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Effect of Problem-Based Learning Supported by PLEXA Media on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

Rima Kusuma Dewi[1*], Cucun Sunaengsih[1], Maulana[1]

[1]Elementary School Teacher Education Program, Sumedang Regional Campus, Universitas Pendidikan Indonesia

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ABSTRACT

The increasing complexity of 21st-century challenges requires students to develop creative thinking skills to generate solutions to everyday problems. However, prior studies indicate that students' mathematical creative thinking remains limited due to low interest in solving math problems, dependence on teacher-given examples, and minimal effort to explore alternative problem-solving strategies. This study examined the effect of PLEXA (Problem Explorer Data)-assisted Problem-Based Learning (PBL) on fifth-grade students' mathematical creative thinking skills, using a quasi-experimental design with three nonequivalent groups (pretest-posttest). The sample comprised 122 fifth-grade students from three A-accredited public elementary schools in Cimalaka Subdistrict, Sumedang Regency: Experimental Group I (PLEXA-assisted PBL, n=49), Experimental Group II (PBL without media, n=43), and a control group (conventional learning, n=30). The research instrument, a mathematical creative thinking test, was validated through limited (n=6) and broad (n=55) pilot tests; 12 of 13 items were valid (Cronbach's alpha = 0.906, very high reliability). Data were analyzed using Shapiro-Wilk, Levene's, t-test, Wilcoxon, N-Gain, Pearson, Spearman, coefficient of determination, and Kruskal-Wallis tests. Results showed PLEXA-assisted PBL had the largest effect on mathematical creative thinking (41.47%), followed by PBL without media (38.19%) and conventional learning (30.91%). PLEXA-assisted PBL therefore has a significant effect on fifth-grade students' mathematical creative thinking skills.

Corresponding Author:

Rima Kusuma Dewi,
Elementary School Teacher Education Program,
Universitas Pendidikan Indonesia
Jl. Mayor Abdurahman No. 211, Kotakaler, North Sumedang District, Sumedang Regency, West Java 45322, Indonesia,
rimakusumadewi24@upi.edu

Introduction

Although mathematics is an important subject, its implementation in Indonesia has yet to achieve optimal results in line with the targeted competencies. The 2015 TIMSS report shows that students' mathematics achievement in Indonesia stands at only 397, which is still below the standard average of 500 points. This places Indonesia in the "low performance with high equity" category, indicating that teachers' enthusiasm and engagement in the learning process are quite high, but most teachers do not yet fully understand the individual learning needs of their students (Mutakin et al., 2023). This situation reveals that there is still a gap between the desired outcomes and the actual conditions. Low mathematics achievement not only reflects suboptimal mastery of the material but also indicates that students' Higher Order Thinking Skills (HOTS), particularly in the dimension of creative thinking, have not shown the ideal level of progress required in mathematics education. Therefore, efforts to improve the quality of mathematics education must be oriented toward comprehensively stimulating and honing all aspects of students' thinking skills.

In the era of globalization, the ability to think creatively has become one of the crucial competencies that every individual must master. Given the increasingly complex challenges of the 21st century, students are expected to possess creative thinking skills so they can generate various innovations and solutions to address the problems of everyday life (Deswita et al., 2023). The importance of creative thinking skills is emphasized life Deswita et al. (2023) that 'students who are able to think creatively are able to solve problems effectively'. This statement shows that students with creative thinking skills tend to be more effective at finding solutions to the various problems they face. Therefore, creative thinking is an essential skill for students, both in the learning process and in their daily lives. Through creative thinking activities, students are taught to view problems from various perspectives, find more innovative solutions, and formulate solutions to a problem using a variety of possible alternative strategies (Deswita et al., 2023). According to Maulana (as cited in Pertiwi, 2022), the indicators of mathematical creative thinking ability consist of sensitivity, flexibility, fluency, elaboration, and originality.

However, these expectations do not yet align with the reality on the ground. Data from observations and interviews indicate that students' creative thinking skills remain relatively low. This situation is characterized by a lack of enthusiasm among students for mathematical problem-solving activities, a high degree of reliance on examples provided by teachers, and a lack of independent initiative to explore a variety of alternative solutions (Herawati et al., 2023). Consistent with these findings, students' passivity in the classroom indicates a lack of creative thinking skills in solving math problems, as evidenced by their reliance on a single learning resource the textbook and their tendency to solve problems using only the method outlined in the textbook (Kumalasari et al., 2024).

The Problem-Based Learning (PBL) approach can be presented as a solution to these issues, in which student engagement is focused on resolving authentic phenomena or problems. As an instructional strategy, PBL integrates real-world problems as the primary stimulus to initiate and drive the entire learning process (Fernando et al., 2024). A study by Pratama (2022) demonstrates that PBL has been shown to significantly enhance students' creative thinking skills beyond what is achieved through conventional teaching methods. Similar findings can be seen in the study by Sinaga et al. (2024) which demonstrated that the implementation of Problem-Based Learning significantly improved students' creative thinking skills. These findings confirm that PBL can create an accommodative learning environment that encourages students to develop new ideas in a more flexible and innovative manner, thereby proving that this approach has a substantial impact on enhancing students' creative thinking abilities. According to Eismawati et al. as cited in (Yulianti et al., 2025), Problem-Based Learning (PBL) consists of six steps: reviewing the learning objectives, receiving the problem, conducting an investigation, analyzing data, preparing a report, and reflecting on the process.

In this context, one tool that can support the successful implementation of the Problem-Based Learning approach is PLEXA (Problem Explorer Data), an educational innovation that

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provides students with alternative visual and manipulative representations for exploring data concepts. PLEXA (Problem Explorer Data) is an interactive learning tool specifically developed to support students in exploring data concepts through the presentation, processing, and interpretation of data in various forms. PLEXA also provides a series of contextual problems that encourage students to analyze data, discover various problem-solving strategies, and generate diverse solutions, thereby helping to enhance students' creative thinking skills. The PLEXA Media consists of four main zones: the problem zone, the data collection and processing zone, the data presentation zone, and the analysis zone, all designed to support active and creative learning of data presentation. In the problem zone, students select problem cards containing real-world problems related to data presentation, thereby fostering curiosity, the courage to make decisions, and active engagement from the very beginning of the learning process. Next, in the data collection and processing zone, students collect data through real-world activities, such as interviewing classmates or observing their surroundings, and then record and process the data, with the freedom to choose their own titles based on the data they've gathered. In the data presentation zone, students present the results of their data processing in the form of pictograms, tables, or bar charts by utilizing various characters, images, colors, and titles that they can choose according to their own creativity. This platform also includes features that allow titles and data results to be deleted so they can be reused, as well as a bar chart feature where the number of bars can be adjusted based on the data obtained. Before entering the analysis zone, students first complete a challenge card containing activities designed to spark creative thinking, such as changing the format of data presentation, comparing data, or formulating questions based on the data they have created. Next, in the analysis zone, students analyze the data by determining the highest value, the lowest value, the total, and the difference in specific data points, then draw conclusions from the results obtained.

All stages of the PLEXA platform are designed to foster the comprehensive development of students' creative mathematical thinking skills, from problem exploration, data collection and presentation, to analysis and drawing conclusions. The PLEXA media has its own unique features: it supports data exploration, provides visual and manipulative representations, and enables students to develop a variety of strategies aligned with the indicators of creative mathematical thinking, which include sensitivity, flexibility, fluency, elaboration, and originality. In the data unit, students have the opportunity to discover a variety of possible answers as well as various strategies for presenting, processing, and interpreting data. Furthermore, the concept of data is closely tied to students' daily lives such as data on hobbies, height, weather, or the results of simple surveys making it easy to contextualize within the learning process. Therefore, the data unit is considered appropriate for honing students' creative thinking skills. Data is one of the topics studied by fifth-grade elementary school students during the second semester under the Merdeka Curriculum. Furthermore, fifth-grade students are at a stage of cognitive development that enables them to internalize higher-order thinking skills, allowing their creative thinking abilities to be developed optimally. Based on these considerations, the researcher selected fifth-grade elementary school students as the subjects for this study.

A study conducted by (Fitriani & Jusra, 2024), indicates that the implementation of Problem-Based Learning integrated with audiovisual media contributes positively and significantly to improving students' mathematical creative thinking skills. This combination is considered capable of stimulating student engagement, conceptual mastery, and creativity in solving mathematical problems in a more varied and in-depth manner. Nevertheless, there remains a research gap regarding the effectiveness of using specific media such as PLEXA when combined with the Problem-Based Learning approach. This is what underlies the urgency of further investigation to test the significance of PBL's implications, with the aid of PLEXA media, on aspects of students' creative thinking. According to Maulana (as cited in Pertiwi, 2022), creative thinking skills include the components of sensitivity, flexibility, fluency, elaboration, and originality.

Furthermore, most previous studies have been limited to comparing two groups (experimental and control), using a single type of treatment, and measuring creative thinking abilities with relatively limited indicators. Thus, there remains a research gap regarding a comparative analysis of the effects of the PBL approach and a combination of both approaches on elementary school students' mathematical creative thinking abilities. Research on PBL whether with or without media has been extensively conducted, but specialized media for data exploration, such as PLEXA, have not yet been widely tested. Furthermore, few studies have compared three groups: a control group using conventional instruction, an experimental Group I using PBL, and an experimental Group II using PBL supported by PLEXA media. The novelty of this research lies in the application of a PBL approach supported by PLEXA to optimize the mathematical creative thinking skills of fifth-grade elementary school students, involving three sample groups consisting of one control class and two experimental classes. Through this design, this study is expected to fill a research gap that has not been addressed in previous studies. Thus, the main objective of this study is to examine the contribution of PBL, supported by the PLEXA media, to the mathematical creative thinking skills of fifth-grade elementary school students. Through the integration of PBL with the PLEXA media, the goal is to achieve a significant improvement in students' mathematical creative thinking skills, particularly in the context of mathematics learning at the elementary school level. Based on this academic urgency, this study was conducted under the title "The Effect of Problem-Based Learning Supported by PLEXA Media on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students."

Method

Type of Research

In this study, a quasi-experimental method was used to design a non-equivalent control group (Maulana et al., 2022). Cook states that a quasi-experiment is an experimental research method that involves administering a treatment, measuring the effect or impact of the treatment, and using experimental units, but without random assignment of groups when determining the control group. Thus, comparisons between groups are made to draw conclusions about the changes resulting from the applied treatment, even though the research subjects are not fully randomized (Abraham & Supriyati, 2022). This study employed a three-group nonequivalent pretest-posttest quasi-experimental design. In this design, there were three research groups: the control group, experimental group I, and experimental group II, whose members were not assigned through a randomization process. Subsequently, differences in outcomes among the groups were analyzed by comparing the situations before and after the intervention was administered (Anantasia, 2025). In this research design, the assignment of research subjects or participants to the control group SDN Cilimbangan with a total of 30 students Experiment I SDN Palasah with a total of 49 students and Experiment II SDN Citimun II with a total of 43 students was not done randomly. All three groups were administered a pretest and a posttest to determine differences in results after the intervention was administered. The experimental groups used by the researcher consisted of Experimental Group I, which employed a Problem-Based Learning approach; Experimental Group II, which employed a Problem-Based Learning approach supported by the PLEXA (Problem Explorer Data) medium; and the control group,

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which used conventional teaching methods. Therefore, this study involved one control group and two experimental groups.

Table 1. Three Group Nonequivalent Pretest Posttest Quasi Experimental Design

0	X_1	0
0	X_2	0
0		0

Description:
X_1 : Problem-Based Learning Approach
X_2 : Problem-Based Learning (PBL) with the PLEXA Media (Problem Explorer Data)
0 : Administering the pretest and posttest

Subject/Population and Sample

A population consists of all research subjects that share specific characteristics consistent with the study's objectives and focus. The scope of this population is not limited to individuals alone; rather, it may include objects, phenomena, events, or other relevant elements that are the focus of the investigation (Susanto et al., 2024). This study involved a population comprising all fifth-grade students at all public elementary schools with A accreditation status in the Cimalaka subdistrict, Sumedang Regency. A subset of a population selected to reflect the characteristics of all subjects in a study is defined as a sample. Sugiyono states that sampling is a data collection procedure in which a subset of the population is selected to obtain an overview of the desired characteristics and properties of that population (Mushofa et al., 2024). The specific criteria and considerations applied in selecting the sample for this study were: 1) schools with an "A" accreditation, 2) schools that have implemented the Merdeka Curriculum, and 3) schools that met the requirements for participation in the study. Based on the defined population, the sample for this study consisted of 122 fifth-grade students from three elementary schools. The breakdown of the sample distribution is as follows: 43 students from Citimun II Public Elementary School, 49 students from Palasah Public Elementary School, and 30 students from Cilimbangan Public Elementary School. Purposive sampling was used in this study to determine the sample size in a systematic manner. Using this approach, sample members were selected intentionally based on specific criteria and objectives formulated by the researcher (Sundayana, 2025). The Problem-Based Learning approach was implemented as the instructional treatment for the first experimental group, and the second experimental group received instruction using the Problem-Based Learning approach integrated with the PLEXA (Problem Explorer Data) medium. Meanwhile, the control group received conventional instruction.

Instruments

A research instrument is defined as a means or tool for collecting data in a study. These instruments play a crucial role in measuring the variables under study in a systematic, measurable, and objective manner. Through the use of these instruments, the data obtained becomes more measurable, consistent, and reliable, thereby supporting the data testing phase in alignment with the established research objectives and preliminary assumptions (hypotheses). The findings from this study are expected to be generalizable so that they can be applied to a broader population (Subhaktiyasa, 2024). An essay-type test administered in two stages a pretest and a posttest was used as the data collection instrument in this study. This evaluation series was designed to compare students' levels of creative mathematical thinking before and after the intervention. The pretest was used to assess students' initial abilities in the realm of creative mathematical thinking, while the posttest was used to determine whether there were any changes or improvements in their abilities following the learning process. By comparing the pretest and posttest results, the researcher could assess the effectiveness of the intervention more accurately and objectively.

The researchers used essay-type questions as the assessment instrument in this test because, scientifically speaking, essay questions are considered better able to explore students' thought processes in depth compared to multiple-choice questions. Essay tests have several advantages. First, this test format is well-suited for measuring complex learning outcomes, particularly those aspects that are difficult to assess through multiple-choice tests. Second, essay tests give students the opportunity to articulate answers based on their own understanding and thought processes. This is important because it trains students to organize their ideas in a coherent, systematic, and logical manner, thereby making their thinking more focused (Putri et al., 2022). Open-ended questions allow students to express their ideas, problem-solving strategies, and various alternative answers that reflect indicators of creative mathematical thinking. In addition, the use of open-ended questions gives students the opportunity to explain their solution steps in a logical sequence, allowing researchers to assess not only the final results but also the creative thinking process students demonstrate in formulating solutions to various mathematical problems. A total of 12 open-ended questions were used in the pretest and posttest.

This study was conducted over five sessions consisting of several stages: the first session involved a pretest to assess the students' initial proficiency. Subsequently, during the second through fourth sessions, learning activities were conducted alongside the implementation of the instructional treatment according to the model applied to each group. Finally, during the fifth session, a posttest was administered to assess the students' final proficiency after receiving the instructional treatment. Details regarding the test instrument blueprint for measuring mathematical creative thinking ability are presented in Table 2

Table 2. Question Outline for the Mathematical Creative Thinking Test

<table>
<tr><th>Indicators of Mathematical Creative Thinking Ability</th><th>Question Indicators</th><th>Cognitive Levels</th><th>Sample Questions</th></tr>
<tr><td>Sensitivity</td><td>Students can identify inconsistencies in data, which is illustrated through representative visual presentations, such as tables, bar charts, and pictograms.</td><td>C4</td><td>Take a look at the following table of hobby data!
<table>
<tr><th>Hobi</th><th>Turus</th><th>Frekuensi</th></tr>
<tr><td>Membaca</td><td>𝍸 |||</td><td>8</td></tr>
<tr><td>Melukis</td><td>|||</td><td>3</td></tr>
<tr><td>Bersepeda</td><td>𝍸</td><td>5</td></tr>
<tr><td>Memasak</td><td>𝍸 𝍸</td><td>10</td></tr>
<tr><td>Berenang</td><td>||||</td><td>4</td></tr>
<tr><td colspan="2">Jumlah</td><td>28</td></tr>
</table>
Based on the data in the table of hobbies above, did you find any information that doesn't match? If you found any information that doesn't match, write down that information and explain why. If not, explain why as well.</td></tr>
<tr><td>Fluency</td><td>Students can identify as many comparisons, conclusions, or</td><td>C4</td><td>Take a look at the table below showing the total amount of plastic waste at Pelita Public Elementary School!</td></tr>
</table>

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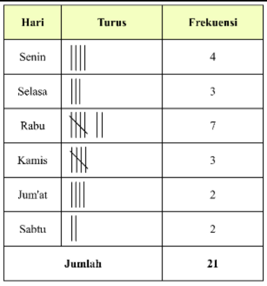
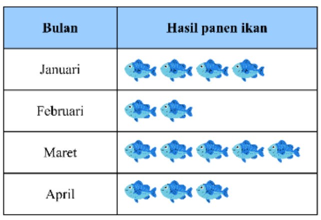
Indicators of Mathematical Creative Thinking Ability	Question Indicators	Cognitive Levels	Sample Questions
	other accurate pieces of information as possible based on the data presented in the form of tables, bar charts, or pictograms.		 What plan can the school implement on Thursday to reduce plastic waste? Describe your plan in a few steps!
Flexibility	Students can determine various ways to present data from a given data source.	C3	The following pictogram shows the number of fifth-grade students 35 in total based on the types of books they read most often.  Description:  :representing 3 students Based on the data in the pictogram above, is there any inconsistency in the information? If so, identify the inconsistent information and provide a clear explanation.
Originality	Students can develop methods of data collection or data presentation that are unusual or different from what they have learned.	C6	The school wants to find out which cafeteria foods are the most popular without having to ask each of the 300 students individually, since time is limited. Come up with a way to collect this data quickly and accurately!
Elaboration	Students can break down the process of solving problems by presenting data in a more detailed and systematic manner.	C5	The following are pictograms showing the fish harvests at Pak Doni's fish farm over a 4-month period.  Description:  : equivalent to 10 kg

Indicators of Mathematical Creative Thinking Ability	Question Indicators	Cognitive Levels	Sample Questions
			of fish Based on the pictogram above, list 5 correct pieces of information or conclusions about Mr. Doni's fish harvest!

The mathematical creative thinking test items listed in the table above are some examples of test items used during the limited and extensive pilot tests. Following that, validity and reliability tests were conducted. The validity test used Spearman's correlation because the data were not normally distributed. Next, the reliability test was conducted using Cronbach's Alpha.

Table 3. Item Validity of the Mathematical Creative Thinking Test

Question Number	Significance Value	Valid/Invalid	Correlation Coefficient	Interpretation of Validity	Description
1	0,716	Invalid	-0,050	Invalid	Not Used
2	0,005	Valid	0,375	Very Low	Used
3	0,000	Valid	0,830	Very High	Used
4a	0,000	Valid	0,805	Very High	Used
4b	0,000	Valid	0,664	High	Used
5	0,000	Valid	0,747	High	Used
6	0,000	Valid	0,808	Very High	Used
7	0,000	Valid	0,865	Very High	Used
8	0,000	Valid	0,839	Very High	Used
9a	0,000	Valid	0,750	High	Used
9b	0,000	Valid	0,781	High	Used
9c	0,000	Valid	0,737	High	Used
10	0,000	Valid	0,806	Very High	Used

Based on Table 3, it can be seen that the test on mathematical creative thinking ability contained one invalid item; thus, there were only nine valid items: items 3, 4a, 6, 7, 8, and 10 showed a very high correlation; items 4b, 5, 9a, 9b, and 9c showed a high correlation; and item 2 showed a very low correlation.

Table 4. Item Reliability of the Mathematical Creative Thinking Test

Reliability Test Results		
Total Questions	**Cronbach's Alpha Coefficient Value**	**Reliability Category**
13	0,906	Very High

The results of statistical tests on the mathematical creative thinking test administered to students yielded a Cronbach's alpha reliability coefficient of 0.906, which falls into the "very high" category.

Procedures

Data collection is a fundamental phase in a study to ensure the accuracy of information that meets the study's objectives. This study employed a test as the primary means of data collection, with the test serving as a measurement tool to assess students' insights, competencies, and level of understanding after receiving the course material. The test was designed based on predetermined indicators to ensure that the data obtained met the criteria for validity and reliability. Next, the test results were analyzed to determine the level of achievement and the effectiveness of the variables under study. Through the use of tests as a

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data collection technique, the researcher was able to obtain data that was objective, systematic, and measurable.

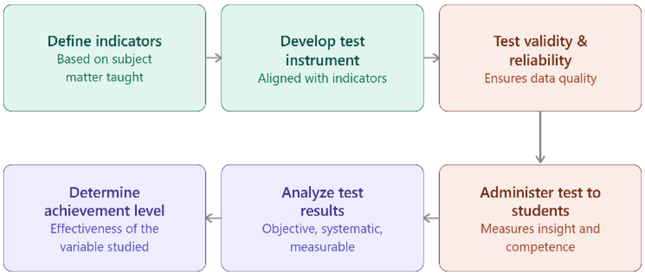

Figure 1. Research Flowchart

Data Analysis

The conduct of this study integrated a series of data analysis procedures that were systematically aligned with the predefined research objectives. A quantitative approach was applied as the method for processing all field data, aimed at testing the research hypotheses and drawing scientific conclusions. The analysis stages included descriptive statistical analysis, testing of analytical requirements (prerequisite tests), and hypothesis testing. Through these data analysis techniques, the researcher aims to demonstrate the significant impact of implementing a PBL approach supported by PLEXA media on the mathematical creative thinking abilities of fifth-grade elementary school students. To ensure valid, systematic, and accurate data output, the researcher used SPSS version 25 statistical software throughout the entire data processing process.

Descriptive statistics is a branch of statistics used to process and summarize complex data through the processes of data collection, grouping, presentation, and analysis. The results of this data processing are simplified to enhance understanding and facilitate the process of drawing conclusions (Subhaktiyasa et al., 2025). The researchers applied descriptive statistical analysis to describe the characteristics and distribution of the data obtained from both the control and experimental groups. Through these statistical procedures, key parameters including the mean, minimum, maximum, and standard deviation of the pretest and posttest data on students' mathematical creative thinking abilities could be comprehensively mapped. The prerequisite analysis phase must be completed before proceeding to hypothesis testing. This initial series of tests includes tests for the normality and homogeneity of the research data. The purpose of these tests is to assess the fit of the data distribution to the normal distribution by comparing the observed data values with the expected values based on the normal distribution (Sianturi, 2025). The Shapiro-Wilk test was used to determine the normality of the data in this study, given that the sample size was less than 50 students. The criterion for determining normality was a significance level (Sig.) > 0.05. Furthermore, the equality of variances across groups was specifically tested using Levene's Test for Equality of Variances, whereby the variances were considered homogeneous if the significance level was greater than 0.05.

After obtaining the results of the normality and homogeneity tests, the next step is to evaluate the difference in means between the pretest and posttest scores in each class. If the assumption of data normality is met, the comparative analysis will proceed by applying a paired-sample t-test. Conversely, if either or both data sets are found not to be normally distributed, the procedure shifts to a nonparametric statistical method, namely the Wilcoxon test. The primary objective of this statistical test is to validate the existence of a significant difference in students' mathematical creative thinking abilities before and after the treatment. Regarding the decision criteria for the Wilcoxon test, if the significance coefficient (Asymp. Sig. 2-tailed) is less than 0.05, it is concluded that there is a significant difference between the pretest and posttest scores. The effectiveness of improving students' mathematical creative thinking skills following instruction was evaluated using N-Gain analysis. This evaluation captured the rate of growth in learning outcomes across three classes simultaneously the control class, experimental class I, and experimental class II with the final N-Gain scores categorized as high, moderate, or low.

This study also employed Pearson's and Spearman's correlation tests to analyze the relationship between variables. Pearson's test was applied specifically to normally distributed data, whereas Spearman's test was used when the data were found to be non-normally distributed. Both tests aimed to determine the strength of the relationship between the implementation of the Problem-Based Learning (PBL) approach aided by PLEXA media and students' mathematical creative thinking abilities. The basis for interpreting the correlation tests refers to the significance value; if this value is less than 0.05, it indicates a significant relationship between the variables under study. After conducting the correlation tests, the next step is to calculate the coefficient of determination based on the correlation values, whether obtained through the Pearson or Spearman correlation tests. The analysis proceeded with the Kruskal-Wallis test to evaluate the significance of differences in the mean scores for mathematical creative thinking ability among the three sample groups (control group, Experiment I, and Experiment II). This nonparametric statistical procedure was used as an alternative to the one-way ANOVA due to the non-normal distribution of the data. The research hypothesis, which assumes the existence of a significant difference in means among the three groups, will be accepted if the resulting significance value is below the 0.05 threshold..

Research Findings

The Effect of Conventional Instruction on Fifth-Grade Elementary School Students' Creative Mathematical Thinking Skills

The control class employed conventional instruction, meaning this group did not receive instruction using either the Problem-Based Learning (PBL) approach or PBL integrated with PLEXA media. Empirical testing was necessary to determine the effect of conventional instruction on improving the mathematical creative thinking skills of fifth-grade elementary school students. The initial stage of this study involved analyzing pretest and posttest data from the control class.   A detailed summary of the pretest and posttest results for students' mathematical creative thinking skills in the control class is presented in Table 5.

Table 5. Summary of Pretest and Posttest Results for the Control Class

Score	N	Range	Lowest Score	Highest Score	Average
Pretest	30	1-100	4	67	32,90
Posttest	30	1-100	28	82	56,63

The summary in Table 5 shows an increase in the students' mathematical creative thinking skills in the control class. This increase is evidenced by a comparison of average scores, where the pretest score of 32.90 rose to 56.63 on the posttest. These data confirm a difference between students' initial competencies and final achievements in mathematical creative thinking within the conventional learning framework. Based on the average difference of 23.73, it can be concluded that conventional learning contributes positively to the

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improvement of fifth-grade elementary school students' mathematical creative thinking skills.

The increase in the average score from the pretest to the posttest in the control class requires further statistical verification through a test of the difference in means to determine its level of significance. This testing procedure begins with a normality test to determine the type of statistical test (parametric or non-parametric) to be used in the comparison. If the pretest and posttest data are normally distributed, then the two-sample paired t-test is used to compare the means. If either both the pretest and posttest data or one of them is non-normally distributed, then the test for the difference in means uses the Wilcoxon test. A summary of the results of the statistical tests conducted using SPSS 25.0 can be seen in Table 6.

Table 6. Summary of the Test for Mean Differences Between the Control Class's Pretest and Posttest Scores

Score	Average	Normality Test (Saphiro-Wilk) (*Sig.*)	Test for Differences in Means (Paired Sample t-Test)	Description
Pretest Posttest	32,90 56,63	0,357 (Normal) 0,346 (Normal)	0,000 (There is a difference in the mean)	Conventional teaching has a significant effect on the mathematical creative thinking skills of fifth-grade elementary school students.

The control group data were found to be normally distributed, as indicated by significance values of 0.357 for the pretest and 0.346 for the posttest. The analysis then proceeded with a t-test, which yielded a significance value of 0.000. This figure indicates a statistically significant difference in students' mathematical creative thinking abilities before and after the implementation of conventional instruction. These findings suggest a transformation in students' mathematical creative thinking abilities following the intervention. Thus, conventional instruction was shown to contribute positively to the improvement of these abilities. This trend of improvement is further supported by the N-Gain index results summarized in Table 7.

Table 7. N-Gain in Creative Mathematical Thinking Skills in the Control Group

Pretest		Posttest		N-Gain		N-Gain Category
Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	
32,90	16,23	56,63	14,92	0,35	0,19	Currently

Based on the data presented in Table 7, the N-Gain index for students' mathematical creative thinking skills reached an average value of 0.35, which is classified as moderate. This result indicates that the implementation of conventional instruction is capable of stimulating an improvement in students' mathematical creative thinking abilities at a moderate level of effectiveness. To examine this result in greater detail, the following section describes the fluctuations in improvement for each indicator of mathematical creative thinking ability.

Table 8. Summary of N-Gain Scores for Indicators of Mathematical Creative Thinking Skills

No.	Indicators of Mathematical Creative Thinking Ability	Average		Average N-Gain	N-Gain Category
		Pretest	Posttest		
1.	Sensitivity	2,66	3,46	0,18	A slight increase
2.	Fluency	2,73	4,66	0,29	A slight increase
3.	Flexibility	0,96	1,63	0,27	A slight increase

No.	Indicators of Mathematical Creative Thinking Ability	Average		Average N-Gain	N-Gain Category
		Pretest	Posttest		
4.	Originality	2,20	4,10	0,24	A slight increase
5.	Elaboration	6,31	12,16	0,52	Moderate increase

Based on the average N-Gain calculations for each indicator of mathematical creative thinking ability in the control class, the values obtained were 0.18 for the sensitivity (sensitivity) in the low category, 0.29 for the fluency indicator in the low category, 0.27 for the flexibility indicator in the low category, 0.24 for the originality indicator in the low category, and 0.52 for the elaboration indicator in the moderate category. Although this class did not receive Problem-Based Learning (PBL) instruction as in Experimental Class I or PBL instruction supported by PLEXA media as in Experimental Class II, all indicators of mathematical creative thinking ability in this group also showed a positive trend. Nevertheless, the increases in each of these indicators were distributed across several varying categories.

The next stage of the analysis was aimed at measuring the extent to which conventional learning contributes to students' mathematical creative thinking abilities by calculating the coefficient of determination. This step required first obtaining the correlation coefficient (r). The measurement of the correlation coefficient is determined based on the fulfillment of the normality assumption; the Pearson correlation test is used when the data are normally distributed, while the Spearman correlation test is applied if the data are not normally distributed. The results of the Pearson test are summarized in Table 9.

Table 9. Summary of the Results of the Pearson Test on Mathematical Creative Thinking Ability in the Control Class

Score	Pearson's Test			
	Sig.	Description	Pearson Correlation (r)	Description
Pretest-Posttest Control Group	0,001	Correlated	0,556	Moderate Correlation

Based on the data presented in Table 9, the Pearson correlation test yielded a p-value of 0.001. Since this value is less than 0.05, the pretest and posttest data for the control group are found to be significantly correlated, meaning that hypothesis H1 is accepted and the null hypothesis H0 is rejected. In addition, the analysis results show a Pearson correlation coefficient (r) of 0.556, indicating a moderate level of correlation. After determining this correlation index, the next step is to calculate the coefficient of determination to measure the extent to which conventional learning contributes to the mathematical creative thinking abilities of fifth-grade elementary school students. A visualization of the results of the coefficient of determination calculation is presented below.

$$KD = r^2 \times 100\%$$
$$KD = 0{,}556^2 \times 100\%$$
$$KD = 30{,}91\%$$

Based on the results of the coefficient of determination calculation, it was found that conventional instruction contributed 30.91% to the improvement in fifth-grade elementary school students' mathematical creative thinking skills; this percentage indicates that changes in mathematical creative thinking scores in the control group can be explained by the conventional instruction they received during the study. This suggests that the change in students' mathematical creative thinking skills falls into the moderate category. The remaining 69.09% is believed to be influenced by various other factors outside the variables investigated in this

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study, such as the learning environment, students' cognitive readiness, teachers' pedagogical strategies, variations in learning media, and the students' own levels of intrinsic motivation.

The Effect of Problem-Based Learning on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

The problem-based learning (PBL) approach was implemented in Experimental Class I. To test whether this approach had an effect on improving the mathematical creative thinking skills of fifth-grade elementary school students, a series of statistical tests needed to be conducted. The initial stage of this evaluation procedure focused on a comparative analysis of the pretest and posttest scores of Experimental Class I. A detailed summary of the pretest and posttest results for students' mathematical creative thinking skills in Experimental Class I is presented in Table 10.

Table 10. Summary of Pretest and Posttest Results for Experimental Class I

Score	N	Range	Lowest Score	Highest Score	Average
Pretest	49	1-100	4	74	36,90
Posttest	49	1-100	28	85	60,08

The summary in Table 10 shows an increase in students' mathematical creative thinking skills in Experimental Class I. This increase is evidenced by a comparison of average scores, where the pretest score of 36.90 rose to 60.08 on the posttest. These data confirm a difference between students' initial competencies and final achievements in mathematical creative thinking within the Problem-Based Learning (PBL) instructional framework. Based on the average difference of 23.18, it can be concluded that Problem-Based Learning (PBL) contributes positively to the improvement of fifth-grade elementary school students' mathematical creative thinking skills.

The increase in the average score from the pretest to the posttest in Experimental Class I requires further statistical verification through a test of the difference in means to determine its level of significance. This testing procedure begins with a normality test to determine the type of statistical test (parametric or non-parametric) to be used in the comparison. If the pretest and posttest data are normally distributed, then the two-sample paired t-test is used to compare the means. If either both the pretest and posttest data or one of them is non-normally distributed, then the test for the difference in means uses the Wilcoxon test. A summary of the results of the statistical tests conducted using SPSS 25.0 can be seen in Table 11.

Table 11. Summary of the T-Test for Mean Differences Between the Pretest and Posttest Scores of Experimental Class I

Score	Average	Normality Test (Saphiro-Wilk) (*Sig.)*	Test for Differences in Means (Wilcoxon)	Description
Pretest	36,90	0,824 (Normal)	0,000 (There is a difference in the mean)	Problem-Based Learning has a significant effect on the mathematical creative thinking skills of fifth-grade elementary school students.
Posttest	60,08	0,003 (Abnormal)		

From the data above, it can be seen that Experimental Class I does not follow a normal distribution: the pretest sig. value of 0.824 indicates a normal distribution, whereas the posttest sig. value of 0.003 indicates a non-normal distribution. Subsequently, a test for differences in means was conducted, yielding a p-value of 0.000, indicating a significant difference between students' mathematical creative thinking scores before and after the intervention (pretest and posttest) in Experimental Class I. This finding suggests that students' mathematical creative thinking abilities changed after participating in the intervention. In other words, Problem-Based Learning had a positive impact on improving students' mathematical creative thinking abilities. This improvement is also supported by the increase in N-Gain shown in Table 12.

Table 12. N-Gain Developing Creative Mathematical Thinking Skills Experimental Class I

Pretest		Posttest		N-Gain		N-Gain Category
Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	
36,90	15,7	60,08	13,6	0,36	0,16	Currently

Based on the data presented in Table 12, the N-Gain index for students' mathematical creative thinking skills reached an average value of 0.36, which is classified as moderate. This result indicates that the implementation of Problem-Based Learning was able to stimulate an improvement in students' mathematical creative thinking skills at a moderate level of effectiveness. To examine these results in more detail, the following section describes the fluctuations in improvement for each indicator of mathematical creative thinking skills.

Table 13. Summary of N-Gain Scores for Indicators of Creative Mathematical Thinking Skills

No.	Indicators of Mathematical Creative Thinking Ability	Average		Average N-Gain	N-Gain Category
		Pretest	Posttest		
1.	Sensitivity	2,81	3,57	0,18	A slight increase
2.	Fluency	2,65	4,57	0,26	A slight increase
3.	Flexibility	0,95	1,51	0,18	A slight increase
4.	Originality	2,22	3,61	0,35	Moderate increase
5.	Elaboration	8,04	13,51	0,67	Moderate increase

Based on the average N-Gain calculations for each indicator of mathematical creative thinking ability in Experimental Class I, the values obtained were 0.18 for the sensitivity (sensitivity) in the low category, 0.26 for the fluency indicator in the low category, 0.18 for the flexibility indicator in the low category, 0.35 for the originality indicator in the moderate category, and 0.67 for the elaboration indicator in the moderate category. Although this class did not receive Problem-Based Learning (PBL) instruction supported by PLEXA media, as was the case in Experimental Class II, all indicators of mathematical creative thinking ability in this group also showed a positive trend. Nevertheless, the increases in each of these indicators were distributed across several varying categories. The next stage of the analysis was aimed at measuring the extent of Problem-Based Learning's contribution to students' mathematical creative thinking abilities through the calculation of the coefficient of determination. This step required first obtaining the correlation coefficient (r) values. The measurement of the correlation coefficient is determined based on the fulfillment of the normality assumption; the Pearson correlation test is used when the data are normally distributed, while the Spearman correlation test is applied if the data are not normally distributed. The results of the Spearman test are summarized in Table 14.

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Table 14. Summary of Spearman's Test Results on Mathematical Creative Thinking Ability in Experimental Class I

Score	Spearman's Test			
	Sig.	**Description**	**Spearman's Correlation (r)**	**Description**
Pretest-Posttest Experimental Group 1	0,000	Correlated	0,618	Strong Correlation

Based on the data presented in Table 14, the Spearman correlation test yielded a p-value of 0.000. Since this value is less than 0.05, the pretest and posttest data for Experimental Group I are found to be significantly correlated, meaning that hypothesis H1 is accepted and the null hypothesis H0 is rejected. In addition, the analysis results showed a Spearman correlation coefficient (r) of 0.618, indicating that the strength of the relationship falls into the "strong" category. After determining this correlation index, the next step is to calculate the coefficient of determination to measure the extent to which Problem-Based Learning contributes to the mathematical creative thinking skills of fifth-grade elementary school students. A visualization of the results of the coefficient of determination calculation is presented below.

$$KD = r^2 \times 100\%$$
$$KD = 0{,}618^2 \times 100\%$$
$$KD = 38{,}19\%$$

Based on the results of the coefficient of determination calculation, it was found that Problem-Based Learning contributed 38.19% to the improvement in the mathematical creative thinking skills of fifth-grade elementary school students; this percentage indicates that the change in mathematical creative thinking scores in Experimental Group I can be explained by the Problem-Based Learning process they received during the study. This suggests that the change in students' mathematical creative thinking skills falls into the moderate category. The remaining 61.81% is presumed to be influenced by various other factors outside the variables investigated in this study, such as the learning environment, students' cognitive readiness, teachers' pedagogical strategies, variations in learning media, and the students' own levels of intrinsic motivation.

The Effect of Problem-Based Learning Assisted by PLEXA Media on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

The PLEXA-assisted problem-based learning (PBL) approach was implemented in Experimental Class II. The PLEXA media were used throughout the learning process over the course of three sessions. The media were used starting when the teacher explained the material in front of the class with the aid of concrete media in the form of boards; students were then given the opportunity to try the concepts hands-on in front of the class to better understand them. Furthermore, the PLEXA media were also used while students worked on worksheets in groups so that they could discuss, explore ideas, and understand the material more actively through direct use of the media. To test the effect of this media-assisted approach on improving the mathematical creative thinking skills of fifth-grade elementary school students, a series of statistical tests needed to be conducted. The initial stage of this evaluation procedure focused on a comparative analysis of the pretest and posttest scores for experimental group II. A detailed summary of the pretest and posttest results for students' mathematical creative thinking skills in Experimental Class II is presented in Table 15.

Table 15. Summary of Pretest and Posttest Results for Experimental Class II

Score	N	Range	Lowest Score	Highest Score	Average
Pretest	43	1-100	20	76	40,93
Posttest	43	1-100	33	89	67,70

The summary in Table 15 shows an increase in students' mathematical creative thinking skills in Experimental Class II. This increase is evidenced by a comparison of average scores, where the pretest score of 40.93 rose to 67.70 on the posttest. These data confirm a difference between students' initial competencies and final achievements in mathematical creative thinking within a learning framework using a Problem-Based Learning approach supported by PLEXA media. Based on the average difference of 26.77, it can be concluded that learning using a Problem-Based Learning approach supported by PLEXA media contributes positively to the improvement of fifth-grade elementary school students' mathematical creative thinking skills. The increase in the average score from the pretest to the posttest in Experimental Class II requires further statistical verification through a test of the difference in means to determine its level of significance. This testing procedure begins with a normality test to determine the type of statistical test (parametric or non-parametric) to be used in the comparison. If the data from the pretest and posttest scores are normally distributed, then the t-test for paired samples is used to compare the means. If either the pretest or posttest data or both are not normally distributed, then the test for the difference in means uses the Wilcoxon test. A summary of the results of the statistical tests conducted using SPSS 25.0 can be seen in Table 16.

Table 16. Summary of the Test for Mean Differences Between the Pretest and Posttest Results of Experimental Class II

Score	Average	Normality Test (Saphiro-Wilk) (*Sig.*)	Test for the Difference in Means (Wilcoxon)	Description
Pretest	40,93	0,045 (Abnormal)	0,000 (There is a difference in the mean)	There is a significant effect of Problem-Based Learning supported by PLEXA media on the mathematical creative thinking skills of fifth-grade elementary school students.
Posttest	67,70	0,297 (Normal)		

From the data above, it can be seen that Experimental Class II does not follow a normal distribution, as the pretest sig. value of 0.045 indicates a non-normal distribution, whereas the posttest sig. value of 0.297 indicates a normal distribution. Subsequently, a t-test was conducted, yielding a p-value of 0.000, indicating a significant difference between students' mathematical creative thinking scores before and after the intervention (pretest and posttest) in Experimental Class II. This finding suggests that students' mathematical creative thinking abilities changed after participating in the intervention. In other words, Problem-Based Learning supported by PLEXA media had a positive impact on improving students' mathematical creative thinking skills. This improvement is also supported by the increase in N-Gain shown in Table 17 below.

Table 17. N-Gain Creative Mathematical Thinking Skills Experimental Class II

Pretest		Posttest		N-Gain		N-Gain Category
Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	
40,93	11,89	67,70	12,28	0,45	0,16	Currently

Based on the data presented in Table 17, the N-Gain index for students' mathematical

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creative thinking skills reached an average value of 0.45, which is classified as moderate. This result indicates that the implementation of Problem-Based Learning supported by PLEXA media was able to stimulate an improvement in students' mathematical creative thinking skills at a moderate level of effectiveness. To examine these results in more detail, the following section describes the variations in improvement for each indicator of mathematical creative thinking skills.

Table 18. Summary of N-Gain Scores for Indicators of Mathematical Creative Thinking Skills

No.	Indicators of Mathematical Creative Thinking Ability	Average		Average N-Gain	N-Gain Category
		Pretest	Posttest		
1.	Sensitivity	2,79	3,58	0,20	A slight increase
2.	Fluency	3,46	5,23	0,27	A slight increase
3.	Flexibility	1,25	2,51	0,65	Moderate increase
4.	Originality	3,39	5,95	0,36	Moderate increase
5.	Elaboration	7,65	15,20	0,72	Significant increase

An analysis of the improvement in students' creative mathematical thinking skills in Experimental Class II revealed variations in N-Gain scores across each indicator. The elaboration indicator showed the highest growth, with a score of 0.72 (high category). Meanwhile, the indicators for flexibility and originality fell into the moderate category, at 0.65 and 0.36, respectively. The other two indicators fell into the low category: fluency at 0.27 and sensitivity at 0.20. Overall, these data demonstrate that the implementation of the Problem-Based Learning approach aided by PLEXA media effectively enhances all five indicators of students' mathematical creative thinking, albeit with varying degrees of effectiveness.

The next stage of analysis is aimed at measuring the extent to which Problem-Based Learning aided by PLEXA media contributes to students' mathematical creative thinking abilities through the calculation of the coefficient of determination. This step requires first obtaining the correlation coefficient (r) value. The measurement of the correlation coefficient is determined based on the fulfillment of the normality assumption; the Pearson correlation test is used if the data are normally distributed, while the Spearman correlation test is applied if the data are not normally distributed. The results of the Spearman test are summarized in Table 19.

Table 19. Summary of Spearman's Test Results on Mathematical Creative Thinking Ability in Experimental Class II

Score	Spearman's Test			
	Sig.	Description	Spearman's Correlation (r)	Description
Pretest-Posttest Experimental Group 1	0,000	Correlated	0,644	Strong Correlation

Based on the data presented in Table 19, the Spearman correlation test yielded a p-value of 0.000. Since this p-value is less than 0.05, the pretest and posttest data for Experimental Group II are found to be significantly correlated, meaning that hypothesis H_1 is accepted and the null hypothesis H_0 is rejected. In addition, the analysis results show a Spearman correlation coefficient (r) of 0.644, indicating that the strength of the relationship falls into the "strong" category. After determining this correlation index, the next step is to calculate the coefficient of determination to measure the extent to which Problem-Based Learning assisted by PLEXA media contributes to the mathematical creative thinking skills of fifth-grade elementary school students. A visualization of the results of the coefficient of determination calculation is presented below.

$$KD = r^2 \times 100\%$$
$$KD = 0{,}644^2 \times 100\%$$
$$KD = 41{,}47\%$$

Based on the results of the coefficient of determination calculation, it was found that Problem-Based Learning supported by PLEXA media contributed 41.47% to the improvement in the mathematical creative thinking skills of fifth-grade elementary school students; this percentage indicates that the change in mathematical creative thinking scores in Experimental Class I can be explained by the Problem-Based Learning process supported by PLEXA media that they received during the study. This indicates that the change in students' mathematical creative thinking skills falls into the moderate category. The remaining 58.53% is presumed to be influenced by various other factors outside the variables investigated in this study, such as the learning environment, students' cognitive readiness, teachers' pedagogical strategies, variations in learning media, and the students' own level of intrinsic motivation.

Significant Differences in the Effects of Conventional Instruction, the Problem-Based Learning Approach, and the Problem-Based Learning Approach Supported by PLEXA Media on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

The analysis in this study focused on the pretest scores and N-Gain values for mathematical creative thinking skills obtained from the control class, Experiment I, and Experiment II. This analytical approach was adopted to compare the effects of three different treatments: conventional instruction, Problem-Based Learning, and Problem-Based Learning integrated with the PLEXA medium. The measurement of students' mathematical creative thinking skills was conducted in two stages: through a pretest and a posttest in the control class, Experiment I, and Experiment II. The pretest was administered before the intervention began to assess students' initial mathematical abilities. Meanwhile, the posttest was administered at the end of the learning period after all classes had received their respective treatments, with the aim of measuring their final achievements in mathematical creative thinking skills. The three sample groups in this study the control class, Experiment I, and Experiment II received different instructional approaches. Conventional instruction was applied in the control class, while Experiment I used Problem-Based Learning. Meanwhile, Experiment II implemented Problem-Based Learning integrated with the PLEXA medium. A summary of the data analysis results from the students' pretest scores in the three classes can be seen in Table 20 below.

Table 20. Descriptive Statistics for Pretest Scores of the Control Class, Experimental Class I, and Experimental Class II

Class	N	Score Range	Pretest			
			Highest Score	Lowest Score	Average	Standard Deviation
Control Class	30	1-100	67	4	32,90	16,23
Experimental Class I	49	1-100	74	4	36,90	15,70
Experimental Class II	43	1-100	76	20	40,93	11,89

Based on the data in Table 20, the average pretest scores for students' initial ability varied among the three groups: 32.90 for the control class, 36.89 for experimental class I, and 40.93 for experimental class II. A comprehensive breakdown of the statistical tests is presented separately. The results of the statistical tests for the pretest scores on students' mathematical

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creative thinking abilities in the three groups can be seen in Table 21.

Table 21. Summary of Statistical Test Results for *Pretest* Scores on Mathematical Creative Thinking Ability in the Control Class, Experimental Class I, and Experimental Class II

Class	Average	Normality Test (Shapiro Wilk)		Homogeneity Test		Test for Differences in Means	
		Sig.	Description	Sig.	Description	Sig.	Description
Control Class	32,90	0,357	Normal	0,368	Homogeneous	0,047	There is a difference in the average *pretest* scores among the control group, Experiment I, and Experiment II
Experimental Class 1	36,90	0,824	Normal				
Experimental Class II	40,93	0,045	Abnormal				

The test results in Table 21 demonstrate a significant difference in initial mathematical creative thinking ability among the three classes. Experimental Class II recorded the highest pretest mean of 40.93, while Experimental Class I scored 36.89 and the control class scored 32.90. Statistical tests further support the evidence that the initial abilities of students in Experimental Class II were better than those in the control class and Experimental Class I. Due to these differences, the evaluation continued with an analysis of N-Gain values to objectively measure the improvement in mathematical creative thinking abilities in each class, the results of which are presented below.

Table 22. Analysis of the N-Gain in Mathematical Creative Thinking Ability in the Control Class, Experimental Class I, and Experimental Class II

N-Gain Control Class		N-Gain Category	N-Gain Experimental Class I		N-Gain Category	N-Gain Experimental Class II		N-Gain Category
Average	Standard Deviation		Average	Standard Deviation		Average	Standard Deviation	
0,35	0,19	Currently	0,36	0,16	Currently	0,45	0,16	Currently

Based on the data presented in Table 22, the average N-Gain scores for students' mathematical creative thinking abilities in all three classes fell into the same improvement category, namely "moderate." However, there were variations in scores among the three classes: the control class scored 0.35, experimental class I scored 0.36, and experimental class II recorded the highest score of 0.45. Based on these findings, a preliminary conclusion can be drawn that the Problem-Based Learning (PBL) approach supported by PLEXA media in Experimental Class II demonstrated higher effectiveness than conventional instruction in the control class or PBL without media in Experimental Class I. Nevertheless, to prove that this difference in improvement is scientifically significant and not merely a matter of chance, further inferential statistical testing is required. This testing is intended to identify the presence of statistically significant differences regarding the improvement in students' mathematical creative thinking skills in the control class, Experimental Class I, and Experimental Class II. As a form of scientific validation, a test of the difference in means was conducted on the N-Gain scores across these three groups. The comprehensive results of the statistical analysis comparing N-Gain scores across classes are presented in Table 23.

Table 23. Summary of the N-Gain Statistical Test of Mathematical Creative Thinking Ability

Class	N	Average N-Gain	Statistical Tests		Test for Differences in Means	Description
			Normality	Homogenity		
Control Class	30	0,35	0,020 (Abnormal)	0,101 (Homogeneous)	0,029	There is a difference in the impact on students' mathematical creative thinking abilities.
Experimental Class I	49	0,36	0,011 (Abnormal)			
Experimental Class II	43	0,45	0,580 (Normal)			

Referring to the data in Table 23, there is a clear disparity in the N-Gain scores for students' mathematical creative thinking skills among the control class, Experiment I, and Experiment II. These differences are reflected in the average scores for each class: the control class scored 0.35, Experiment I scored 0.36, and Experiment II led with 0.45. Although the growth in ability across all three classes is collectively classified as moderate, the higher achievement of Experiment II demonstrates that the implementation of Problem-Based Learning aided by PLEXA media has a more significant impact on stimulating students' creative mathematical thinking compared to conventional instruction or PBL without media. The improvement observed in Experiment II class demonstrates that the use of PLEXA media in Problem-Based Learning serves as more than just a visual aid. This media has proven capable of helping students understand data-related material in a tangible and more meaningful way. In contrast, the improvements in the control class and Experiment I class tended to be lower. This is to be expected since the learning process in both of those classes relied solely on conventional methods and PBL without the support of concrete media that foster student engagement and creative thinking skills.

The research findings indicate that conventional instruction, the PBL approach, and the PBL approach supported by PLEXA media have significantly different effects on the mathematical creative thinking skills of fifth-grade elementary school students. This is supported by a significance value of 0.029. In terms of effectiveness, the control class achieved an average N-Gain of 0.35, Experiment Class I achieved 0.36, and Experiment Class II reached 0.045. Although all classes showed moderate improvement, the highest score in Experimental Class II demonstrates that the combination of the PBL approach and PLEXA media is far more effective in enhancing students' creative thinking skills than conventional instruction or PBL without media.

Discussion

The Effect of Conventional Instruction on Fifth-Grade Elementary School Students' Creative Mathematical Thinking Skills

The results of the study in the control class showed that conventional teaching also influenced the mathematical creative thinking skills of fifth-grade elementary school students. The factors driving the improvement in mathematical creative thinking skills in the control class were the learning experiences students continued to receive through the teacher's presentation of material, practice problems, and simple discussion activities throughout the learning process. According Hamidah & Ain (2022), students are trained to solve problems by understanding the problem, constructing a mathematical model, solving it, and being able to interpret the solution found. In addition, mathematics instruction is also aimed at honing students' skills in conveying

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mathematical ideas and symbols logically, clearly, and systematically (Hamidah & Ain, 2022). In conventional instruction, teachers still serve as the primary source of information, ensuring that students acquire a basic understanding of data collection and presentation. This conceptual understanding also contributes to the development of students' mathematical creative thinking skills.

Although there was an improvement, the results from the control class indicated that students' mathematical creative thinking skills had not yet developed optimally. This suggests that conventional instruction tends to lead students to passively receive information rather than independently explore ideas. In line with the views of Kumalasari et al. (2024), learning that is solely teacher-centered and relies on a single learning resource causes students to become accustomed to solving problems in only one way, thereby hindering the development of their creative thinking skills (Kumalasari et al., 2024). Conventional instruction in this study still had a positive impact because teachers continued to provide practice problems related to students' daily lives. In the data unit, students were asked to understand simple tables and diagrams, thereby engaging in thinking activities to interpret information. It was this connection between the material and the students' experiences that enabled an improvement in their creative mathematical thinking skills, even though instruction was conducted conventionally. Mathematics instruction proceeds in stages. Content is presented systematically, progressing from concrete illustrations to abstract theoretical understanding. Additionally, the curriculum is structured to move from simple foundational concepts to more advanced topics, aligning with students' stages of cognitive development (Trisnani, 2022). This finding aligns with Piaget's theory of cognitive development, which states that the thinking characteristics of elementary school-aged children are in the concrete operational stage. During this period, children already possess the capacity to think logically and systematically, particularly when dealing with real-world objects or situations. In this stage, intuitive thinking begins to be replaced by logical thinking, provided that the concepts being learned can be applied through specific, easily observable examples (Imanulhaq & Ichsan, 2022). Conventional instruction accompanied by concrete examples can still help students understand the material. However, this approach does not sufficiently provide students with opportunities to develop flexible and original alternative solutions to problems.

According Maulana (as cited in Pertiwi, 2022), mathematical creative thinking skills include sensitivity, fluency, flexibility, originality, and elaboration. In conventional learning, some of these indicators have not been fully developed because students more often follow the solution examples provided by the teacher. The findings of this study are also supported by the results of research by Herawati et al. (2023) which state that students' creative thinking skills remain low due to a lack of enthusiasm in solving math problems, reliance on the teacher's examples, and a lack of effort on the part of students to independently discover diverse problem-solving methods (Herawati et al., 2023). In this study, the contribution of conventional instruction to students' mathematical creative thinking skills was recorded at 30.91%. This percentage indicates that the majority of the improvement in students' mathematical creative thinking skills is actually influenced by other, far more dominant factors. Conventional instruction essentially still has several advantages, such as making it easier for teachers to manage the classroom and deliver material systematically. According to Trisnani (2022), mathematics instruction in elementary school does indeed need to be conducted in a gradual and structured manner in accordance with students' cognitive development (Trisnani, 2022). Thus, conventional instruction can still be used to help students understand basic mathematical concepts before they are guided toward more complex and exploratory learning.

Overall, the research findings conclude that although conventional instruction has a positive impact on the mathematical creative thinking skills of fifth-grade elementary school students, its effectiveness is not yet optimal. The improvement observed in the control group demonstrates that the conventional learning process is, in fact, still effective in helping students understand basic concepts and solve math problems. According to Maulana (as cited in Pertiwi, 2022), mathematical creative thinking ability essentially comprises various indicators such as originality, fluency, flexibility, elaboration, and sensitivity. Unfortunately, learning activities in conventional classrooms do not sufficiently facilitate students in developing diverse ideas and alternative answers, so these five indicators do not improve to their full potential. Therefore, the implementation of innovative, student-centered learning is urgently needed to enhance students' creative thinking skills.

The Effect of Problem-Based Learning on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

The research findings in Experimental Class I confirm that the implementation of the Problem-Based Learning (PBL) approach has a positive impact on the mathematical creative thinking skills of fifth-grade elementary school students. The main factor driving the improvement in students' mathematical creative thinking skills in Experimental Class I is the implementation of Problem-Based Learning, which places students at the center of the learning process. During the learning process, students are presented with contextual problems that they must analyze and solve collaboratively. According to Pratama (2022), students' creative thinking skills can improve through Problem-Based Learning because students are encouraged to actively find solutions to their own problems. This activity fosters greater student engagement in honing their thinking processesa condition rarely found in classrooms that employ conventional teaching methods. Problem-Based Learning also provides students with the opportunity to develop various alternative solutions to problems. According to Guilford, as cited in Istikomah et al. (2024), creative mathematical thinking is characterized by the ability to generate innovative solutions and not be limited to a single method of resolution. In this study, students began to provide more diverse answers when solving problems involving data collection and presentation. This indicates that the implementation of Problem-Based Learning can sharpen students' creative mathematical thinking, particularly by fostering the aspects of originality, flexibility, and fluency.

Furthermore, the implementation of Problem-Based Learning helps students develop sensitivity toward mathematical problems. At the beginning of the learning process, students are presented with problems related to daily life, requiring them to understand the available information before determining a solution strategy. According to Maulana (as cited in Pertiwi, 2022), sensitivity is the ability to accurately recognize and understand problems. Through Problem-Based Learning, students become more accustomed to identifying problems and determining appropriate solution steps. According to Mayasari et al. in (Panggabean et al., 2025), the advantage of PBL is its ability to help students solve problems more effectively through group work and to communicate their ideas and thoughts effectively. Furthermore, PBL encourages students to be more active in the learning process. The implementation of PBL also reflects a shift in the learning paradigm, in which students are no longer viewed as objects of learning but rather as active agents in constructing their own knowledge. The findings of this study align with the results of a study conducted by Sinaga et al. (2024) which concluded that the implementation of Problem-Based Learning contributes to a significant improvement in students' creative thinking skills. Problem-based learning encourages students to think more actively, critically, and creatively when solving mathematical problems. In this study, students were observed to be more active in discussing and expressing their opinions throughout the

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learning process.

The success of PBL in enhancing mathematical creative thinking skills is also supported by the approach's emphasis on contextual learning. According to Fitrianawati et al. (2022), data-related material is closely tied to students' daily lives, making it easy to relate to real-world situations. When students are presented with real-world data problems, they find it easier to understand concepts and are motivated to seek creative solutions. The implementation of PBL also helps students improve their elaboration skills. During the learning process, students are asked to explain the reasoning behind their answers and to develop their ideas in greater detail. These activities ensure that students do not merely focus on the final outcome but also understand the thought processes involved. This aligns with Torrance's view, as cited in Istikomah et al. (2024), that creative thinking is not only about the result but also about the ability to develop and organize ideas.

The findings of this study are supported by the research of Saadah et al. (2024) which shows that Problem-Based Learning can enhance students' mathematical creative thinking skills by providing them with opportunities to explore various problem-solving strategies. In this study, students appeared more confident in presenting their ideas and answers during the discussion process. This active student participation was one of the key elements driving the development of their mathematical creative thinking skills. Nevertheless, the improvement in mathematical creative thinking skills in Experimental Class I remained in the moderate category. This indicates that the implementation of Problem-Based Learning without the aid of specific learning media has not yet been fully optimized. Some students still struggled to understand the problems presented because there were no visual or concrete learning materials to support their learning. The use of learning materials motivates students to think actively, analyze information, and participate directly in the entire sequence of learning activities (Karomah et al., 2024). Based on the overall research results, it can be concluded that the Problem-Based Learning approach has a positive effect on the mathematical creative thinking skills of fifth-grade elementary school students. This approach encourages students to be more active, creative, and directly involved in the learning process. Through problem-solving activities, discussions, and the exploration of ideas, students have the opportunity to develop their mathematical creative thinking skills more effectively than through conventional learning methods.

The Effect of Problem-Based Learning Assisted by PLEXA Media on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

The findings of this study confirm that the implementation of a PLEXA-media-based PBL approach has a positive impact on the mathematical creative thinking skills of fifth-grade elementary school students. Based on empirical data from Experimental Group II, the Problem-Based Learning intervention supported by PLEXA media had the most significant impact on optimizing students' mathematical creative thinking skills compared to the other groups. The concrete and engaging visualization of data concepts facilitated by the PLEXA media served as a driving factor in the enhancement of students' creative mathematical thinking skills in Experimental Group II. The PLEXA media is designed to help students explore data through visual, manipulative, and contextual activities. According to Andrijati (as cited in Fitri, 2023), mathematics teaching and learning, the use of instructional media plays a crucial role in supporting teachers' tasks. Through the appropriate use of media, teachers can convey basic mathematical concepts more clearly, in a structured manner, and in a way that is easier to understand, especially for abstract material. In this study, students appeared more enthusiastic when using the PLEXA media compared to when they were simply listening to the teacher's explanations. Students were not only asked to solve problems but also to explore various possible answers using the available media. According to Munandar (as cited in Kamalia & Ruli, 2022), creative thinking is the ability to generate various alternative solutions to a problem. The PLEXA media provides students with the opportunity to try various problem-solving strategies, resulting in a wider range of ideas.

Additionally, the PLEXA platform helps students understand the relationship between data and visual representations more clearly. In lessons on data presentation, students need to understand how data is organized in tables, bar charts, and pictograms. According to Hanifah et al. (2025), data presentation aims to help students understand information systematically and in an easily comprehensible manner. With the help of the PLEXA platform, students find it easier to grasp concepts, allowing them to focus on enhancing their creative thinking skills in solving problems. In classroom activities, students began to demonstrate answers that were more unique and different from the solution models provided by the teacher. This occurred because students had the opportunity to experiment and discover problem-solving strategies independently through the PLEXA platform. According to Ali & Hartono (2024), creative mathematical thinking is characterized by the cognitive capacity to find solutions to problems without being limited to a single method. The findings of this study align with those of Fitriani & Jusra (2024) which demonstrated that a media-assisted PBL approach can significantly develop students' creative mathematical thinking skills. The use of media in problem-based learning helps students become more active, motivated, and better able to understand mathematical concepts. In this study, the PLEXA platform served as a tool that facilitated students in exploring data and finding creative solutions.

The results of this analysis further reinforce previous research by Saadah et al. (2024). That study demonstrated that the use of interactive media combined with the PBL approach contributes positively to optimizing students' creative mathematical thinking skills more effectively than learning without media. Media helps students understand problems more concretely, thereby allowing the creative thinking process to develop more effectively. Learning media that are presented in an engaging and enjoyable way not only boost student motivation but also foster a sense of safety and comfort that supports the smooth progression of their learning process (Sunaengsih et al., 2023). According to Nurfadhillah et al. as cited in (Nurcahyandi et al., 2024), improving students' abilities is not only achieved through the implementation of varied teaching methods but also requires the support of appropriate instructional media. Instructional media play a role in facilitating and smoothing interactions between teachers and students throughout the learning process. In addition to enhancing students' creative mathematical thinking skills, the use of PLEXA media also fosters increased enthusiasm and active student participation in teaching and learning activities. Students appeared more active in asking questions, engaging in discussions, and attempting to solve problems through the media used. According to Putri et al. (2022), 21st-century learning must motivate students to remain participatory, innovative, and capable of collaborating to solve problems. Learning activities in Experimental Class II demonstrated that the use of PLEXA media effectively supports the creation of 21st-century learning.

The success of Problem-Based Learning facilitated by PLEXA media is also influenced by the media's suitability for the characteristics of elementary school students. Fifth-grade students still require concrete and visual media to understand abstract mathematical concepts. The PLEXA media helps students connect data concepts to real-world situations, making the teaching-learning process more relevant and meaningful. These empirical findings reinforce Trisnani (2022) view regarding the importance of presenting elementary school mathematics material in a contextual and systematic manner, in accordance with students' cognitive development levels. Based on the overall research findings, the researcher concludes that PBL

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supported by PLEXA media has a positive and more optimal effect on the mathematical creative thinking skills of fifth-grade elementary school students. The combination of the PBL approach and the use of concrete media can lead to a more active, engaging, and meaningful teaching-learning process. The use of media during the teaching and learning process can foster students' enthusiasm and motivation to learn (Fadilah et al., 2023). Through these teaching and learning activities, students gain broader opportunities to develop creative ideas, strategies, and solutions for solving mathematical problems.

Significant Differences in the Effects of Conventional Instruction, the Problem-Based Learning Approach, and the Problem-Based Learning Approach Supported by PLEXA Media on the Mathematical Creative Thinking Skills of Fifth-Grade Elementary School Students

The research findings indicate that conventional instruction, the PBL approach, and the PBL approach using PLEXA media have significantly different effects on the mathematical creative thinking skills of fifth-grade elementary school students. The differences in the improvement of these mathematical creative thinking skills are influenced by the different instructional treatments administered to each class. In the control class, instruction remained teacher-centered, so students tended to passively receive information. Meanwhile, in Experimental Class I and Experimental Class II, students were directly engaged in the problem-solving process through the Problem-Based Learning approach. According to Pratama (2022), problem-based learning enhances creative thinking skills because students are trained to seek solutions independently and actively. Experimental Class II showed the greatest improvement because, in addition to using the Problem-Based Learning approach, instruction was also supported by the PLEXA learning medium, which helped students understand concepts more concretely. This medium made it easier for students to explore ideas and comprehend the problems presented. According to Fitriani & Jusra (2024), the use of learning media in problem-based learning can increase student engagement and help them generate more creative solutions.

The results of this study indicate that the use of instructional media plays a crucial role in supporting the success of the Problem-Based Learning approach. For students, instructional media plays a vital role in boosting motivation and interest in learning because the material is presented in a more engaging and enjoyable manner (Karomah et al., 2024). In Experimental Class I, students were indeed active in solving problems; however, some students still struggled to understand the concepts due to the absence of concrete media to support their learning. Conversely, in Experimental Class II, the PLEXA media helped students visualize data and understand problems more clearly, allowing the creative thinking process to develop more optimally. This disparity in results between the classes demonstrates that a student-centered learning approach is far more effective in enhancing mathematical creative thinking skills compared to conventional learning. According to Putri et al. (2022), 21st-century learning requires students to possess creative and critical thinking, communication, and collaboration skills. The Problem-Based Learning approach supports the development of these skills because students actively discuss, share ideas, and collaborate to solve problems.

Furthermore, the results of this study support the theories of Guilford and Torrance as cited in (Istikomah et al., 2024) which state that creative thinking develops when individuals are given the opportunity to explore various alternative solutions. In Experimental Class II, students had greater opportunities to develop ideas through the use of the PLEXA medium. Consequently, students' abilities in sensitivity, flexibility, fluency, originality, and elaboration developed more effectively compared to those in other classes. These findings are also consistent with the results of a previous study by Minata et al. (2024) which indicated that the implementation of media-assisted Problem-Based Learning is more effective at enhancing students' creative thinking skills than conventional learning. Through the use of media, students can understand a problem more easily and interactively, thereby increasing their interest and enthusiasm for learning.

The significant differences between classes demonstrate that the learning process greatly influences the development of students' mathematical creative thinking skills. Instruction that emphasizes only memorization and the presentation of examples tends to make students passive and less accustomed to developing ideas independently. Conversely, instruction that provides opportunities for exploration and problem-solving trains students to think more creatively. The Problem-Based Learning approach serves as an alternative that can train students in creative mathematical thinking through problem-based learning. Problem-Based Learning emphasizes the use of real-world problems closely related to daily life as the starting point for learning, thereby creating an innovative learning process and encouraging active student engagement (Muhartini et al., 2023). In this context, the groups that received conventional instruction and Problem-Based Learning without media showed lower impact or effectiveness due to the absence of concrete media to help students better understand each learning process, which would have led to more optimal outcomes. The findings of this study also reinforce the importance of using innovative media in elementary school mathematics instruction. Elementary school students still need concrete media to help them understand abstract mathematical concepts. Media help teachers explain difficult or abstract material in a way that is more concrete and easier for students to understand (Karomah et al., 2024). Thus, the use of PLEXA media in this study was proven to help students understand data-related material while also enhancing their mathematical creative thinking skills.

Based on the overall research results, it can be concluded that there is a significant difference between the effects of conventional learning, Problem-Based Learning, and Problem-Based Learning supported by PLEXA media on the mathematical creative thinking skills of fifth-grade elementary school students. Problem-Based Learning supported by PLEXA media had the greatest impact because it was able to create active, contextual, and meaningful learning. Thus, the use of innovative learning approaches supported by concrete media is highly recommended in elementary school mathematics instruction to help develop students' mathematical creative thinking skills. The Problem-Based Learning approach provides students with the opportunity to explore ideas, discover various alternative solutions, and develop creativity in solving mathematical problems (Riyanto et al., 2024). Consequently, there are several practical implications from this study: (1) Teachers can use PBL for data-related material, but it must be supported by visual media; (2) PLEXA media should be designed with open-ended tasks so that students can generate a variety of strategies; (3) Creative learning requires more than just contextual problems; it also requires the support of concrete representations; and (4) The evaluation of mathematical creative thinking skills should assess the thinking process, not just the final answer.

Conclusion

Based on the research findings, it can be concluded that the implementation of conventional instruction, Problem-Based Learning (PBL), and Problem-Based Learning supported by the PLEXA medium all three forms of instruction had a moderate effect on improving the mathematical creative thinking skills of fifth-grade elementary school students, although the degree of effectiveness varied significantly. Conventional learning had an effect of 30.91% with an N-Gain value of 0.35 (moderate category); PBL had an effect of 38.19%

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with an N-Gain value of 0.36 (moderate category); while PBL supported by PLEXA media had the highest effect at 41.47% with an N-Gain value of 0.45 (moderate category). These results demonstrate that the implementation of an innovative, contextual learning approach supported by concrete media can help students become more active in exploring ideas, discovering various alternative solutions, and developing creativity in solving mathematical problems. Meanwhile, various factors play an active role in stimulating the development of students' mathematical creative thinking skills, such as motivation, cognitive readiness, the learning environment, as well as teaching approaches and media. This study still has limitations regarding the subject matter used, as the application of the Problem-Based Learning (PBL) approach supported by PLEXA media was focused solely on data-related material in the fifth grade of elementary school. Therefore, future researchers are advised to try applying the Problem-Based Learning (PBL) approach supported by PLEXA or similar media to other mathematics topics so that the effect of this approach on students' mathematical creative thinking skills across different topics can be determined.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Auhor Contributions

R.K.D. collected data and gained an understanding of the proposed research topic. The development of the theory and methodology, data processing and analysis, discussion of the findings, and approval of the final version of this article all involved the active participation of the other two authors, C.S. and M. Each author has expressed agreement with the final version of this article. Regarding the conception of the ideas, drafting, and the editing process, the relative contributions of each author were agreed upon as follows: R.K.D.: 40%, C.S.: 30%, and M.: 30%.

Data Availability Statement

The authors state that the data supporting the findings of this study can be obtained from the author [R.K.D.], upon reasonable request.

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Authors Biography

	**Rima Kusuma Dewi,** is a student in the Elementary School Teacher Education Program at the Sumedang Regional Campus of the Indonesia University of Education. ✉ rimakusumadewi24@upi.edu
	**Cucun Sunaengsih,** is a lecturer in the Elementary School Teacher Education Program at the Sumedang Regional Campus of the Indonesia University of Education. ✉ cucunsunaengsih@upi.edu
	**Mulana,** is a lecturer in the Elementary School Teacher Education Program at the Sumedang Regional Campus of the Indonesia University of Education. ✉ maulana@upi.edu