Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

Integration of PBL, TaRL, and RME in Developing Creative Mathematical Thinking in Secondary School Students

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Abstract. *This study evaluates the effectiveness of the Problem-Based Learning (PBL) model, integrated with the Teaching at the Right Level (TaRL) approach and the Realistic Mathematics Education (RME) strategy, in enhancing students' creative thinking skills. Focusing on the Pythagorean Theorem at SMPN 1 Sakra, this research aims to: 1) measure the effectiveness of the integrated PBL-TaRL-RME model in improving students' creative thinking levels, and 2) describe the distribution of students' creative thinking abilities following the intervention. Using a mixed-methods approach with a one-group pretest-posttest design, data were collected and analyzed both quantitatively and qualitatively. The Paired Samples t-test showed a p-value of 0.000 (< 0.05), confirming that the integrated learning model significantly improves students' creative thinking skills. Qualitative analysis revealed that 6 students reached Level 0, 10 reached Level 1, 7 reached Level 2, and 5 reached Level 3.*

Keywords: *Problem-Based Learning; Teaching at The Right Level; Realistic Mathematics Education; Creative Thinking Skills; Pythagoras.*

INTRODUCTION

Education issues that remain a significant concern in Indonesia include mathematics. An indicator of this problem is clearly seen in the 2022 PISA Mathematics Literacy scores released by the OECD. The recorded score was 366, a 13-point decline from the previous score (379) on the PISA mathematics test (Rahmadani et al., 2024). Indonesia's performance in mathematics lags far behind that of other countries. Specifically, Indonesia still ranks below neighbouring countries such as Malaysia, Singapore, Brunei Darussalam, and Australia. This lag is mainly due to several factors related to student ability. Some of the main shortcomings include: students' difficulty in expressing arguments accurately, inability to come up with solutions in line with the material taught, confusion over questions presented at the beginning of the learning session, low proficiency in solving problems using the correct methods, and limited ability to review and correct their answers. As a result, this condition is not aligned with the 21st-century skills students should master during the learning process.

The essential competencies of the 21st century, known as the 4C Skills, encompass four key abilities: critical thinking and problem solving, creative and innovative thinking, collaboration, and communication (Effendi et al., 2024). All of this knowledge needs to be developed through learning activities organised for students. The aim is to ensure that students have the necessary skills and competencies in line with the educational needs of the 21st century (Rahmadani et al., 2024).

Based on the researcher's observations, classroom learning activities have not been optimal because teachers' teaching practices are still not maximised, resulting in minimal student activity. This situation is primarily due to the conventional methods that teachers continue to use. Particularly in mathematics, this approach often causes boredom among students and leads to a lack of understanding of the material, making the classroom atmosphere uninteresting. Students are often only instructed to listen, solve standard problems, and take notes, which makes it difficult for them to understand concepts, analyse problems, and draw conclusions. As a consequence, students' creative thinking skills for solving various problems are inhibited (low).

To overcome the above obstacles, the learning process should be student-centred, allowing students to explore and develop their creative thinking skills. In addition, the choice of learning model must align with the material being taught. This approach is expected to increase students' interest in active participation, help achieve learning objectives, and improve problem-solving and creative thinking skills.

One recommended model is Problem-Based Learning (PBL), which is implemented through the teaching and learning process. (Yang et al., 2023), (Setyawati et al., 2024) define the Problem-Based Learning (PBL) model as an instructional approach that encourages students to learn through various authentic problems encountered in real life (Afelia et al., 2024). These real-world problems provide a context for students to develop creative thinking and problem-solving skills, as well as gain broad knowledge in a subject.

Thus, PBL can be defined as a synonym for problem-based learning that focuses on the difficulties students encounter during the learning process (Boom-Cárcamo et al., 2024). This model is expected to provide solutions to overcome these problems by utilising students' creative thinking skills (Ssemugenyi, 2023). In addition, Smith et al. (2022) emphasise that the classroom learning process must accommodate and recognise the differences among students. This classroom diversity arises from students from different backgrounds, with varying levels of competence and characteristics. Given that PBL (Problem-Based Learning) is a cooperative learning model, this approach is required to foster a supportive atmosphere that respects each difference (Dulyapit et al., 2023).

Therefore, a strategy is needed to specifically accommodate these differences in ability, namely the implementation of Teaching at the Right Level (TaRL). TaRL is a teaching approach that no longer relies on class levels but focuses on students' actual ability levels (Muammar et al., 2023; Syafaah et al., 2024; Azhari & Yuliana, 2025). Furthermore, according to Anggriani et al. (2023), Hadiawati et al. (2024), Putri & Muldash (2024), and Setyawati et al. (2024), TaRL is a learning approach that does not refer to grade levels but to students' ability levels. TaRL can be a solution to classroom ability gaps (Afandi et al., 2024; Busri et al., 2023; Mustafa et al., 2024).

In the Teaching at the Right Level (TaRL) approach, students are organised into learning groups based on similar developmental phases or ability levels, which are tailored to each learner's potential, needs, and unique characteristics (Afandi et al., 2024; Mustafa et al., 2024). In addition to utilising learning models that aim to activate students, it is also important that these models contribute to the development of creative thinking skills in the mathematics learning process (Jazuli, 2022). When teaching mathematics, teachers should connect the material to everyday contexts so that students can better understand the concepts (Amalia et al., 2024). Given the urgency of mathematics education in practical life, instilling accurate mathematical concepts in the learning process is essential.

Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

Understanding mathematical concepts is one of the skills or competencies in mathematics expected to be mastered through the learning process (Zakiyah et al., 2024; Aryanti & Muthamainah, 2024). This mastery can be demonstrated by students showing their understanding of the concepts learned, explaining the interrelationships among concepts, and applying concepts or algorithms flexibly, accurately, efficiently, and correctly to solve problems (Aryanti & Muthamainah, 2024). Thus, an approach that connects mathematics learning to everyday contexts is needed. (Zakiyah et al., 2024), The aim is to make it easier for students to absorb the information the teacher conveys. One approach considered relevant for this purpose is Realistic Mathematics Education (RME) (Laurens et al., 2017; Papadakis et al., 2021).

The Realistic Mathematics Education (RME) approach greatly assists students in problem-solving by facilitating learning through activities related to their daily experiences (Iskandar, 2022). Juandi et al. (2022) explain that this approach provides students with opportunities to reconstruct and organise mathematical concepts based on realistic problems presented by teachers. This is important because students build their own knowledge, which makes the concepts more memorable. Furthermore, Ulfah et al. (2020) define RME as a mathematics teaching approach applied in everyday life and oriented towards real experiences. This orientation makes it easier for students to absorb the material and provides a direct learning experience (Wahyudi et al., 2017). To optimise creative thinking skills in the mathematics learning process, students need space to develop their own knowledge and understanding (Suherman & Vidákovich, 2022).

This creative thinking ability is essential in learning because it enables students to generate a variety of ideas and concepts. Azaryahu et al. (2023) define creative thinking as a cognitive process capable of producing a variety of original ideas or concepts. Therefore, creative thinking is considered crucial in mathematics learning, especially in problem-solving. In line with this, Risnanosanti et al. (2020) state that students who have creative tendencies will demonstrate superior thinking patterns and absorption compared to those with minimal creative thinking skills.

Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

Logically, students who have mastered creative thinking skills will be able to formulate new ideas or concepts to solve problems.

Thus, it is clear that creative thinking skills are a vital aspect of the learning process. Based on the above background to the problem, the researcher was motivated to conduct an in-depth investigation to assess the effectiveness and impact of the PBL model integrated with TaRL using the RME approach. This study specifically aims to identify the extent to which this model can maximise and effectively improve students' creative thinking skills, in line with the established learning objectives.

RESEARCH METHOD

The research method used is a mixed-methods approach that combines quantitative and qualitative research strategies. This approach provides statistical validity and qualitative depth of analysis, resulting in much more accurate research conclusions (Harrison et al., 2020; Stern et al., 2020; Strijker et al., 2020). This study aims to comprehensively examine the effectiveness of integrating Problem-Based Learning (PBL), Teaching at the Right Level (TaRL), and Realistic Mathematics Education (RME) in developing students' mathematical creative thinking skills. The research population included all Year 8 students at SMP Negeri 1 Sakra in the 2025/2026 academic year. The research subjects were selected from one class of 28 students based on interviews with mathematics teachers at SMP Negeri 1 Sakra, who assessed the students' levels of creative thinking.

The research instruments included a pre-test and a post-test of mathematical creative thinking skills, each comprising three essay questions. These instruments were used to identify students' creative thinking skills before and after the implementation of the PBL model integrated with TaRL and the RME approach.

The instrument's validity was assessed through content validity, with each item adjusted to the indicators of mathematical creative thinking ability. Furthermore, construct validity was assessed to evaluate the accuracy of word usage, sentence structure, and contextual appropriateness across test and non-test instruments. To obtain more in-depth data on students' mathematical creative thinking abilities, this study also included interviews based on creative thinking ability tests. The interviews were conducted after levelling students' abilities based on post-test results. The selection of interview subjects was based on their average pre-test scores.

The data obtained were analysed in several stages. Normality testing was performed using the Shapiro–Wilk test in IBM SPSS Statistics version 24. Next, hypothesis testing on the effectiveness of integrating PBL, TaRL, and RME in improving students' mathematical creative thinking skills was conducted using the Paired Samples t-Test. All data analysis was performed at the $\alpha = 0.05$ significance level.

The research instruments in this study included researchers and written tests. Given that the study used a mixed-methods approach, the researchers served as the primary instrument, particularly in the qualitative component, responsible for identifying problems, determining subjects and data sources, designing and implementing data collection, analysing results, and compiling research reports. In addition, the test instruments consisted of a pre-test and a post-test of creative thinking skills, each comprising three essay questions on the application of the Pythagorean Theorem in real-life contexts. The pre-test is used to identify students' initial abilities and creative thinking skills before learning. In contrast, the post-test is used to evaluate students' creative thinking skills after participating in learning using the Problem-Based Learning (PBL) model integrated with Teaching at the Right Level (TaRL) using the Realistic Mathematics Education (RME) approach. Although the questions differed in content, both tests were structured with consistent assessment indicators and underwent expert validation to ensure the suitability and feasibility of the research instruments.

RESULTS AND DISCUSSION

The grouping of initial ability levels was carried out after analysis of the pre-test data. The analysis showed that there were 9 students at level 0, 13 at level 1, 5 at level 2, and 1 at level 3. Details of the level distribution are shown in Table 1.

Table 1. Distribution of Subjects' Initial Creative Thinking Ability Levels

Ability Level	Number of Students	Subject Code	Description
Level 0	9 student	S01, S06, S07, S11, S14, S15, S22, S25, S27	Not creative
Level 1	13 student	S02, S03, S04, S05, S08, S12, S13, S17, S18, S19, S20, S23, S26	Quite creative
Level 2	5 student	S09, S10, S16, S21, S24	Creative
Level 3	1 student	S28	Very creative

Analysis of the initial ability test (pre-test) results shows the distribution of students' creative thinking ability levels as follows: nine (9) students were at Level 0, which is defined as the non-creative category. Furthermore, thirteen (13) students were at Level 1 (moderately creative), five (5) students reached Level 2 (creative), and only one (1) student was at Level 3 (highly creative). Full details regarding this level classification are presented further in Figure 1.

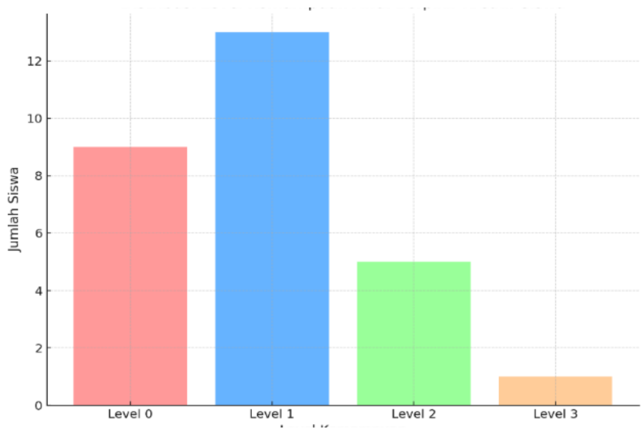

Figure 1. Initial Level of Creative Thinking Ability

Learning Process

In the learning process, the research uses the PBL Model with an integrated RME Approach Teaching at The Right Level (TaRL), in which the learning is adjusted to students' levels of understanding. This approach comprises four main stages: initial assessment to identify students' ability levels, grouping based on assessment results, the application of pedagogical strategies appropriate to each group's ability level, and continuous monitoring and mentoring.

In the core learning stage, 28 students in Class VIII A were heterogeneously grouped into four categories based on an initial ability assessment (TKA). The group distribution was as follows: Level 0 (9 students), two Level 1 subgroups (6 and 7 students each), Level 2 (5 students), and Level 3 (1 student). Next, the researcher applied a differentiated approach, providing guidance and mentoring appropriate to each group's level of mastery of the material, using textbooks and student worksheets. The researcher actively monitored the learning process by visiting each group and providing necessary support and assistance. In particular, Level 0 and Level 1 groups required more intensive attention and guidance to understand and master the material optimally.

Creative Thinking Ability Test

Based on data analysis from the final creative thinking test, the distribution of student ability levels was as follows: 6 students at Level 0, 10 at Level 1, 7 at Level 2, and 5 at Level 3. Full details regarding this level distribution are visualised in Figure 1.2.

Figure 2. Creative Thinking Ability Level (Post-Test)

Based on the analysis of post-test results, student performance was grouped into several levels of creative thinking ability: 1) Level 0 (Not Creative): Students in this group showed minimal ability. They can identify only basic information from the questions, provide one solution that is generally inaccurate, and have not yet mastered any indicators of creative thinking. 2) Level 1 (Beginning to be Creative): Students begin to show early creative thinking skills by mastering one indicator. However, their achievement of this indicator is still limited and only seen in one question; 3) Level 2 (Moderately Creative): Students at this level can analyse the information in the question and solve it correctly using the methods discussed. In addition, they begin to try alternative methods. However, the application of other solutions is only seen in two questions: 4) Level 3 (Highly Creative): This group describes students with high creative thinking skills. They not only provide the correct solution but also consistently find and use alternative methods that differ from the standard methods for each question.

The data shows a decrease in the number of students at Level 0 (not creative) from 9 to 6, and a significant increase at Level 3 (highly creative) from 1 to 5. This reinforces the findings (Afelia et al., 2024; Boom-Cárcamo et al., 2024; Dulyapit et al., 2023; Smith et al., 2022; Yang et al., 2023) that the PBL model, combined with contextual problems, can encourage students to explore various solutions, ultimately increasing their thinking flexibility. In the context of RME, contextual problems serve as a bridge for students to perform horizontal and vertical mathematisation (Iskandar, 2022).

The success of this improvement was also influenced by the heterogeneous grouping strategy and intensive guidance for Level 0 and Level 1 groups. As explained by Afandi et al. (2024), Mustafa et al. (2024), Putri & Muldash (2024), and Setyawati et al. (2024), differentiated learning, at the core of TaRL, enables teachers to provide the right amount of scaffolding for students who experience difficulties with fluency indicators. The intensive guidance provided by the researchers to subjects such as S08 helped students understand the core of the problem, although achieving the originality indicator still requires further work.

Normality Test Result

Before testing the hypothesis, a normality test was conducted to determine the appropriate statistical test for analysing the pre-test and post-test data. The results of the normality test using the Shapiro-Wilk technique (or Kolmogorov-Smirnov, depending on which you use) are presented in the following table 2.

Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

Table 2. Normality Test Results

Test Group	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	.100	28	.200[b]	.946	28	.155
Post-test	.123	28	.200[b]	.966	28	.481

[a] Lilliefors Significance Correction

[b] This is a lower bound of the true significance.

The normality test results analysed using IBM SPSS Statistics 24 show that the research data is typically distributed. The significance value (Sig.) obtained for the pre-test data is 0.155, and for the post-test data is 0.481. Both values are greater than 0.05, so the alternative hypothesis (Ha) stating that the data is normally distributed can be accepted. Based on these results, further analysis was conducted using parametric statistical tests. This method was chosen because of its optimal effectiveness and validity for data that conform to the assumption of normality.

Hypothesis Testing

The researchers tested the hypothesis that the TaRL learning model improves students' creative thinking skills using the Paired Samples t-Test. This test was selected based on the normality test results, which indicated that the pre-test and post-test data were normally distributed. Thus, the hypothesis analysis was carried out using a parametric statistical approach, which was considered most appropriate for the characteristics of the research data.

Table 3. Paired Samples Statistics

Pair	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	42.04	28	24.79	4.69
Post-test	54.58	28	31.47	5.95

Table 4. Paired Samples Correlations

Pair	N	Correlation	Sig.
Pretest & Posttest	28	.783	.000

Based on the data in Table 3 (Paired Samples Statistics), the pre-test mean was 42.04, and the post-test mean was 54.58. This difference indicates an increase in the average score after the implementation of the Problem-Based Learning (PBL) model integrated with TaRL and the Realistic Mathematics Education (RME) approach. Furthermore, data from Table 4 (Paired Samples Correlations) reveals a significance value of 0.000, which is clearly less than 0.05 ($0.000 < 0.05$). This result reinforces the conclusion that there is a significant correlation (relationship) between the pre-test and post-test results. This finding is consistent with the decision-making criteria for the correlation test, which indicate that a p-value below 0.05 confirms the existence of a relationship between variables. Furthermore, to verify the existence of significant differences in student learning outcomes after using the TaRL-integrated PBL model with the RME approach, the following hypothesis testing was conducted:

- Null hypothesis (H_0): There is no difference in students' creative thinking skills before and after the implementation of the Teaching at the Right Level (TaRL) approach.
- Alternative hypothesis (H_1): There is a difference in students' creative thinking skills after the implementation of the PBL approach with the RME approach integrated with Teaching at the Right Level (TaRL).
- Test criteria: H_0 is rejected if the Asymp. Sig value is < 0.05.

Table 5. Paired Samples Test

	Paired Differences			95% Confidence
	Mean	Std. Deviation	Std. Error Mean	Lower
Pair 1 Pre-test - Post-test	-13.98679	9.36909	1.77059	-17.61974

Table 6. Hypothesis Test Results

	95% Confidence Interval of the Difference			
	Upper	t	df	Sig. (2-tailed)
Pair 1 Pre-test - Post-test	-10.35383	-7.899	27	0.000

Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

In general, based on the statistical output results, an Asymptotic Significance (Asymp. Sig.) value of 0.000 was obtained. Since this value is much smaller than the significance threshold of 0.05, the Null Hypothesis (H_0) is rejected, and the Alternative Hypothesis (H_1) is accepted. The implications of this Paired Samples t-Test confirm that there is a significant difference between the pre-test and post-test average scores. In other words, the application of the Problem-Based Learning (PBL) approach model, synergised with Realistic Mathematics Education (RME) and Teaching at the Right Level (TaRL), has been proven to have a tangible impact on improving students' creative thinking skills.

This improvement demonstrates that integrating these three elements (PBL, RME, and TaRL) creates effective synergy. This aligns with research (Mustafa et al., 2024) that the TaRL approach is very effective in guiding students to achieve a deeper understanding because the material is delivered according to their cognitive ability levels, so students do not feel burdened by material that is too difficult.

Analysis of Creative Thinking Ability Levels

Based on the measurements that have been carried out, Subject S08 is classified as Level 0 (not creative) in the dimension of creative thinking ability. This level determination is supported by the fluency indicator, which measures students' capacity to generate multiple ideas, or at least one alternative solution, to a problem. More specifically, this indicator requires students to provide more than one answer to the first question or problem. Written evidence of Subject S08's answers to these questions is presented in Figure 2.

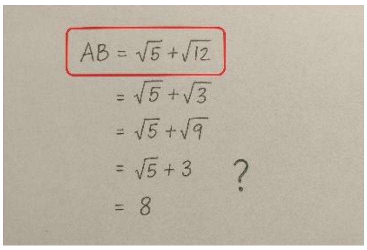

Figure 3. Answer sheet for subject S08

Analysis of the answer sheet shows that Subject S08 did not meet the established indicator criteria, as he was unable to provide an accurate explanation or solution to the question. Further interview transcripts (excerpts) emphasise that Subject S08 has limitations in expressing reasoning related to Question Number 1. These shortcomings include inaccuracy in explaining (describing) known information, as well as errors in recognising the core issues required by the question.

1. **Flexibility**

The flexibility indicator is the student's capacity to present (propose) various alternatives or methods of solution to arrive at the correct answer. Thus, students are expected to be able to offer solutions in a variety of ways. However, for Question Number 2, Subject S08 did not respond. Therefore, it can be concluded that this subject was not yet able to demonstrate or explain an answer that met the criteria of the flexibility indicator.

2. **Originality**

Originality reflects students' ability to present exceptional (unique) and unusual answers (responses), utilising their own framework of thinking and style of expression (verbal expression). This criterion requires students to develop and formulate solutions independently, which ultimately results in solutions that demonstrate individual uniqueness. Written work for Subject S08 related to this indicator can be examined in Figure 1.5.

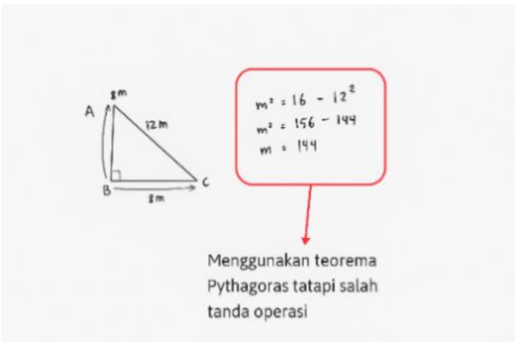

Figure 4. Answer to question number 3, subject S08

Subject S22 was classified as Level 1 in creative thinking ability.

The Fluency indicator is a parameter that measures students' ability to generate diverse ideas or solutions (divergent thinking) when faced with a problem. This criterion requires students to present a variety of alternative answers to the first

Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

question. To evaluate the performance of Subject S22 in meeting this Fluency criterion, see Figure 4.

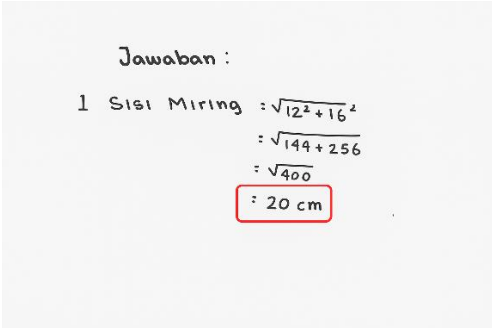

Figure 5. Answer to question 1, subject S22.

Subject S22 demonstrated adequate competence in expressing reasoning related to Question Number 1. He successfully analysed the information presented in the question and identified the problem to be solved. In addition, this subject was able to explain the data available in the question, although in the end, he presented only one alternative solution.

1. **Flexibility**

Flexibility is the cognitive ability of students to propose a series of alternative methods or solutions (divergent thinking) to arrive at the correct answer. In essence, students are required to demonstrate variety in their problem-solving approaches. The performance of Subject S22, as reflected in this flexibility indicator, is shown in Figure 5.

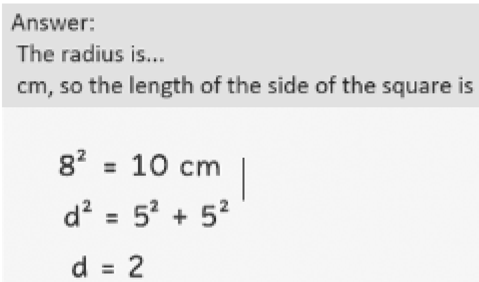

Figure 6. Answer to question no. 2, subject S22

2. **Original**

The Originality indicator is the ability of students to produce responses in their own style of language (verbal expression). This means that students are required to find or explain their answers using their own methods or understanding, which will naturally differ from those of other students.

Table 7. Test and interview results

Indicator	Written Test Results	Interview Results
Fluency	The response given by Subject S22 was limited to one answer, even though the solution procedure (steps) used was accurate.	Based on the interview, Subject S22 stated that he could not find any other alternative answers. Nevertheless, the subject was able to describe the steps to solve the problem in line with the information provided in the question.
Flexibility	Subject S22's response was limited to providing minimal data, and there was no indication that he used various approaches or alternative solutions.	The subject explained that the only information he obtained from the question was the length of the radius and the diameter of the circle, without any other strategies for solving the problem.
Original	Subject S22 successfully arrived at the correct final answer, but did not include an explanation of the steps (process) used to arrive at that answer.	Based on verbal statements, the subject demonstrated an understanding of the information contained in the questions and was able to explain the steps to solve the problems, even though these explanations were not written down.

Qualitative analysis results on subjects S08 and S22 show that the originality indicator remains the most challenging aspect to master. This is consistent with the results of a study (Ulfah et al., 2020), which revealed that students tend to feel secure with the methods taught by teachers and are hesitant to try their own unique ideas. However, through the RME approach, students are encouraged to construct their own understanding (self-reconstruction), which is the main capital for achieving higher levels of creativity in the future.

The findings of this study are in line with the results of previous studies (Iskandar, 2022; Juandi et al., 2022; Laurens et al., 2017; Papadakis et al., 2021), which show that the integration of Realistic Mathematics Education (RME) in problem-based learning models contributes significantly to improving students' mathematical representation and creative thinking skills. The RME approach places real-world contexts as the starting point for learning, so that mathematical concepts are understood as conceptual tools for solving contextual problems, rather than merely a collection of abstract procedures and formulas. Furthermore, the

Kontinu: Jurnal Penelitian Didaktik Matematika
E-ISSN: 2656-5544
P-ISSN: 2715-7326
Vol. 10, No. 1: May 2026
Page. 36-55

application of the Teaching at the Right Level (TaRL) approach in this study reinforces the findings (Abidin et al., 2024; Amalia et al., 2024; Astuti et al., 2024; Lakhsman, 2019; Syafaah et al., 2024) which emphasise the importance of differentiated learning to overcome learning loss and student ability heterogeneity post-pandemic. TaRL allows adjustments to learning strategies based on students' initial mastery levels, making learning interventions more personalised, adaptive, and targeted. Thus, the combination of RME and TaRL is not only theoretically relevant but also responsive to the empirical challenges of mathematics learning in the current educational context. Overall, the integration of PBL, RME, and TaRL not only improved learning outcomes quantitatively but also enhanced students' qualitative reasoning, discussion, and alternative-solution finding in mathematics.

CONCLUSION

Based on the results of the data analysis described in the previous chapter, several conclusions can be drawn as follows: the significant effect of the Paired Samples t-Test learning model produced a significance value (p-value) of 0.000. This figure indicates that implementing the PBL (Problem-Based Learning) model, integrated with the RME and Teaching at the Right Level (TaRL) approaches, significantly improves the creative thinking skills of Grade VIII A students at SMPN 1 Sakra in solving Pythagorean Theorem problems. The distribution of ability levels after the intervention, comparing pre-test and post-test scores, produced the following data on student ability distribution: Six (6) students remained at Level 0, meaning they had not successfully met all creative thinking indicators; Three (3) students were at Level 1, indicating they were only able to meet one creative thinking indicator and could generally only answer one question; Furthermore, seven (7) students reached Level 2, as shown by their ability to meet two indicators of creative thinking on two different questions; Finally, five (5) students were at Level 3, meaning they were able to meet all three indicators of creative thinking (fluency, flexibility, and originality) in solving the questions given.

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