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Investigating students' mathematical creative thinking skills in integral calculus using Google Sites

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Abstract

Students need to develop creative mathematical thinking skills because these skills support academic success and are linked to a creative attitude an affective aspect that fosters the emergence of new ideas. In reality, students struggle to come up with new ideas when solving problems because they remain fixated on the examples provided. Therefore, learning that integrates technological support is necessary. This study aimed to investigate mathematical creative thinking skills in integral calculus using Google Sites. This study employed a qualitative method with a case study strategy. Data were obtained from students enrolled in the integral calculus course through interviews, observation, documentation, and questionnaires. The results showed that students with high and moderate creative attitudes were not yet able to fully meet the four indicators of mathematical creative thinking skills. The errors that emerged were predominantly conceptual errors that developed into procedural and technical errors. Google Sites-assisted learning through PBL was able to support group collaboration, but it had not optimized conceptual understanding and individual mathematical creative thinking skills. These findings imply the need to strengthen conceptual understanding, provide more interactive learning activities, and conduct individual evaluations to optimize the development of mathematical creative thinking skills.

Keywords: creative attitude; Google Sites; integral calculus; mathematical creative thinking skills; problem-based learning

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Introduction

Creativity has become one of the skills needed to ensure that human resources have good quality, are dependable, and are competitive at the global level. The characteristics of creativity consist of two dimensions: first, the cognitive dimension, which includes fluency, flexibility, originality, and elaboration; and second, the non-cognitive dimension, which includes motivation and creative attitude (Irmayanti & Putra, 2023; Qomariyah & Subekti, 2021). The development of mathematical creativity is not merely a cognitive process but is also strongly influenced by affective factors such as attitude (Yudha & Rosnawati, 2025). Thus, cultivating creativity requires synergy between creative thinking skills as the operational form and creative attitude as the affective foundation that encourages individuals to explore new ideas confidently.

Creative attitude enables individuals to think beyond conventional habits (out of the box), discover innovative solutions, become better prepared to face future challenges, and influence the way they think. Creative attitude is one element in the formation of creativity and is needed to address problems that may arise in the future (Tafirehan et al., 2022), This attitude is necessary for university students because it supports mathematical creative thinking skills, namely the ability to find new solutions to mathematical problems in varied and simpler ways (Amaliyah, 2022).

The indicators of mathematical creative thinking skills include fluency, flexibility, originality, and elaboration (Gunawan et al., 2022). Fluency refers to the ability to provide ideas that are relevant to problem solving correctly and clearly; flexibility refers to the ability to provide varied answers or more than one solution method, with correct processes and results; originality refers to the ability to provide unique answers based on one's own ideas, with correct calculation processes and results; and elaboration refers to the ability to provide detailed answers accompanied by in-depth reasoning and correct results (Amidi, 2018; Gunawan et al., 2022; Suherman & Vidákovich, 2022). These four indicators are interrelated and serve as benchmarks for assessing students' mathematical creative thinking skills in problem solving. Mathematical creative thinking skills play an important role in the learning process because their development can positively affect students' academic achievement (Susanto et al., 2025). This indicates that the higher students' mathematical creative thinking skills are, the greater their opportunity to achieve optimal mathematics learning outcomes.

In fact, students' mathematical creative thinking skills remain inconsistent (Siregar et al., 2022). In courses that require deep understanding, such as calculus, students' mathematical creative thinking skills are still not evident, as shown by the fact that some students have not been able to solve problems involving the volume of solids of revolution using the concept of integrals (Romadiastri, 2013). Preliminary observation in the differential calculus course also showed that students' mathematical creative thinking skills were still low. As a result, during learning, students tended to follow examples provided by the lecturer without exploring new ideas, which could lead to greater difficulties in the integral calculus course.

The low level of mathematical creative thinking skills is caused by learning that focuses mainly on completing the syllabus and provides limited contextual relevance. Mathematical creative thinking skills can be developed through learning that is educationally designed to train students to explore their abilities, one way being through an effective learning model (Fayakuun & Agoestanto, 2023; Nisrina et al., 2021). One learning model that supports students in actively thinking creatively while solving real-world problems is problem-based learning (PBL). Students are presented with contextual problems, requiring them to construct knowledge independently through exploration and by testing various possible solutions. This process naturally stimulates the four indicators of mathematical creative thinking while also building creative attitude through the experience of successfully solving problems independently.

The effectiveness of PBL in this context is supported by empirical findings showing that the model is student-centered and effective in improving both critical and creative thinking skills in addressing contextual problems (Franoto et al., 2025). It also produces more significant improvements in mathematical creative thinking skills than conventional learning (Ningrum & Puadi, 2023). Nevertheless, conventional implementation of PBL has limitations, including limited time for independent exploration in class and limited visualization tools for abstract concepts such as integrals. Technology integration addresses these limitations because it has been shown to support problem-solving processes and collaboration in testing ideas more flexibly (Berrin et al., 2024; Fatmanissa et al., 2025; Nguyen et al., 2023). Therefore, mathematical creative thinking skills need to be developed through information technology-based mathematics learning (Widana & Septiari, 2021).

One learning technology that can be used is Google Sites, which is effective in improving students' critical and creative thinking skills and is useful in calculus learning (Bueno et al., 2022; Hidayati et al., 2024). Google Sites provides interactive features that support student-centered learning, facilitate the presentation of materials, encourage active participation, and can be accessed flexibly anytime and anywhere (Lutfiyah et al., 2025; Muhammad et al., 2025; Pratiwi et al., 2024). In integral calculus learning, Google Sites can be optimized as a platform that brings together visual simulations of solids of revolution, for example through integration with GeoGebra, supporting materials, interactive worksheets, and learning outcome sheets. This capacity strengthens the implementation of PBL by providing an environment that enables repeated practice in elaboration and flexibility in problem solving beyond class hours. It therefore continuously stimulates students' mathematical creative thinking skills in generating varied, flexible, and original solution ideas.

Previous studies have generally examined mathematical creative thinking skills through PBL without linking them to creative attitude (Malau & Siagian, 2021); analyzed the relationship between mathematical creative thinking skills and creative attitude in different disciplines (Isnaeni et al., 2021); investigated the effectiveness of Google Sites combined with Wordwall.net in online basic integral learning without a specific learning model (Bueno et al., 2022); and examined the contribution of Google Workspace in calculus 1 without measuring creative thinking skills or creative attitude (Acar & Prudente, 2024). These studies have generally remained limited to the secondary education level, so research on university students, who have different cognitive characteristics and learning independence, is still limited. Thus, no study has been found that simultaneously integrates mathematical creative thinking skills, the PBL model, Google Sites media, integral calculus material, and students' creative attitude within a single comprehensive research framework. Unlike previous studies, this study not only integrates PBL and Google Sites but also analyzes mathematical creative thinking skills in integral calculus based on students' creative attitude categories in the context of higher education. This contribution fills an empirical gap and enriches technology-assisted and PBL-based calculus pedagogy by considering affective aspects.

Methods

This study employed a qualitative method to describe students' mathematical creative thinking skills on the topic of integrals through the use of Google Sites and PBL, based on students' creative attitude. The data sources consisted of spoken and written data from 15 students enrolled in an integral calculus course, from whom three research subjects were selected for observation and interviews. The three subjects were selected using purposive sampling, a sampling technique based on specific considerations (Dalilan & Sofyan, 2022). The three subjects, each representing high (M3), moderate (M14), and low (M7) ability categories, were selected based on their learning outcomes in the prerequisite differential calculus course and the consideration of the course lecturer.

The first instrument used in this study was the researcher. In qualitative research, the main instrument is the researcher, although after the research focus becomes clear, simple research instruments may be developed (Hardani et al., 2020). The researcher served as the planner, implementer, data collector, analyst, interpreter, and reporter of the research findings. Second, a structured interview guide was used to explore in depth the process of mathematical creative thinking, the integration of course material with Google Sites, and the implementation of the PBL syntax. The interviews were conducted at the end of the learning process. Third, observation sheets were used to observe mathematical creative thinking activities, the implementation of the PBL syntax, the use of Google Sites, and students' creative attitudes during learning. The observations in this study referred to the three stages proposed by Spradley (Armanda et al., 2020), namely the descriptive, focused, and selected stages. Fourth, a mathematical creative thinking skills test was used to determine the level of students' mathematical creative thinking skills in solving integral application problems. The test was constructed in essay form and developed based on the course learning outcomes and indicators of mathematical creative thinking skills. The test was completed by students at the end of the learning process. Finally, a creative attitude questionnaire was distributed to students to measure creative attitude. The questionnaire consisted of 15 positive statements and 15 negative statements based on Munandar's indicators of creative attitude, namely curiosity, imagination, feeling challenged by complexity, willingness to take risks, and appreciation (Agustin et al., 2019). The questionnaire was administered at the beginning of learning before the implementation of Google Sites.

Before being administered, the test and questionnaire were first content-validated by two expert lecturers in calculus for the test and two expert lecturers in learning and value education for the questionnaire. The validators provided scores on the validation sheets. The total scores were then summed and the average validity score was calculated using the formula proposed by Sudjana (Riyani et al., 2017):

$$VR = \frac{\sum_{i=1}^{n} \bar{V_i}}{n} \qquad (1)$$

Notes:
VR = Average validity
$\bar{V_i}$ = Average score from each validator
n = Number of validators

The calculation results were then analyzed descriptively according to the validity criteria in Table 1. The validation results for the test and questionnaire showed valid criteria.

Table 1. Validity criteria

Category	Score Criteria
$3 \leq VR \leq 4$	Very valid
$2 \leq VR < 3$	Valid
$1 \leq VR < 2$	Less valid
$0 \leq VR < 1$	Invalid

Data analysis was carried out after all data had been collected by following the stages proposed by Miles and Huberman (Zulfirman, 2022), namely data collection, data reduction, data display, and conclusion drawing. Interview data reduction was conducted by selecting audio recordings to ensure the accuracy of the statements. Observation data were reduced by summing the scores obtained based on four assessment categories: 1 (very poor), 2 (poor), 3 (good), and 4 (very Good). The data were then analyzed descriptively based on the modified criteria (Hartanto & Purwanto, 2019), as shown in Table 2.

Table 2. Observation criteria

Category	Score Criteria
≥ 86	Very good
$70 - 85$	Good
$55 - 69$	Fair
< 55	Poor

The students' mathematical creative thinking skills test results were assessed based on the proposed scoring rubric (Moma, 2015), as shown in Table 3.

Table 3. Scoring guidelines for the mathematical creative thinking skills test

Indicator	Response to the problem/item	Score
Fluency	No answer provided	0
	Provides an idea that is not relevant to problem solving	1
	Provides an idea that is relevant to problem solving, but the result is incorrect	2
	Provides an idea that is relevant to problem solving, but the solution is incomplete	3
	Provides an idea that is relevant to problem solving and produces a correct result	4
Flexibility	No answer provided	0
	Provides ideas/answers that are not varied and are incorrect	1
	Provides ideas/answers that are not varied but are correct	2

Indicator	Response to the problem/item	Score
	Provides varied ideas/answers, but they are incorrect	3
	Provides varied ideas/answers and they are correct	4
Originality	No answer provided	0
	Expresses an independent idea, but it cannot be understood	1
	Expresses an idea, but only modifies an existing one; the solution process is already directed but incomplete	2
	Expresses an independent idea, but the result is incorrect	3
	Expresses an independent idea and produces a correct result	4
Elaboration	No answer provided	0
	Develops an idea and provides an answer that is not detailed and is incorrect	1
	Develops an idea and provides an answer that is not detailed, but the result is correct	2
	Develops an idea and provides a detailed answer, but the result is incorrect	3
	Develops an idea and provides a detailed answer with a correct result	4

The scores obtained were raw scores that were then transformed into a 0-100 scale using the following formula.

$$Value = \frac{raw\ score}{maximum\ score} \text{ x } 100 \qquad (2)$$

The total value from the four indicators was then converted into categories of mathematical creative thinking skills by Munandar (Putri & Awalludin, 2024), as shown in Table 4.

Table 4. Categories of mathematical creative thinking ability

Category	Score Criteria
High	$X > (\overline{X} + S)$
Moderate	$(\overline{X} - S) \leq X \leq (\overline{X} + S)$
Low	$X < (\overline{X} - S)$

The creative attitude questionnaire sheet was scored using a Likert scale and referred to the creative attitude questionnaire scoring rubric shown in Table 5.

Table 5. Questionnaire scoring guidelines

Response Option	Positive Statement	Negative Statement
Strongly agree	4	1
Agree	3	2
Disagree	2	3
Strongly disagree	1	4

The scores obtained were then transformed into a 0-100 scale using the following formula.

$$Value = \frac{raw\ score}{maximum\ score} \text{ x } 100 \qquad (3)$$

The criteria for categorizing creative attitude were the same as those for mathematical creative thinking skills shown in Table 4. The reduced data were then presented in the form of descriptive narratives. The trustworthiness of the data in this study was strengthened through triangulation by comparing data obtained from four different data collection techniques, namely test results, questionnaires, observations, and interviews, to examine the consistency of the findings regarding mathematical creative thinking skills. The research conclusions were then drawn descriptively based on data whose trustworthiness had been verified and were presented clearly and transparently in accordance with the field findings.

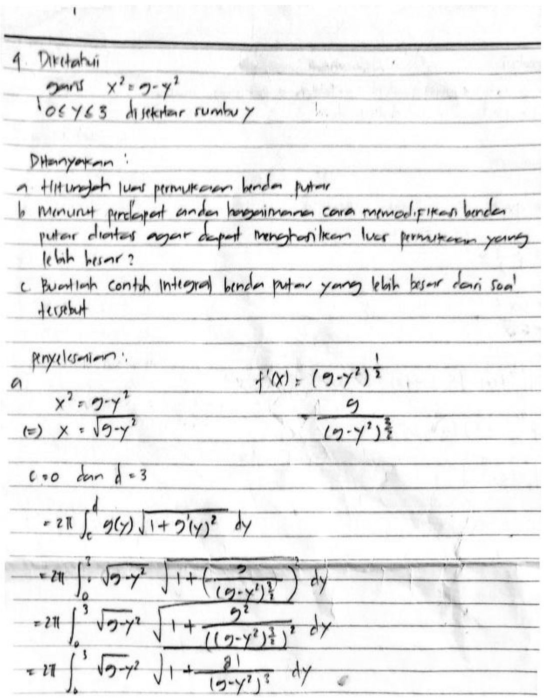
Results

The results showed that the mathematical creative thinking skills and creative attitudes of the research subjects are presented in Table 6.

Table 6. Results of the classification of mathematical creative thinking ability and creative attitude

Subject	Creative Attitude Category	Mathematical Creative Thinking Skills Category
M3	High	Moderate
M7	Moderate	Low
M14	High	Moderate

Each indicator was analyzed based on three data sources, namely the individual written test results, group observation results during learning, and interviews, in order to obtain a more complete picture of the subjects' achievements and thinking processes. The following presents students' work on the problem related to the fluency indicator.



Translation:

Known: line $x^2 = 9 - y^2$

$0 \le y \le 3$ around the y-axis

Question:

a. Calculate the surface area of the rotating object!
b. In your opinion, how can you modify the rotating object above to produce a larger surface area?
c. Make an integral example of a rotating object that is larger than the problem!

Answer:

a. $x^2 = 9 - y^2$ $\qquad f'(x) = (9 - y^2)^{\frac{1}{2}} = \frac{9}{(9-y^2)^{\frac{3}{2}}}$

b.

$\Leftrightarrow x = \sqrt{9 - y^2}$

c = 0 and d = 3

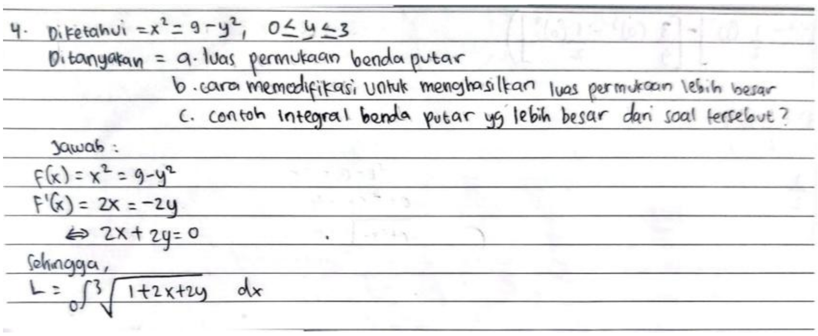
$= 2\pi \int_c^d g(y) \sqrt{1 + g'(y)^2}\, dy$

$= 2\pi \int_0^3 \sqrt{9 - y^2} \sqrt{1 + \left(\frac{9}{(9-y^2)^{\frac{3}{2}}}\right)^2}\, dy$

$= 2\pi \int_0^3 \sqrt{9 - y^2} \sqrt{1 + \frac{9^2}{\left((9-y^2)^{\frac{3}{2}}\right)^2}}\, dy$

$= 2\pi \int_0^3 \sqrt{9 - y^2} \sqrt{1 + \frac{81}{(9-y^2)^3}}\, dy$

Figure 1. Subject M3's answer to the fluency indicator



4. Diketahui = $x^2 = 9 - y^2$, $0 \leq y \leq 3$

Ditanyakan = a. luas permukaan benda putar

b. cara memodifikasi untuk menghasilkan luas permukaan lebih besar

c. contoh integral benda putar yg lebih besar dari soal tersebut?

Jawab :

$f(x) = x^2 = 9 - y^2$

$f'(x) = 2x = -2y$

$\Leftrightarrow 2x + 2y = 0$

Sehingga,

$L = \int_0^3 \sqrt{1+2x+2y}\ dx$

Translation:

Known:

$x^2 = 9 - y^2, 0 \leq y \leq 3$

Asked:

a. Calculate the surface area of the rotating object!
b. In your opinion, how can you modify the rotating object above to produce a larger surface area?
c. Make an integral example of a rotating object that is larger than the problem!

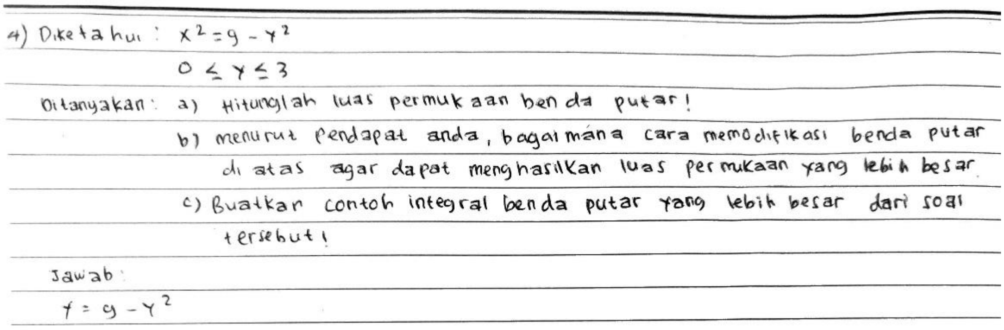
Answer:

$$\begin{aligned} f(x) &= x^2 = 9 - y^2 \\ f'^{(x)} &= 2x = -2y \\ &\Leftrightarrow 2x + 2y = 0 \end{aligned}$$

Therefore,

$L = \int_0^3 \sqrt{1 + 2x + 2y}\ dx$

Figure 2. Subject M14's answer to the fluency indikator



4) Diketahui : $x^2 = 9 - y^2$

$0 \leq y \leq 3$

Ditanyakan : a) Hitunglah luas permukaan benda putar!

b) menurut pendapat anda, bagaimana cara memodifikasi benda putar di atas agar dapat menghasilkan luas permukaan yang lebih besar

c) Buatkan contoh integral benda putar yang lebih besar dari soal tersebut!

Jawab :

$y = 9 - y^2$

Translation:

Known:

$x^2 = 9 - y^2$

$0 \leq y \leq 3$

Asked:

a. Calculate the surface area of the rotating object!
b. In your opinion, how can you modify the rotating object above to produce a larger surface area?
c. Make an integral example of a rotating object that is larger than the problem!

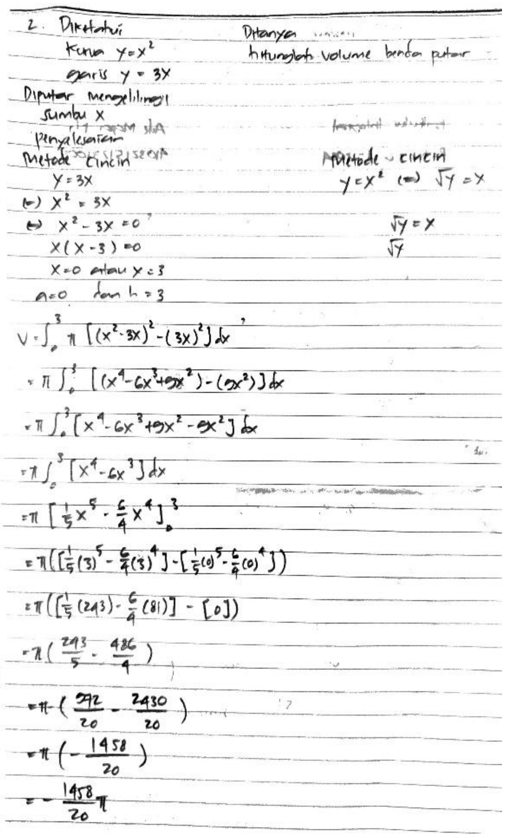
Answer:

$y = 9 - y^2$

Figure 3. Subject M7's answer to the fluency indicator

For the fluency indicator, the subjects were asked to calculate the surface area of a solid of revolution. Based on Figure 1, Subject M3 developed a relevant solution idea, namely determining the derivative of the function and formulating the integral for surface area, but made an error in the differentiation stage so that the final result was not correct. This was supported by the interview results, which confirmed that the subject's conceptual mastery was not yet complete. Based on Figure 2, Subject M14 wrote an idea that was not relevant to the problem request, including an error in stating the formula for the surface area of a solid of revolution during the interview. Meanwhile, based on Figure 3, Subject M7 was not yet able to provide a solution idea and only wrote the information given in the problem. The three subjects were therefore considered not to have met the fluency indicator. As a comparison, the observation results during group learning showed that the fluency indicator was achieved in the good category in the M3 and M14 groups and in the fair category in the M7 group.

The following presents the subjects' work on the problem related to the flexibility indicator.


2. Diketahui
Kurva $y=x^2$
garis $y = 3x$
Diputar mengelilingi sumbu x
Ditanya
hitunglah volume benda putar
Penyelesaian
Metode cincin
$y=3x$
$\Leftrightarrow x^2 = 3x$
$\Leftrightarrow x^2-3x=0$
$x(x-3)=0$
$x=0$ atau $x=3$
$a=0$ dan $b=3$
Metode cincin
$y=x^2 \Leftrightarrow \sqrt{y}=x$
$\sqrt{y}=x$
$\sqrt{y}$
$V=\int_0^3 \pi\,[(x^2-3x)^2-(3x)^2]\,dx$
$=\pi\int_0^3 [(x^4-6x^3+9x^2)-(9x^2)]\,dx$
$=\pi\int_0^3 [x^4-6x^3+9x^2-9x^2]\,dx$
$=\pi\int_0^3 [x^4-6x^3]\,dx$
$=\pi\left[\frac{1}{5}x^5-\frac{6}{4}x^4\right]_0^3$
$=\pi\left(\left[\frac{1}{5}(3)^5-\frac{6}{4}(3)^4\right]-\left[\frac{1}{5}(0)^5-\frac{6}{4}(0)^4\right]\right)$
$=\pi\left(\left[\frac{1}{5}(243)-\frac{6}{4}(81)\right]-[0]\right)$
$=\pi\left(\frac{243}{5}-\frac{486}{4}\right)$
$=\pi\left(\frac{972}{20}-\frac{2430}{20}\right)$
$=\pi\left(-\frac{1458}{20}\right)$
$=-\frac{1458}{20}\pi$

Translation:

Known:

curve $y = x^2$

line $y = 3x$

rotated around the x-axis

Asked:

calculate the volume of the rotating object!

Answer:

Washer method

$y = 3x$

$\Leftrightarrow x^2 = 3x$

$\Leftrightarrow x^2 - 3x = 0$

$x(x-3) = 0$

x = 0 or x = 3

a = 0 and b = 3

$V = \int_0^3 \pi\, ((x^2-3x)^2 - (3x)^2)dx$

$= \pi \int_0^3 ((x^4 - 6x^3 + 9x^2) - 9x^2)dx$

$= \pi \int_0^3 (x^4 - 6x^3 + 9x^2 - 9x^2)dx$

$= \pi \int_0^3 (x^4 - 6x^3)dx$

$= \pi \int_0^3 (x^4 - 6x^3)dx$

$= \pi \left[\frac{1}{5}x^5 - \frac{6}{4}x^4\right]_0^3$

$= \pi \left(\left[\frac{1}{5}(3)^5 - \frac{6}{4}(3)^4\right] - \left[\frac{1}{5}(0)^5 - \frac{6}{4}(0)^4\right]\right)$

$= \pi \left(\left[\frac{1}{5}(243) - \frac{6}{4}(81)\right] - [0]\right)$

$= \pi \left(\frac{243}{5} - \frac{486}{4}\right)$

$= \pi \left(\frac{972}{20} - \frac{2430}{20}\right)$

$= \pi \left(-\frac{1458}{20}\right)$

$= -\frac{1458}{20}\pi$

Washer method

$y = x^2 \Leftrightarrow \sqrt{y} = x$

$\sqrt{y} = x$

$\sqrt{y}$

Figure 4. Subject M3's answer to the flexibility indikator

Translation:

Known:

$y = x^2$

$y = 3x$

Asked:

Calculate the volume of the rotating object!

Answer:

Method 1

$y_1 = y_2$ lower limit = 0

$x^2 = 3x$ upper limit = 3

$x = 3$

$V = \int_0^3 \pi\ (3x - x^2)dx$

$= \pi \int_0^3\ (3x - x^2)dx$

$= \pi \left[\frac{3}{2}x^2 - \frac{1}{3}x^3\right]_0^3$

$= \pi \left[\frac{3}{2}(3)^2 - \frac{1}{3}(3)^3\right] - \left[\frac{3}{2}(0)^2 - \frac{1}{3}(0)^3\right]$

$= \pi \left(\left[\frac{3}{2}(9) - \frac{1}{3}(27)\right] - 0\right)$

$= \pi \frac{27}{2} - 9$

$= \frac{27-18}{2}\pi$

$= \frac{9}{2}\pi$ So, volume of the rotating object is $\frac{9}{2}\pi$.

Method 2

$y = x^2 \quad \Leftrightarrow \quad \sqrt{y} = x$

$x^2 = 3x \quad \Leftrightarrow \quad \frac{1}{3}y = x$

Therefore,

$V = \int_0^3 \pi \left(\frac{1}{3}y\right)^2 - \left(\sqrt{y}\right)^2 dx$

$= \pi \int_0^3\ \frac{1}{9}y^2 - y\, dx$

$= \pi \left[\frac{3}{9}y^3 - \frac{1}{2}y^2\right]_0^3$

$= \pi \left(\left[\frac{3}{9}(3)^3 - \frac{1}{2}(3)^2\right] - \left[\frac{3}{9}(0)^3 - \frac{1}{2}(0)^2\right]\right)$

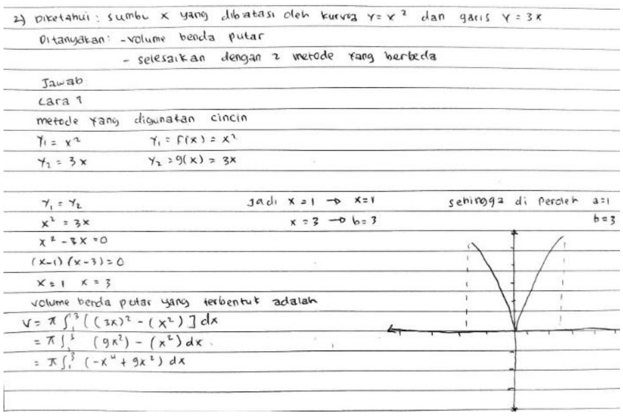
$= \pi \left(\frac{3}{9}(27) - \frac{1}{2}(9)\right)$-0

$= \pi\, 9 - \frac{9}{2}$

$= \frac{18-9}{2}\pi$

$= \frac{9}{2}\pi$ So, volume of the rotating object is $\frac{9}{2}\pi$.

Figure 5. Subject M14's answer to the flexibility indikator



Known:

The x-axis bounded by the curve $y = x^2$ and line $y = 3x$

Asked:

Volume of the rotating object using two different methods!

Answer:

Method 1

Using washer method

$y_1 = x^2$ $y_1 = f(x) = x^2$

$y_2 = 3x$ $y_2 = g(x) = 3x$

$y_1 = y_2$ So, x = 1 -> x = 1

$x^2 = 3x$ x = 3 -> b = 3

$x^2 - 3x = 0$ Therefore: a = 1

$(x-1)(x-3) = 0$ b = 3

x = 1 or x = 3

the volume of the solid of revolution formed is

$V = \pi \int_1^3\ ((3x)^2 - (x)^2)dx$

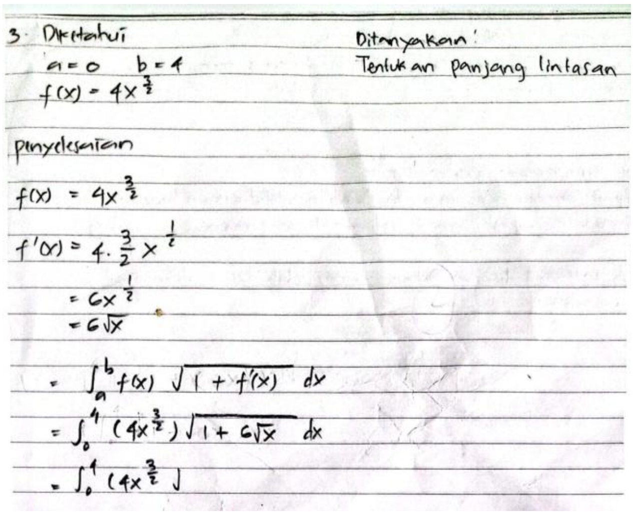
$= \pi \int_1^3\ (9x^2) - (x^2)dx$

$= \pi \int_1^3\ (-x^4 + 9x^2)dx$

Figure 6. Subject M7's answer to the flexibility indicator

For the flexibility indicator, the subjects were asked to calculate the volume of a solid of revolution using more than one method. In Figure 4, Subject M3 is seen to have solved the problem using only one method, namely the washer method, and made an error in applying the volume formula, although the integral limits had been determined correctly. This was reinforced by the interview results, in which the subject acknowledged being unable to solve the problem in another way. Based on Figure 5, Subject M14 wrote two solution methods, namely the washer method and the cylindrical shell method, but the final result was still inaccurate because of confusion in understanding the concept of the volume of a solid of revolution, particularly in the cylindrical shell method. Meanwhile, Figure 6 shows that Subject M7 also used only one method, the washer method, with correct limits but incorrect calculations, and stated in the interview that the subject did not consider other methods. The three subjects had not met the flexibility indicator individually, in line with the interview results. The group observation results, however, showed a poor category for the M3 group and a good category for the M14 and M7 groups because group discussion guidance directed them to use two different methods.

The following presents the work of Subjects M3, M14, and M7 on the problem related to the originality indicator.



Translation:

Known:

$a = 0 \quad b = 4$

$f(x) = 4x^{\frac{3}{2}}$

Asked:

Determine the length of the track!

Answer:

$f(x) = 4x^{\frac{3}{2}}$

$f'(x) = 4.\frac{3}{2}x^{\frac{1}{2}}$

$= 6x^{\frac{1}{2}}$

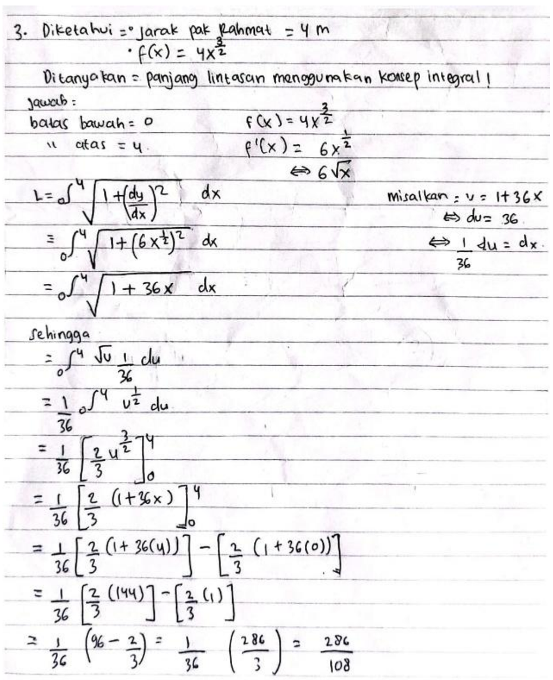
$= 6\sqrt{x}$

$= \int_a^b f(x)\sqrt{1+f'(x)}dx$

$= \int_0^4 4x^{\frac{3}{2}}\sqrt{1+6\sqrt{x}}\,dx$

$= \int_0^4 4x^{\frac{3}{2}}$

Figure 7. Subject M3's answer to the originality indicator



Translation:

Known:

Mr. Rahmat's distance = 4 m

$f(x) = 4x^{\frac{3}{2}}$

Asked:

Determine the length of the track using the integral concept!

Answer:

Lower limit = 0 $\quad f(x) = 4x^{\frac{3}{2}}$

Upper limit = 4 $\quad f'(x) = 6x^{\frac{1}{2}} = 6\sqrt{x}$

$L = \int_0^4 \sqrt{1+\left(\frac{dy}{dx}\right)^2}\,dx$

$= \int_0^4 \sqrt{1+\left(6x^{\frac{1}{2}}\right)^2}\,dx$

$= \int_0^4 \sqrt{1+36x}\,dx$

Therefore,

$= \int_0^4 \sqrt{u}\frac{1}{36}\,du$

$= \frac{1}{36}\int_0^4 u^{\frac{1}{2}}\,du$

$= \frac{1}{36}\left[\frac{2}{3}u^{\frac{3}{2}}\right]_0^4$

$= \frac{1}{36}\left[\frac{2}{3}(1+36x)\right]_0^4$

$= \frac{1}{36}\left[\frac{2}{3}(1+36(4))\right] - \left[\frac{2}{3}(1+36(0))\right]$

$= \frac{1}{36}\left[\frac{2}{3}(144)\right] - \left[\frac{2}{3}(1)\right]$

$= \frac{1}{36}\left[96 - \frac{2}{3}\right]$

$= \frac{1}{36}\left[\frac{286}{3}\right]$

$= \frac{286}{108}$

Misalkan: $u = 1 + 36x$

$\Leftrightarrow du = 36$

$\Leftrightarrow \frac{1}{36}du = dx$

Figure 8. Subject M14's answer to the originality indicator

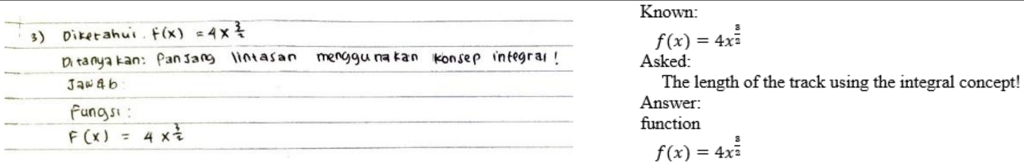


Figure 9. Subject M7's answer to the originality indicator

For the originality indicator, the subjects were asked to calculate arc length. Based on Figure 7, Subject M3 expressed an idea independently, but the method was a modification of an example that had been given, and the solution was incomplete because of an error in writing the arc-length formula. Figure 8 shows that Subject M14 wrote the arc-length formula correctly and partly solved the problem using an independent idea, although the final result was still inaccurate. This was reinforced by the interview results, which revealed that the subject sometimes only followed the available examples. Figure 9 shows that Subject M7 did not provide an answer at all and only wrote the known and asked information. The three subjects had not met the originality indicator in the individual test. At the same time, the group observation results showed very good achievement in the M3 group, which was associated with the effective use of Google Sites to access materials during classroom learning.

The following presents the work of Subjects M3, M14, and M7 on the problem related to the elaboration indicator.

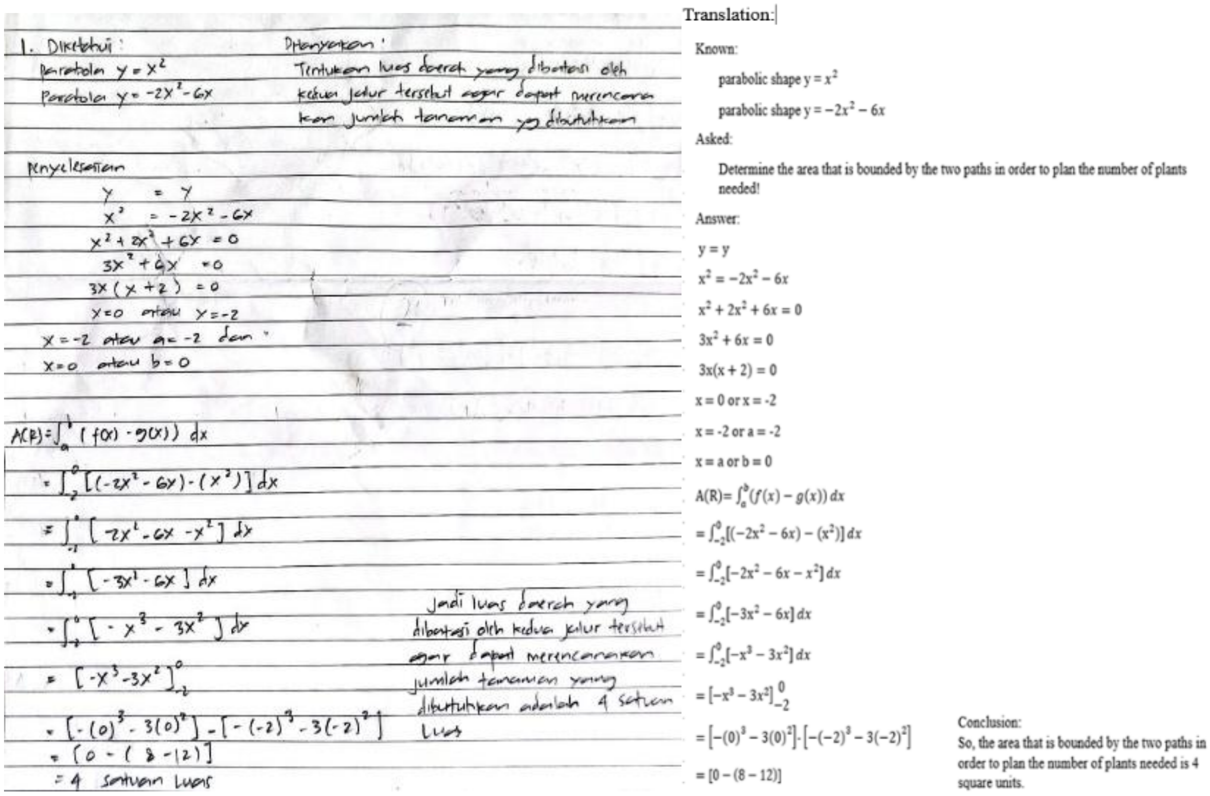
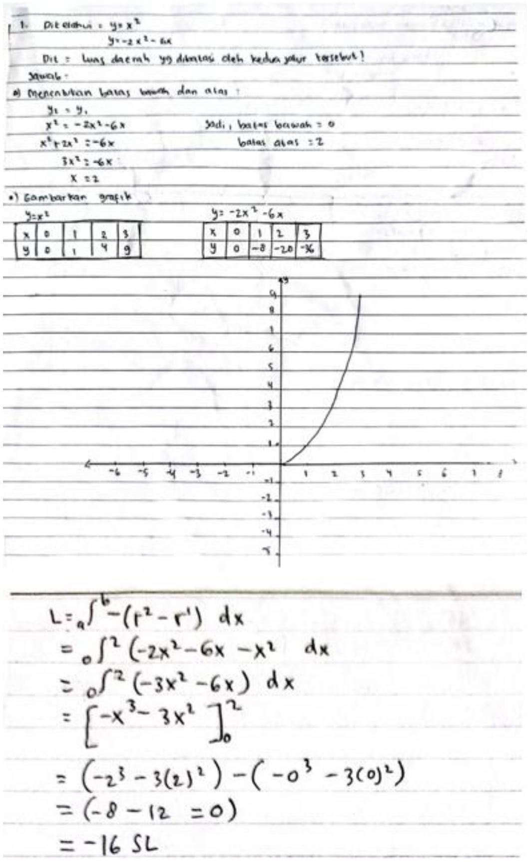


Figure 10. Subject M3's answer to the elaboration indicator



Translation:

$y = -2x^2 - 6x$

Asked:

The area that is bounded by the two paths in order to plan the number of plants needed!

Answer:

- determine the lower and upper limits

$y_1 = y_2$ So, lower limit = 0

$x^2 = -2x^2 - 6x$ upper limit = 3

$x^2 + 2x^2 = -6x$

$3x^2 = -6x$

$x = 2$

- Draw a graph

$y = x^2$

X	0	1	2	3
y	0	1	4	9

$y = -2x^2 - 6x$

X	0	1	2	3
y	0	-8	-20	-36

$L = \int_a^b (r2 - r1)\, dx$

$= \int_0^2 (-2x^2 - 6x - x^2)\, dx$

$= \int_0^2 (-3x^2 - 6x)\, dx$

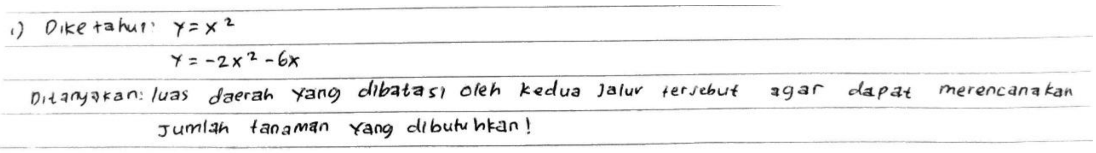
$= [-x^3 - 3x^2]_0^2$

$= (-2^3 - 3(2)^2) - (-0^3 - 3(0)^2)$

= (-8-12-0)

= -16 SL

Figure 11. Subject M14's answer to the elaboration indikator



1) Diketahui: $y = x^2$

$y = -2x^2 - 6x$

Ditanyakan: luas daerah yang dibatasi oleh kedua jalur tersebut agar dapat merencanakan jumlah tanaman yang dibutuhkan!

Translation:

Known:

$y = x^2$

$y = -2x^2 - 6x$

Asked:

Determine the area that is bounded by the two paths in order to plan the number of plants needed!

Figure 12. Subject M7's answer to the elaboration indicator

For the elaboration indicator, the subjects were asked to determine the area of a region bounded by two curves while also detailing the solution steps. Based on Figure 10, Subject M3 obtained the correct final result but did not include a curve sketch or a division of the region/approach as supporting details, so the subject was considered not to have met this indicator. Based on Figure 11, Subject M14 made errors in determining the limits of integration, drawing the curves, and applying the formula for the area between two curves, so the answer was neither detailed nor correct, although the subject's contribution to group discussion was recorded as good. Meanwhile, Subject M7 only wrote the known and asked information without any solution steps. The three subjects had not met the elaboration indicator individually, even though the observation results recorded positive involvement in group discussions.

Overall, the three subjects, both those in the high creative attitude category (M3 and M14) and the moderate category (M7), were not able to meet any of the four indicators of mathematical creative thinking skills based on the individual test and interviews, even though the group observation results were generally in the good to very good categories during PBL-based learning assisted by Google Sites. The patterns of errors varied across indicators, ranging from errors in differentiating functions and selecting formulas, difficulty applying alternative solution strategies, a tendency to modify examples rather than generate new ideas, and a lack of supporting details in the answers.

Discussion

The analysis of the three subjects' answers revealed various errors involving conceptual, procedural, and technical aspects. Conceptual errors occurred because of insufficient understanding of integration functions. Procedural errors were caused by the selection of inappropriate formulas or operations and the incorrect application of integration methods. Technical errors were caused by mistakes in algebraic calculations or in the presentation of answers (Guenyari et al., 2024). These findings indicate that limited conceptual understanding and lack of calculation accuracy were the main factors causing the errors. A lack of conceptual understanding can stem from preconceptions or misconceptions that hinder comprehension and ultimately manifest as problem-solving errors (Abakah & Brijlall, 2024). This aligns with Radatz's perspective which posits that mathematical errors are rooted in weaknesses within an individual's cognitive structure that govern their thinking process (Shimizu & Kang, 2025).

For the fluency indicator, the errors made by M3, namely incorrect differentiation of the function, and M14, namely the incorrect surface-area formula, were conceptual in nature because both subjects had not understood the relationship between the function and the relevant integral formula. Meanwhile, M7's inability to provide an idea indicated that the initial cognitive schema for starting a solution had not yet been formed. According to Hidayati et al. (2024) Google Sites is effective in learning. Ideally the learning videos and supporting materials on Google Sites, which could be accessed repeatedly, should have strengthened fluency because they provide space for students to reconstruct their cognitive schemas.

For the flexibility indicator, the errors were procedural in nature. The three subjects basically understood one method for solving the volume of a solid of revolution, but they applied the formula incorrectly or had not mastered the cylindrical shell method. This was closely related to Google Sites assisted learning, which presented visualization passively through videos and practice problems in the teaching materials, without interactive simulations such as GeoGebra that would allow students to manipulate and compare the two methods independently before carrying out the algebraic procedures. Students therefore became spectators of a one-way visualization flow and worked on exercises with fixed patterns, without sufficient room for independent exploration to compare methods, so their flexibility in thinking did not develop optimally. The shortcomings of the web-based application need to be explored further in order to optimize its benefits and anticipate possible limitations (Amaro et al., 2024).

For the originality indicator, the inability to generate new ideas and the tendency to modify existing examples indicated that the subjects were not yet able to produce new knowledge. Interactive features that support student-centered learning (Muhammad et al., 2025), should provide space for originality through worksheet exploration that does not merely imitate standard examples. However, the three subjects appeared to use Google Sites mainly to access materials and discuss in groups, rather than to practice independently.

For the elaboration indicator, the lack of supporting details, such as curve sketches and approximation stages, was largely triggered by conceptual understanding that had not been solidly established in the previous indicators. Elaboration should ideally also be trained through students' learning outcome sheets on Google Sites, which require the presentation of steps and sketches in detail. Thus, the potential of Google Sites, which is theoretically relevant to the four indicators of mathematical creative thinking skills, had not yet been translated into improved individual performance.

A gap emerged between the achievement of mathematical creative thinking skill indicators at the group level during observation, which was consistently in the good to very good categories, and individual achievement on the final test, which did not meet any indicator. This indicates that group discussion in PBL learning is able to foster a collaborative environment that supports the exploration of ideas and the exchange of various problem-solving strategies. As explained by Guo et al. (Meiliati et al., 2026), PBL confronts individuals with open-ended problems that encourage exploration, collaboration, and the formulation of solutions. Collaborative discussion, meanwhile, enables students to obtain a range of alternative solutions through interaction with peers. This condition is consistent with Vygotsky's zone of proximal development, which explains that cognitive performance in collaborative situations with peer support can exceed the capacity that students are able to demonstrate independently (Boke et al., 2025). Collaborative dynamics strengthen both social skills and cognitive ability (Algiranto et al., 2026). In this study, PBL assisted by Google Sites was sufficiently able to build scaffolding spaces during group discussions, but it had not been followed by the transfer of understanding to the individual level. This finding confirms and extends the conclusion of Ningrum and Puadi (2023) that PBL emphasizes group collaboration in exploring mathematical problems. Such collaboration is effective in increasing participation and shared understanding, but it does not guarantee the reconstruction of independent understanding by each member. The implication is that the success of PBL implementation cannot be measured only from observations of group processes; it also needs to be balanced with mechanisms for continuously monitoring individual understanding throughout the PBL stages.

From the analysis of mathematical creative thinking skills conducted by the researcher using different creative attitude categories, it was found that students' creative attitude did not always correlate directly with their mathematical creative thinking skills. Students with high creative attitudes did not show high mathematical creative thinking skills, and the same pattern also applied to students with moderate creative attitudes. This finding is in line with the study by Muniroh et al. (2019), which reported variations in mathematical creative thinking skills across each category of students' affective aspects and emphasized that affective aspects such as creative attitude and self-concept do not always correlate directly with cognitive ability. However, this differs from the emphasis of Johar et al. (2025), who argued that affective responses play an important role in cognitive ability. Creative attitude is motivational in nature and does not necessarily translate into measurable creative performance without conceptual mastery. Other factors also influence mathematical creative thinking skills besides creative attitude, including internal factors such as intelligence, talent, interest, attitude, self-efficacy, and motivation, as well as external factors such as environment, family socioeconomic status, and support from parents, teachers, and peers (Rahyuningsih et al., 2022). Although creative attitude is an affective aspect that motivates students, it does not always correlate directly with mathematical creative thinking skills because measurable cognitive performance depends strongly on conceptual mastery and various other factors.

These findings provide several implications for the implementation of PBL assisted by Google Sites in integral learning. First, the success of Google Sites was more evident as a medium for providing and accessing materials and learning videos than as a means of strengthening individual understanding. Future development of Google Sites needs to include adaptive formative exercises, such as staged quizzes with automatic feedback so that students can practice and reflect on their understanding independently, curve visualization, and the addition of real-time interactive features. Second, the implementation of PBL, which was generally still in the fair category in the process-evaluation phase, requires stronger lecturer support so that the transfer of understanding can take place more optimally. Finally, because Google Sites was used effectively only for classroom activities without ensuring independence outside class, structured independent assignments that can be monitored by lecturers are needed, so that technology does not stop at providing access to materials but also encourages individual learning accountability.

Conclusion

The students' mathematical creative thinking skills in integral calculus using Google Sites through PBL based on creative attitude had not developed optimally. Students in both the high and moderate creative attitude categories were not yet able to fully meet the four indicators of mathematical creative thinking skills. The errors identified were dominated by conceptual errors that developed into procedural and technical errors. This indicates that mastery of integral concepts is a key prerequisite for the development of mathematical creative thinking skills. At the same time, creative attitude functions more as affective capital that needs to be supported by adequate conceptual understanding.

Learning assisted by Google Sites through PBL was able to facilitate creative thinking processes at the group level, but it had not fully encouraged the internalization of understanding at the individual level. Therefore, the implementation of PBL assisted by Google Sites needs to be accompanied by strengthening conceptual understanding, more interactive and exploratory learning activities, and continuous individual evaluation.

Theoretically, this study enriches research on the relationship between mathematical creative thinking skills and creative attitude by showing that creative attitude is not always directly proportional to mathematical creative thinking skills. Practically, this study provides recommendations for developing integral learning assisted by Google Sites through PBL that not only focuses on collaboration but also encourages the formation of conceptual understanding and mathematical creative thinking skills among university students.

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Declarations

Conflicts of Interest	:	The authors declare no conflict of interest.
Generative AI Statement	:	AI Used for Limited, Non-Substantive Support: Generative AI tools, such as DeepL, were employed solely for language editing and minor phrasing enhancement. All conceptualization, analysis, and scholarly content were independently developed and verified by the authors.
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Author Contributions	:	**Yayu Laila Sulastri:** Conceptualization, writing - original draft, editing, and visualization; **Deti Ahmatika:** Validation and supervision, formal analysis, and methodology; **Annisa Nurmaulani:** Writing - review & editing.

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