given with confidence. In the fluent thinking indicator, students are able to express and explain fluently how to obtain written answers on Desmos. In the flexible thinking indicator, students are able to explain their reasons using the method written on the answer sheet and are able to understand the concepts needed to get the answer. Students are also able to provide various different methods for solving problems using Desmos. In the original thinking indicator, the subject is able to think precisely how to get the desired answer that other subjects have not thought of perfectly.

Subjects with moderate creative thinking abilities are able to solve problems related to Pythagoras correctly and meet the predetermined creative thinking indicators. In the fluent thinking indicator, the subject understands the meaning of the statements and questions given but requires validation whether the ideas the subject has are suitable for working on the questions. In the flexible thinking indicator, the subject is able to determine the solution to the first question, but is less able to express ideas that support the written answer using Desmos. Subjects also experienced misconceptions in finding the side lengths of right triangles. In the genuine thinking indicator, the subject appears to express a logical answer on the Desmos page by providing one that is different from the others**.** Subjects with low creative thinking abilities are still unable to solve problems related to Pythagoras using Desmos well and do not meet the predetermined creative thinking indicators. In the indicator of fluent thinking, the subject needs some scaffolding that guides him to find ideas in solving a given problem. In the flexible thinking indicator, the subject is able to determine the solution to the first problem even though they still encounter obstacles. However, the subject was not able to provide various relevant problem-solving strategies using Desmos. Apart from that, the subject also experienced several misconceptions when solving the second question so further guidance was needed at a later date. In the original thinking indicator, the subject shows the ability to think original, even though in practice the concept proposed is still not appropriate to solve the problem given.

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