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Effect of Problem-Based Learning Approach Assisted by GEO-KODE on Understanding the Mathematical Concepts of Composition and Decomposition of Plane Shapes

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ABSTRACT

Students' limited understanding of mathematical concepts may hinder their ability to solve problems requiring analysis of relationships among concepts. This study examined the effectiveness of Problem-Based Learning (PBL) supported by GEO-KODE (Geometry-Composition Decomposition), an interactive learning medium designed to help students visualize the composition and decomposition of plane figures. A quantitative quasi-experimental method with a nonequivalent control group design was employed. The participants were 61 fourth-grade students selected through purposive sampling. The experimental group consisted of 31 students from Cijambe II Public Elementary School, while the control group included 30 students from Sukamulya Public Elementary School. Data were collected using a mathematical concept understanding test consisting of 15 valid items with high reliability. Data analysis included tests of normality, differences in mean scores, and normalized gain (N-Gain). The experimental group's mean score increased from 31.55 on the pretest to 74.97 on the posttest, whereas the control group's mean score increased from 38.83 to 51.77. A significant difference in posttest performance was found between the two groups ($p < .001$). The N-Gain analysis also showed a significant difference in improvement between the experimental and control groups ($p < .001$). These findings indicate that students who learned through PBL supported by GEO-KODE demonstrated greater improvement in mathematical concept understanding than those who received conventional instruction. The results suggest that integrating problem-based activities with interactive visual media can support fourth-grade students in understanding the composition and decomposition of plane figures, particularly by making relationships among component shapes more explicit during classroom problem solving.

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Introduction

Low understanding of mathematical concepts is a pressing issue in mathematics education (Yatri et al., 2025). This ability actually plays a very important role. According to Umam & Zulkarnaen (2022), a solid grasp of concepts is one of the key skills every student must possess when learning mathematics. A similar perspective is offered by the NCTM, as cited in Hafriani (2021), This ability serves as the foundation for students to understand the concepts they are learning, solve various mathematical problems, and develop the ability to think and reason logically. Without a solid conceptual understanding, students tend to memorize procedures without understanding the meaning behind them (Rosita et al., 2023; Suryana et al., 2025). This aligns with the findings of Yatri et al. (2025) who noted that in different situations, students struggle to apply mathematical concepts, connect one concept to another, and present mathematical representations accurately.

Topics involving composition and decomposition, such as those in geometry, require conceptual understanding that is not only procedural but also visual-spatial. Students must be able to break down an object into its constituent parts and reassemble those parts into a complete form (Marliana et al., 2023). However, in practice, many students struggle due to limited ability to understand relationships between geometric figures and difficulties in mentally visualizing abstract objects. In addition to being hierarchical, composition and decomposition concepts are highly abstract in nature. Students are not only required to understand concepts symbolically but must also be able to visualize the relationships between shapes or between transformations in the form of mental representations (Zuwandi et al., 2025). Difficulties arise when students are unable to imagine how a shape can be decomposed or reassembled, so learning often stops at merely memorizing procedures without understanding the true meaning of the concepts. This situation indicates that conceptual understanding depends not only on declarative knowledge but also on visual and spatial representation skills. This issue becomes even more apparent in topics that require the simultaneous integration of various concepts. Students often have difficulty connecting the parts of a shape into a single whole or, conversely, breaking down a shape into several basic forms (Wildan et al., 2024). A lack of spatial visualization skills makes it difficult for students to understand the relationship between parts and the whole, resulting in poor performance on non-routine problems. Therefore, a learning approach is needed that not only emphasizes procedures but also provides visual and hands-on experiences so that students can develop a more meaningful understanding of the concepts of composition and decomposition (Sengkey et al., 2023).

An understanding of mathematical concepts plays a crucial role in helping students solve various math problems accurately. This is because the process of solving mathematical problems requires the application of rules and principles based on mathematical concepts that have been understood. Fauzi et al. (2022) view the understanding of mathematical concepts as the primary foundation of mathematics learning, given that mathematics itself is a discipline related to logic, patterns, shapes, and various concepts that are interconnected. Through a solid grasp of these concepts, students can connect new information with their prior knowledge. This approach aims to help students understand the material more deeply, enabling them to apply it correctly and avoid mistakes caused by a lack of understanding.

However, in reality, the development of students' thinking skills is not sufficiently encouraged in the learning process because educators still frequently employ an approach that emphasizes the use and memorization of formulas. Students also often struggle to understand basic material due to a one-way teaching approach and the lack of interactive media in the classroom. The current situation reveals a gap between the actual practice and the ideal goals

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

of mathematics education, particularly regarding plane figures. Ideally, students should be able to recognize, understand, and make connections among various types of plane figures, including how these shapes can be assembled or broken down into smaller parts through various forms of representation. Failure to grasp these concepts can result in students' inability to solve math problems when the algorithms or formulas they have memorized begin to fade from memory.

Referring to previous studies that state that by facilitating students through the presentation of contextual and meaningful problems and developing their understanding of mathematical concepts (Safirah & Abdillah, 2024). PBL learning activities encourage students to build an understanding of the knowledge and key concepts contained in the learning material (Khadijah et al., 2025). PBL helps students gain confidence in tackling problems by enabling them to grasp mathematical concepts more quickly (Ningrum et al., 2025). In PBL-based flat-shape geometry instruction, this approach has also been shown to effectively enhance students' understanding of mathematical concepts (Mangaraja et al., 2025). Problem-Based Learning has six main characteristics: learning begins with a problem; the problem is related to students' real-world experiences; learning is organized around the problem; students are responsible for the learning process from problem identification to problem-solving; small groups are used for discussion and collaboration; and there is a demonstration of products or performance outcomes (Fathurahman; Nanda & Zainil, 2021). These six characteristics do not always appear in sequence but can unfold dynamically throughout the learning process, depending on classroom conditions, the teacher's role, and student activities.

A learning approach that begins with contextual problems encourages students to connect their prior knowledge with new concepts, thereby helping them to restate concepts, provide examples and counterexamples, and apply concepts in real-world situations. When learning is organized around problems, students are required to identify relevant information, connect various concepts, and determine appropriate problem-solving strategies. This process supports students' ability to identify the necessary and sufficient conditions for a concept and to apply mathematical procedures or operations correctly. In addition, students' responsibility for managing the learning process and small-group discussion activities provides opportunities to classify objects based on specific properties, convey ideas, compare various solutions, and build understanding through interaction with peers. During the stage of demonstrating results or products, students present concepts in various forms of representation—whether visual, symbolic, or verbal. Thus, the overall characteristics of PBL contribute to the achievement of indicators of mathematical conceptual understanding, which include the ability to restate concepts, classify objects, provide examples and counterexamples, present concepts in various representations, use appropriate procedures, and apply concepts to problem-solving.

This PBL approach requires the use of learning media; the GEO-KODE media serves as a learning aid that facilitates active learning. The GEO-KODE media features four main menus: (1) the "Explore Buildings" menu; (2) the "KODE Game" menu, an adventure activity where students search for two-dimensional shapes and then arrange them using a drag-and-drop mechanism to form a complete structure or object; and (3) the "Worksheet" menu, an activity in which students break down a structure into its constituent two-dimensional shapes. These menu sections are designed to be interactive, allowing students to create a new two-dimensional shape from the shapes provided for composition activities. For decomposition activities, students are provided with an image of a shape that they can break down into several alternative two-dimensional shapes. In line with this, previous research by Aeni, et al. (2022) indicates that interactive learning media can support teachers in conducting the learning process in the classroom.

Several previous studies have shown that both the Problem-Based Learning (PBL) approach and the use of interactive learning media have the potential to improve the quality of mathematics instruction. Rahmadani et al. (2025) found that the implementation of PBL supported by Wordwall media was able to improve students' understanding of mathematical concepts in the topic of fractions. Similar results were also reported by Indah & Ain (2025) who showed that PBL effectively increased student engagement, critical thinking skills, and understanding of mathematical concepts compared to conventional learning.

Regarding instructional media, by Sulistia & Ritonga (2025) demonstrated that the use of acrylic puzzle media in teaching plane figures can enhance students' creativity and engagement during the learning process. Furthermore, Awwaliyah & Sutriyani (2025) indicate that a PBL model supplemented with tangram media has a significant effect on students' understanding of mathematical concepts regarding the area and perimeter of plane figures. Based on these research findings, it can be concluded that both PBL and manipulative/interactive media have an impact on students' mathematical abilities. However, most studies still examine PBL and learning media separately or use media limited to specific topics, such as fractions, area, and perimeter of two-dimensional shapes. Research that integrates the PBL approach with interactive digital media specifically designed to facilitate elementary school students' understanding of the concepts of composition and decomposition of two-dimensional shapes remains very limited. Interactive learning media such as GEO-KODE can encourage students to construct their own understanding independently, in line with the statement by Aeni et al (2023) that teachers can be supported by interactive learning media. GEO-KODE serves as a tool that facilitates more optimal student learning. According to Heruman (2016) learning media are expected to help develop students' thinking patterns, particularly regarding the composition and decomposition of plane figures. This aligns with Bruner's theory of mathematics learning, as cited in Safari & Inayah (2024) through learning media, students can visualize and communicate their understanding using various engaging design formats, rather than merely grasping mathematical concepts. Therefore, this study aims to address this gap by applying a Problem-Based Learning approach supported by the GEO-KODE media to enhance students' understanding of mathematical concepts regarding the composition and decomposition of plane figures.

Based on the identified research gaps, the purpose of this study is to analyze the effect of implementing a Problem-Based Learning approach aided by the GEO-KODE media on students' mathematical concept comprehension in the topic of composition and decomposition of plane figures. Specifically, this study aims to determine the differences in mathematical conceptual understanding between students who were taught using the PBL approach supported by GEO-KODE media and those who received conventional instruction.

Method

Type of Research

This research uses a quantitative approach which is carried out systematically, controlled, empirically and critically in testing hypotheses regarding the relationship between variables (Widodo, 2021). The chosen design is a quasi-experimental design, which is a method used when the researcher cannot fully randomize the subjects. In this method, the effect of a treatment can be analyzed by comparing the subjects' conditions before and after the treatment is administered, as well as with another group that did not receive the same treatment. This method was chosen because the researcher could not exercise full control over the entire sample, so there was no random sampling (Millah et al., 2024). This research method was chosen because it was not possible to exercise complete control over the research sample, so

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

there was no random sampling. In other words, groups were selected from each school based on the number of students in each class. The research design is as follows:

Sample	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3		O_4

Sumber: Abraham & Supriyati (2022)

Figure 1. Nonequivalent Control Group Design

Notes:
X : Problem-Based Learning Approach Using GEO-KODE Media.
O_1 : Pretest for the experimental class.
O_2 : Posttest for the experimental class.
O_3 : Pretest for the control class.
O_4 : Posttest for the control class.

Population and Sample

According to Isnawan (2020) the entire research sample is referred to as the population. The population in this study consists of fourth-grade students at public elementary schools in Paseh Subdistrict during the 2025/2026 school year, specifically the 13 schools holding B accreditation. The sample was selected using purposive sampling, as described by Sugiyono from Rahmansyah et al. (2025). In this study, the sample was selected based on specific criteria, a method commonly known as purposive sampling. The considerations and criteria used as guidelines for sample selection were as follows: the researcher selected schools with 30 or more students to meet the requirements for an experimental study; the schools had fully implemented the Merdeka Curriculum; and, finally, the schools had not previously taught material on decomposition and composition. Consequently, the following two schools were selected:

Table 1. Research Sample

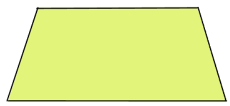
Sample	Number of Students
SDN Cijambe II	31
SDN Sukamulya	30

Instruments

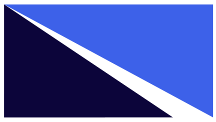
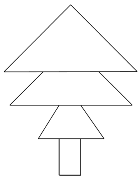
According to Zayrin et al. (2025), research instruments are tools used by researchers to ensure that the data collection process proceeds in a more structured manner. Test items are used to measure students' conceptual understanding before and after instruction.

Table 2. Outline of Understanding Mathematical Concepts

Concept Understanding	Question Indicator	Problems example
Restating a concept	Students can re-explain the meaning of decomposition of flat shapes.	What is meant by decomposition of plane shapes?
	Students can mention the basic differences between composition and decomposition.	Explain the difference between composition and decomposition of flat shapes!
Classifying objects according to certain properties	When presented with a picture of a composite shape, students can name the types of shapes that form it	Look at the picture of the "geometric swan"! From the properties of the plane figures that you know, state the names of the plane figures that form it and their number!

Concept Understanding	Question Indicator	Problems example
	based on the characteristics of the flat shape.	
	Given a picture of a square, students can name the types of shapes that form it based on the characteristics of flat shapes.	Look at the tangram image below! Based on the properties of plane figures, group the square-forming figures in the image and their numbers! 
Giving examples and non-examples	Students can choose images that meet the correct composition requirements and provide reasons for not choosing non-example images.	From the three images below a. Choose the image that shows the most appropriate composition without gaps and without overlapping. Give your reasons! b. Then give a reason why you didn't choose the other image!  (A) (B) (C)
	Students can select images that do not meet the requirements for correct decomposition and can differentiate them from correct decomposition.	From the three images below a. Which image is not an example of dividing a rectangle into 4 triangles without any remainder/gaps? Give your reason! b. And give a reason why you didn't choose the other image! 
Presenting concepts in various mathematical representations	Students can draw variations of flat shapes.	Combine two right triangles to form two new geometric shapes! Describe how they are arranged and write down the names of the shapes!
	Students can draw two different ways to decompose a plane figure.	Draw two different lines on the image to divide the trapezoid below into other plane shapes! Write down the names of the plane shapes resulting from the division! 
	Students can combine flat shapes into a new shape.	Draw two new plane shapes, by combining the three plane shapes below, then write the names of the shapes that have been drawn! 
Developing necessary or sufficient conditions for a concept	Students explain why two shapes cannot be combined if their sides are not the same length.	Why can't these two triangles form a perfect rectangle?

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

Concept Understanding	Question Indicator	Problems example
		
	Students can explain the technical reasons behind the perfect combination of shapes.	Why must two plane shapes that are to be assembled have the same side length on the part that will be attached? What happens if two plane shapes that are combined have different side lengths on the part that is attached?
Using, utilizing, and selecting certain procedures or operations	Students can use procedural units to analyze the flat shapes that make up the shape of a house.	 So that the shape on the side becomes various types of flat shapes simpler! a. What steps will be taken? b. Why choose that step? c. After completing these steps, group the simpler plane shapes based on the number and shape of each shape! Present them in table form!
	Students break down complex shapes into simpler plane shapes.	Create two different ways of dividing, with draw a line on the two pictures below to form other simpler flat shapes! Name the flat shapes that are formed and How many of each flat shape are there? Explain how you would divide it! 
Applying problem-solving concepts or algorithms	Students solve problems related to arranging or cutting paper.	Aqmal has a square piece of paper. a. Divide it into 4 identical/congruent triangles! b. Then rearrange them into 2 flat shapes in 2 different ways! c. What flat shapes will be formed? d. Describe how you arrange it!
	Students determine flat shapes with compositions that can form hexagons.	A student wants to make a hexagonal greeting card by combining the same plane shapes. a. Name one type of flat shape that can be arranged into a hexagon (with the note that the number of shapes is adjusted to your needs)? b. Then describe how to arrange them to form a hexagon!

Before using the test instrument, a validity test is first conducted; the results are attached in Table 3

Table 3. Test Instrument Validity

Question Number	Sig. (2-tailed)	Criteria
1	0,000	Valid
2	0,000	Valid
3	0,000	Valid
4	0,000	Valid
5	0,001	Valid
6	0,005	Valid
7	0,036	Valid
8	0,002	Valid
9	0,010	Valid
10	0,000	Valid
11	0,001	Valid
12	0,000	Valid
13	0,000	Valid
14	0,022	Valid
15	0,001	Valid
16	0,186	Invalid

Based on the results of the question validity test, it can be concluded that 15 items are valid, while 1 item is invalid; all valid items will be used in this study, and the invalid item will not be used. Reynold in Zayrin et al. (2025), states that reliability is related to the consistency or stability of assessment results. Reliability is defined as the degree of consistency of a research instrument.

Table 4. Reliability Test

Number of Questions	Reliability Coefficient	Criteria
16	0,878	Highly reliable

Based on the results of the test above, a reliability coefficient of 0.878 was obtained, indicating that the test items are highly reliable.

Data Collection

Creswell in Pasaribu *et al*. (2025), a way to collect data consistently in accordance with the focus of the research. This study used a conceptual understanding test, used to measure students' mathematical conceptual understanding and to determine the effect of the implementation of the Problem-Based Learning approach assisted by GEO-KODE media on the conceptual understanding abilities of fourth-grade students. A test with 15 questions was used.

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
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Figure 2. Research Procedure

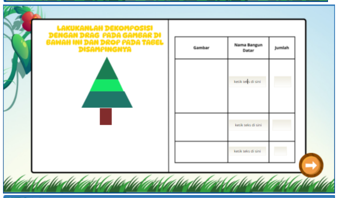
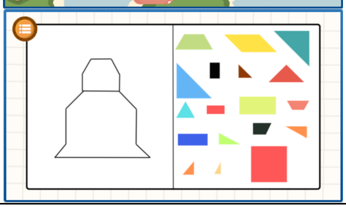
Table 5. Data Collection Techniques

Instrument			**Target**	**Time**
Form		**Goal**		
Concept Understanding Test	pretest-posttest	Measuring students' understanding of mathematical concepts at the beginning and at the end	Student	Before and after the learning session

This section explains the application of the GEO-KODE media in the Experimental class. In the first meeting, the implementation of GEO-KODE through the exploration menu focused on the composition of plane figures. Learning began with the presentation of a contextual problem in the form of observing an object composed of several plane figures. Through identifying and classifying the constituent figures, students built conceptual understanding through discussion and exploration. This activity reflects the characteristics of Problem-Based Learning (PBL), which begins learning with a real-world problem and centers on student activity.

In the second meeting, students used the CODE game menu and LKPD to compose, describe, and integrate the concepts of composition and decomposition of flat shapes through drag and drop activities. Learning began with contextual problems that encouraged students to analyze the constituent shapes of an object, then decompose and rearrange them into new shapes. Through group work, discussions, and presentations of results, students presented concepts in visual form, chose appropriate solution strategies, and applied concepts to different situations. Thus, the implementation of GEO-KODE in the PBL model supported the achievement of indicators of mathematical concept understanding, starting from identifying and explaining concepts to applying them in contextual problem solving.

Table 6. Experimental Class Learning Activities

Meetings	Explanation of activities	Example
First	Students begin to observe the material displayed on the GEO-KODE media. (Students are asked to look for the plane shapes mentioned, then when they click on that section there will be an explanation of the properties of the plane shapes)	
	Students are encouraged to actively try to decompose existing shapes.	
	Students actively conduct experiments to analyze flat shapes.	
	Students try to arrange random flat shapes according to the shape specified in the application	
Second	Students analyze the problems presented in the game, which of course must be solved with a deep structural understanding	
	Students begin to observe and understand problems in GEO-KODE media	
	Students begin to experiment with the challenges presented in the game	
	Each group carries out learning about the composition and decomposition of flat shapes which is related to the problems or challenges in the LKPD provided	

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

Analysis

Data analysis in this study was conducted quantitatively through several stages. The first stage was a normality test to determine whether the data distribution was normal or not. The decision rule applied was $\alpha = 0.05$. If the data were normally distributed, the study proceeded to a homogeneity test. The decision rule applied was $\alpha = 0.05$. Next, a t-test was conducted to compare the pretest and posttest scores. The hypotheses for the t-test to examine differences between the pretest and posttest data are as follows: H0: There is no difference between the pretest and posttest; H1: There is a difference between the pretest and posttest. Using SPSS software, the significance level ($\alpha = 0.05$) is set such that H_0 is accepted if the p-value (sig.) is $\geq \alpha = 0.05$, and H_0 is rejected if the p-value (sig.) is $< \alpha = 0.05$. The testing procedure is as follows: if the data are normally distributed, a t-test is used; if the data are not normally distributed, a W-test is used. After that, to compare the mean initial and final ability scores between the two independent groups, a t-test was used if the data were normally distributed and homogeneous, or a U-test if the data were not normally distributed. The established criteria for hypothesis testing are as follows. H0: There is no difference between the mean scores of the experimental class and the control class. H1: There is a difference between the mean scores of the experimental class and the control class. Therefore, the hypothesis testing criteria were set at a significance level of $\alpha = 0.05$, meaning H0 is accepted if the p-value (sig.) is $\geq \alpha = 0.05$, and H0 is rejected if the p-value (sig.) is $< \alpha = 0.05$. Next, to determine the extent of the increase in students' conceptual understanding, the average N-Gain was calculated. Finally, to determine the magnitude of the effect of the treatment on each class, the coefficient of determination was used with the following formula: $KD = r^2 \times 100\%$

Research Findings

Effect of Problem-Based Learning Approach Assisted by GEO-KODE Media on Fourth Grade Students' Understanding of Mathematical Concepts

In the first meeting, the implementation of GEO-KODE focused on the composition of flat shapes through the Building Exploration and CODE Game menus. Learning began with the presentation of contextual problems in the form of observations of various buildings and objects composed of several flat shapes. This activity reflects the main characteristics of Problem-Based Learning (PBL), namely learning begins with a problem related to the students' real world. Through the activity of identifying the constituent shapes of an object, students are encouraged to classify objects based on certain properties and distinguish examples from non-examples of flat shapes according to the concepts being learned. Next, in the CODE Game menu, students work in small groups to arrange various flat shapes using a drag-and-drop mechanism to form a specific object or building. This activity gives students the responsibility to construct their own knowledge through exploration and group discussion. In this process, students not only present concepts in the form of visual representations, but also use and select appropriate procedures in arranging the shapes to form the desired object. The resulting arrangement presented at the end of the lesson is a product that demonstrates students' understanding of the concept of flat shape composition. In the second meeting, the implementation of GEO-KODE was directed at understanding the concept of flat shape decomposition through the Interactive Student Worksheet menu.

Learning continues to begin with the presentation of a contextual problem in the form of a picture of a complete building that students must analyze to determine its constituent plane figures. PBL characteristics are evident in the organization of learning that centers on problem solving and provides opportunities for students to conduct investigations independently or in groups. Through the activity of decomposing a shape into several constituent figures, students learn to develop necessary and sufficient conditions for a concept, for example, understanding that a shape can be composed of a combination of several different plane figures.

In addition, students also present concepts in various mathematical representations through decomposition drawings and oral explanations during group discussions. The opportunity to try various decomposition alternatives allows students to flexibly use learned concepts while applying specific procedures to find the most appropriate solution. Thus, the decomposition process facilitated by GEO-KODE supports the development of students' conceptual thinking skills in greater depth. In the third meeting, students integrate the concepts of composition and decomposition through solving more complex problems. Students first decompose an object using the LKPD menu, then rearrange the parts into a new shape using the KODE Game menu. This activity represents all the characteristics of PBL, namely problem-based learning, oriented to real situations, carried out in small groups, giving students learning responsibility, and producing a product in the form of a new building design that is presented to the class. At this stage, students are required to restate the concepts of composition and decomposition in their own words, classify buildings based on their characteristics, present concepts in visual and symbolic forms, choose appropriate solution strategies, and apply problem-solving concepts and algorithms to different situations. Through the integration of these two concepts, GEO-KODE not only functions as a visualization medium, but also as a means of knowledge construction that allows students to build meaningful relationships between geometric concepts. Therefore, the implementation of GEO-KODE within the PBL framework contributes to the achievement of all indicators of mathematical concept understanding, from the ability to recognize and explain concepts to the ability to apply them in contextual problem solving.

The effect of the PBL approach was examined by comparing the pretest and posttest scores of students in the experimental class. The analysis was conducted in stages, beginning with descriptive statistics, a normality test, a paired samples t-test, and ending with the calculation of N-Gain. The summary of the scores is attached below.

Table 7. Recap of Pretest and Posttest Scores for the Experimental Class

Mark	N	Range	Lowest Score	Highest Score	Average
Pretest	31	0-100	21	47	31,55
Posttest	31	0-100	46	96	74,97

Based on Table 7, the difference between the students' average posttest and pretest scores was found to be 43.42. This increase indicates that the treatment had an effect. To determine whether the data were normally distributed, a normality test was conducted, with the following results.

Table 8. Results of Normality Test for Pretest and Posttest in the Experimental Class

Mark	Average	Shapiro-Wilk Normality Test	
		Sig.	Information
Pretest	31,55	0,059	Normally Distributed
Posttest	74,97	0,145	Normally Distributed

The results of the normality test for the pretest scores showed a Sig. value of $0.059 > 0.05$, while the posttest scores yielded a Sig. value of $0.145 > 0.05$, indicating that both datasets are normally distributed. Therefore, a paired-sample t-test can be used to test for differences in means.

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https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

Table 9. Average Difference Test Between Pretest and Posttest of the Experimental Class

Mark	Paired Sample t-Test Sig. (2-tailed)	Information
Pretest Posttest	0,000	There is a significant average difference between the initial abilities of students and the final abilities of students in the experimental class.

The results of the mean difference test yielded a significance value of 0.000 < 0.05. This indicates a significant difference between the pretest and posttest means of the students in the experimental class, leading to the conclusion that the students' initial and final abilities showed a significant change. The N-Gain summary results are presented in Table 10

Table 10. N-Gain Calculation of Indicators in the Experimental Class

Indicators	N-Gain	Criteria
Restating a concept	0,526437	Medium
Classifying objects according to certain properties	0,637685	Medium
Giving examples and non-examples	0,671946	Medium
Presenting concepts in various mathematical representations	0,548951	Medium
Developing necessary or sufficient conditions for a concept	0,694444	Medium
Using, utilizing, and selecting certain procedures or operations	0,662434	Medium
Applying problem-solving concepts or algorithms	0,614085	Medium

Table 10 shows the N-Gain for each indicator of mathematical concept understanding, with the highest increase observed for the indicator "Developing necessary and sufficient conditions for a concept." In the following section, we will calculate the overall N-Gain for the experimental class.

Table 11. Recap of N-Gain Calculation for Students in the Experimental Class

N	Range	Number of Students Based on N-Gain Interpretation			Lowest	Highest	Average	Category
		High	Medium	Low				
31	0-100	12	17	2	0,28	0,94	0,64	Medium

Overall, students in the experimental class showed an improvement in their understanding of mathematical concepts. Of the 31 students, 12 showed a high level of improvement, 17 showed a moderate level, and 2 showed a low level. The average N-Gain of 0.64 indicates that the PBL approach supported by the GEO-KODE media has an effect on students' understanding of mathematical concepts. To determine the extent of the effect of the PBL approach supported by the GEO-KODE media, a coefficient of determination analysis was conducted.

Table 12. Experimental Class Determination Coefficient

Mark	Pearson Test			
	Sig.	Description	Correlation Coefficient	Description
Pretest and Posttest of Experiment Class	0,000	Correlated	0,654	Strong Correlation

The correlation coefficient was found to be 0.654; therefore, to determine the coefficient of determination, it will be calculated using the following formula:

$$\mathrm{KD} = \mathrm{r}^2 \times 100\%$$
$$\mathrm{KD} = 0{,}654^2 \times 100\%$$
$$\mathrm{KD} = 42{,}77\%$$

Based on the above calculations, the coefficient of determination was found to be 42.77%, which means that the PBL approach supported by the GEO-KODE media had a 42.77% influence on students' understanding of mathematical concepts in the experimental class, where the average N-Gain score was 0.64.

Impact of Conventional Approaches on Fourth Grade Students' Understanding of Math Concepts

In the control class, instruction was conducted conventionally using a contextual approach aided by tangrams, covering the same material: the composition and decomposition of two-dimensional shapes. Data analysis followed the same steps: a normality test, a test for differences in means, and the calculation of N-Gain.

Table 13. Recap of Pretest and Posttest Scores for the Control Class

Mark	N	Range	Lowest Score	Highest Score	Average
Pretest	30	0-100	23	80	38,83
Posttest	30	0-100	26	83	51,77

The average difference between the posttest and pretest scores in the control class was 12.94 points. This figure indicates that the conventional approach also had an effect on students' conceptual understanding, although it was smaller than that observed in the experimental class.

Table 14. Normality Test Results for Pretest and Posttest of the Control Class

Mark	Average	Shapiro-Wilk Normality Test	
		Sig.	Description
Pretest	38,83	0,002	Not Normally Distributed
Posttest	51,77	0,098	Normally Distributed

The results of the normality test showed that the pretest scores for the control class were not normally distributed (Sig. $0.002 < 0.05$), whereas the posttest scores were normally distributed (Sig. $0.098 > 0.05$). Because one of the datasets was not normally distributed, the test for differences in means was conducted using the Wilcoxon test.

Table 15. Results of the Difference Test for the Average Pretest and Posttest of the Control Class

Mark	Wilcoxon test Sig. (2-tailed)	Information
Pretest Posttest	0,000	There is a significant average difference between students' initial abilities and students' final abilities in the control class.

The results of the Wilcoxon test showed a p-value of $0.000 < 0.05$, indicating a significant difference between the students' initial and final performance in the control class. These findings suggest that even a conventional approach can influence students' understanding of mathematical concepts. To determine the magnitude of the improvement, an N-Gain calculation was performed.

Table 16. Calculation of N-Gain Indicators in the Control Class

Indicator	N-Gain	Criteria
Restating a concept	-0.01044	Decrease
Classifying objects according to certain properties	0.223152	Low
Giving examples and non-examples	0.328165	Medium
Presenting concepts in various mathematical representations	0.179211	Low
Developing necessary or sufficient conditions for a concept	0.275362	Low

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

Indicator	N-Gain	Criteria
Using, utilizing, and selecting certain procedures or operations	0.170109	Low
Applying problem-solving concepts or algorithms	0.12983	Low

The table above shows the N-Gain scores for each indicator of mathematical concept understanding in the control class, with the highest N-Gain scores observed for the "identifying examples and non-examples" indicator, where most students improved their scores on that indicator. Next, the N-Gain scores for all students in the control class will be calculated.

Table 17. Recapitulation of N-Gain Calculations for Control Class Students

N	Range	Number of Students based on N-Gain Interpretation			Lowest	Highest	Average	Category
		High	Medium	Low				
30	0-100	-	7	23	0.3	0.66	0.21	Low

30 students in the control group, 7 showed moderate improvement and 23 showed low improvement. The average N-Gain of 0.21 is considered low. This indicates that the conventional approach does have an effect, but the level of improvement is still relatively low. Therefore, to determine the extent of the conventional approach's effect on the control class, the coefficient of determination was calculated

Table 18. Control Class Determination Coefficient

Score	Spearman test			
	Sig.	Information	Correlation Coefficient	Information
Pretestand Posttest Control Class	0,000	Correlated	0.721	Strong Correlation

The correlation coefficient was found to be 0.721; therefore, to determine the coefficient of determination, it will be calculated using the following formula:

$$\mathrm{KD} = \mathrm{r}^2 \times 100\%$$
$$\mathrm{KD} = 0{,}721^2 \times 100\%$$
$$\mathrm{KD} = 51{,}98\%$$

Based on the above calculation, the coefficient of determination is 51.98%, which means that with a 51.98% influence from the conventional approach, the average N-Gain value in the control class is only 0.21, which falls into the low category.

Difference The influence of the Problem-Based Learning approach assisted by GEO-KODE media with the conventional approach on the ability to understand mathematical concepts

The subsequent analysis compared the initial abilities of the experimental and control groups to ensure that the initial conditions were equivalent before the treatment was administered. The following explains the results of the statistical analysis.

Table 19. Recapitulation of Pretest Scores in the Experimental Class and Control Class

Class	N	Range	Lowest Value	The highest score	Average
Experiment	31	0-100	21	47	31.55
Control	30	0-100	23	80	38.83

Based on the information in the table above, the average pretest score for students in the experimental class was 31.55, while the average pretest score for the control class was 38.83. The following are the results of the statistical test comparing the average pretest scores between the experimental and control classes.

Table 20. Statistical Test Results of Pretest Scores in the Experimental Class and Control Class

Class	Average	Normality Test (Shapiro-Wilk)		Average Difference Test (U-Test)	
		Sig.	Information	Sig.	Information
Experiment	31.55	0.059	Normally Distributed	0.86	There was no difference in the average pretest score between the experimental class and the control class.
Control	38.83	0.002	Not Normally Distributed		

Because one of the datasets was non-normal, the Mann-Whitney U test was used to compare the pretest means. The results showed a p-value of 0.86 > 0.05, indicating that there was no significant difference between the pretest means of the two classes. Thus, it can be concluded that students in the experimental and control classes had equivalent initial abilities, allowing for a valid comparison of the treatment effects. After confirming that the initial abilities of the two classes were equivalent, the analysis continued with the students' final abilities.

Table 21. Recapitulation of Posttest Scores in the Experimental Class and Control Class

Class	N	Range	Lowest score	The highest score	Average
Experiment	31	0-100	46	96	74.97
Control	30	0-100	26	83	51.77

Based on the information in Table 21, the average posttest score for students in the experimental class was 74.97, while that for the control class was 51.77. To determine whether there is a difference, a statistical test will be conducted by comparing the posttest scores between the two classes.

Table 22. Statistical Test Results of Posttest Scores in the Experimental Class and Control Class

Class	Aver age	Normality Test (Shapiro-Wilk)		Homogeneity Test		Mean Difference Test (t-Test)	
		Sig.	Information	Sig.	Information	Sig.	Information
Experiment	74.97	0.145	Normally Distributed	0.024	Not Homogeneo us	0,00 0	There is a difference in the average posttest scores in the experimental class and the control class.
Control	51.77	0.098	Normally Distributed				

Both classes had posttest data that were normally distributed. However, the homogeneity test showed Sig. 0.024 < 0.05, meaning that the variances of the two groups were not homogeneous. Therefore, a test for the difference in means was conducted using the t'-test. The results showed Sig. 0.000 < 0.05, so H1 was accepted. This means there is a significant difference in the mean posttest scores between the experimental class and the control class. In

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

other words, the final proficiency levels of the students in the two classes are at significantly different levels.

Thus, it can be concluded that the treatment administered to the control group did not yield better results than that of the experimental group. Next, an analysis was conducted using N-Gain to determine the magnitude of the improvement. The summary of the N-Gain results for both groups is presented in the table.

Table 23. N-Gain Results in the Experimental Class and Control Class

Class	N	Number of Students based on N-Gain Interpretation			Lowest N-Gain Score	Highest N-Gain Score	Average	Category
		High	Medium	Low				
Experiment	31	12	17	2	0.28	0.94	0.64	Medium
Control	30	-	7	23	0.3	0.66	0.21	Low

Based on Table 23, each student showed an increase in mathematical conceptual understanding. It can be seen from the average N-Gain scores that the two classes fell into different criteria: the experimental class, with an average of 0.64, met the moderate criterion, whereas the control class, with an average of 0.21, fell into the low criterion. This is also evident from the average N-Gain scores for each class, where 0.64 > 0.21; thus, it can be concluded that the average N-Gain for the experimental class is higher than that of the control class. The following are the results of the statistical test of the N-Gain scores in both classes.

Table 24. Results of the N-Gain Score Statistical Test in the Experimental Class and the Control Class

Score	Average	Shapiro-Wilk test		Mann-Whitney test	
		Sig.	Information	Sig.	Information
Experiment	0.64	0.426	Normally Distributed	0,000	There is a difference in the average N-Gain score in the experimental class and the control class.
Control	0.21	0.002	Not Normally Distributed		

The average N-Gain for the experimental class (0.64) was higher than that of the control class (0.21). The Mann-Whitney test also showed a p-value of 0.000 < 0.05, proving that the difference in improvement between the two classes was significant. Thus, it can be concluded that learning using the PBL approach aided by the GEO-KODE media resulted in a greater improvement in mathematical concept understanding compared to the contextual approach aided by tangram media.

Discussion

The implementation of a PBL approach supported by the GEO-KODE media has shown an impact on students' understanding of mathematical concepts. The improvement in students' ability to understand mathematical concepts in the experimental class was influenced by the characteristics of the GEO-KODE media, which enable students to construct concepts through visual, interactive, and contextual learning experiences. The exploration feature helps students connect geometric concepts with objects encountered in everyday life. By observing various structures composed of several two-dimensional shapes, students not only recognize geometric shapes but also learn to identify the relationships between the constituent shapes and the resulting composite shape. This activity contributes to students' ability to classify objects based on specific properties and to provide examples and non-examples of a concept.

In addition, the KODE game's features give students the opportunity to manipulate objects directly using a drag-and-drop mechanism. The activity of arranging several plane figures into new shapes allows students to gain concrete experience in understanding the concept of plane figure composition. This process helps students present concepts through various visual representations, use specific procedures to achieve the desired shape, and develop an understanding that a single figure can be formed from a combination of several different plane figures.

Meanwhile, the Interactive game feature makes an important contribution to students' understanding of the concept of decomposing two-dimensional shapes. Through the activity of breaking down a shape into its constituent parts, students can explore more than one possible answer. The opportunity to compare various possible decompositions encourages students to think more flexibly in understanding the relationship between the parts and the whole of a shape. This activity helps students develop a deeper understanding of the conditions for forming a shape, choose the appropriate solution procedure, and apply the concepts of composition and decomposition to problem-solving. Thus, the improvement in students' understanding of mathematical concepts is influenced not only by the visual presentation of the material but also by the opportunity to actively explore, manipulate, and reflect on concepts through the features available in GEO-KODE.

There was a difference in the average scores obtained by students between the pretest and posttest results. This increase in scores indicates that students' understanding of mathematical concepts improved after participating in instruction using the approach and media employed, compared to before the instruction took place. Indah & Ain (2025), reported an increase in students' understanding of mathematical concepts following the implementation of the PBL approach, as evidenced by a significant difference in scores. The findings of Rahmadani et al. (2025), support the view that the PBL approach to mathematical concept understanding is considered more effective at improving learning than conventional approaches. According to Suhartami et al. (2023), the implementation of PBL influences the learning process. Thus, these findings further strengthen the evidence from previous studies. The impact of PBL can be understood through constructivist learning theory, which views students as active agents who construct their own knowledge through learning experiences (Suryana et al., 2022). In line with this perspective, Piaget's theory explains that in a PBL context, students are placed in situations that require them to solve complex problems. This process encourages students to assimilate new information while accommodating their prior knowledge. Furthermore, the implementation of PBL in this study was designed in accordance with various learning theories that support the process of knowledge construction and the enhancement of students' understanding of mathematical concepts (Wardani, 2022).

In addition to the implementation of the PBL approach, the use of the GEO-KODE medium also contributed to the development of students' understanding of mathematical concepts. This aligns with the findings of Aeni et al. (2022), which states that when teachers implement the learning process, media can support learning to be more effective. In this study, the GEO-KODE media was developed as a tool to encourage students' active engagement during learning activities. Through the use of this media, students gain broader opportunities to interact with the learning material, thereby allowing the process of understanding mathematical concepts to occur more optimally. As an interactive, technology-based medium, GEO-KODE is capable of facilitating the enhancement of students' learning motivation and encouraging them to construct their own understanding through meaningful learning experiences. The GEO-KODE medium can not only be used as a tool for delivering learning information but also plays a role in introducing digital skills to students. Mastery of digital skills is essential to help

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5358 Volume 6, No 3, July - September 2026, pp. 1143 –1166

students become more critical and selective in filtering the various types of information they encounter in the digital environment (Isrokatun et al., 2022). He importance of learning media is further reinforced by findings from previous research, which revealed that third-grade students struggle to understand the concept of the perimeter of two-dimensional shapes, partly due to a lack of relevant learning aids (Virra et al., 2023). Given these conditions, the GEO-KODE media serves as an alternative learning aid that can facilitate the students' learning process more effectively. This aligns with Heruman (2016), assertion that media, as a visual aid, can help develop students' thinking patterns when learning basic mathematical concepts. Based on the research findings, it can be concluded that the combination of the PBL approach and the GEO-KODE medium is influenced not only by the medium's strengths but also by the characteristics of PBL itself, which encourages students to be active learners. Khadijah et al. (2025), emphasize that one of the strengths of PBL is its ability to help students understand concepts through problem-solving connected to real-life situations.

In the control class, the research results also showed an improvement, but the improvement was smaller than that in the experimental class. Nopitry et al. (2025), who noted an improvement in mathematical concept comprehension before and after the implementation of conventional instruction, documented an improvement in mathematical concept comprehension before and after the implementation of conventional instruction. Furthermore, low mastery of basic mathematical concepts is not only influenced by students' internal factors but can also be influenced by factors stemming from teachers as the facilitators of learning (Isrokatun et al., 2026). herefore, teachers play a crucial role as facilitators capable of creating learning experiences that are not only enjoyable but also meaningful. Khairo (2025), argues that connecting mathematical concepts to real-life contexts can help students understand their applications more easily and naturally. This view is supported by Ghozali & Ismah (2025), whose research shows that mathematics learning outcomes improved significantly after the implementation of a contextual approach. Therefore, learning that involves real-life situations and the use of concrete objects can provide a more meaningful learning experience, thereby contributing to students' understanding of mathematical concepts.

Although both approaches were equally effective, a significant difference was observed when the final performance of the two classes was compared. In fact, the analysis of initial performance showed that both classes were on an equal footing before the intervention. This equivalence in initial performance served as a valid basis for comparing the effects of each intervention. The average difference between pretest and posttest scores in the experimental class was much greater than in the control class. This was reinforced by the results of the posttest mean difference test, which revealed a significant difference between the two classes. The N-Gain calculations also confirmed that, although the conventional approach was effective, the level of improvement achieved was still relatively low. This indicates that the conventional approach still contributes to helping students understand mathematical concepts, particularly through the use of concrete objects and experiences relevant to students' daily lives. However, its effectiveness is not as great as that of the GEO-KODE media-assisted PBL approach, which has been proven to yield a higher average improvement.

This difference is also evident in how each approach works in learning. The GEO-KODE-assisted PBL approach starts with presenting a complex real-world problem as the initial trigger for learning. The GEO-KODE media functions not just as an information provider, but as a tool for investigation that encourages students to actively seek information, conduct independent research, and collaborate to find solutions (Wahyuni et al., 2024). PBL basically develops critical thinking skills and data-based decision making, where students not only learn calculation procedures, but also understand when and why a concept is applied to solve real problems (Ariyanto et al., 2024). Meanwhile, the contextual approach assisted by tangram media emphasizes giving meaning by connecting the material to students' real-life situations. Andriansah et al. (2024), explained that concrete media like tangrams really help during the experiencing and applying stages, where students can do physical activities to discover concepts on their own. However, tangram media has limitations if used for two different sessions, so students' motivation usually drops in the second session. So, combining the PBL approach with GEO-KODE media has been proven to have more impact compared to conventional approaches in improving students' mathematical concept understanding.

Conclusion

The implementation of a Problem-Based Learning approach assisted by GEO-KODE media influences students' understanding of mathematical concepts in the subject of composition and decomposition of flat shapes. The conventional approach also has an effect, but it is not better compared to the PBL approach with GEO-KODE media, as seen from the statistical test results and N-Gain scores where the improvement in the experimental class was higher than in the control class. This finding shows that integrating PBL with GEO-KODE media effectively supports concept understanding through interactive activities of exploring, arranging, and breaking down flat shapes, allowing students to build geometry concepts more meaningfully. The novelty of this study lies in the integration of the PBL approach with GEO-KODE media, specifically designed to facilitate learning composition and decomposition of flat shapes through digital visual and manipulative activities. This study has some limitations because it was conducted in a limited number of schools, the treatment lasted only 2 sessions which is relatively short, and it focused solely on the material of composition and decomposition of flat shapes. Therefore, future research is recommended to test the use of GEO-KODE on other geometry topics, involve a larger sample, and examine its impact on other mathematical skills like problem-solving, reasoning, communication, and mathematical critical thinking.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Auhor Contributions

G.D.A. was responsible for the initial research concept, field data collection and documentation, and the preparation of the first draft of the manuscript. I and A.N.A. contributed to the development of the theoretical framework, methodological design, statistical analysis, interpretation of findings, manuscript refinement, and final approval. Proportion of contributions: G.D.A.: 40%, I.: 30%, A.N.A.: 30%.

Data Availability Statement

The authors state that the data supporting the results of this study will be provided by the corresponding author, [G.D.A.], upon reasonable request.

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