

Effectiveness of the GeoGebra Media-Assisted Project Based Learning Model on the Understanding of Concepts and Mathematical Reasoning of Students

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Received: June 17, 2026

Revised: September 10, 2026

Accepted: September 29, 2026

Published: September 30, 2026

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DOI: [10.29303/jppipa.v12i9.15745](https://doi.org/10.29303/jppipa.v12i9.15745)

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Abstract: This study aims to analyze the influence of GeoGebra-assisted Project Based Learning (PjBL) model on the ability of junior high school students to understand mathematical concepts and mathematical reasoning. This study uses a quantitative approach with a quasi-experimental method and a pretest-posttest nonequivalent control group design. The research population is all grade VIII students of SMP Negeri 47 Batam for the 2025/2026 academic year which totals 357 students. The research sample was selected using purposive sampling techniques, namely class VIII.5 as the experimental group and class VIII.4 as the control group, each totaling 40 students. The research instruments are in the form of a mathematical concept understanding test and a mathematical reasoning test in the form of a description that has met valid and reliable criteria. Data analysis was carried out using normality tests, homogeneity tests, and Independent Samples t-tests with the help of SPSS 25. The results showed that there was a significant difference between the ability to understand mathematical concepts of students in the experimental group and the control group with a significance value of $0.000 < 0.05$. The same results were also found in mathematical reasoning ability with a significance value of $0.000 < 0.05$. In addition, the percentage of achievement of mathematical concept comprehension skills is 86.07% and mathematical reasoning skills are 86.52%, which are included in the very good category. Thus, the GeoGebra-assisted PjBL model has proven to be effective in improving the conceptual understanding and mathematical reasoning skills of junior high school students.

Keywords: GeoGebra; Junior high school; Mathematical reasoning; Project based learning; Understanding of mathematical concepts

Introduction

Improving the quality of education is one of the important factors in the development of human resources that are able to face the challenges of the 21st century. Quality education not only plays a role in improving individual competence, but also becomes the main foundation in nation building through strengthening students' critical thinking, problem-solving, and numeracy literacy skills (Indarta et al., 2022; Yanto et al., 2021). In the context of formal education, mathematics is one of the subjects that has a strategic

role because it supports the development of science, technology, and various activities of daily life.

Mathematics has different characteristics compared to other disciplines because the object of study is abstract, structured, hierarchical, and arranged based on a deductive mindset (Meliyanti et al., 2018; Schoenfeld, 2016). These characteristics require students to have a strong understanding of concepts as a basis for building more complex mathematical knowledge (Gusteti & Neviyarni, 2022; Masitoh & Prabawanto, 2016). Understanding mathematical concepts is the ability of students to recognize, connect, and apply mathematical concepts to various situations and problems. This ability

How to Cite:

Fitria, Y., Darmansyah, D., Zen, Z., & Rayendra, R. (2026). Effectiveness of the GeoGebra Media-Assisted Project Based Learning Model on the Understanding of Concepts and Mathematical Reasoning of Students. *Jurnal Penelitian Pendidikan IPA*, 12(9), 301-309. <https://doi.org/10.29303/jppipa.v12i9.15745>

is an important foundation in the mathematics learning process because it allows students to understand the meaning behind the symbols, procedures, and algorithms used (Afridiani et al., 2020; Komariyah et al., 2018). In addition to understanding concepts, mathematical reasoning skills are also essential competencies that students must have. Mathematical reasoning allows students to formulate logical arguments, draw conclusions, make generalizations, and solve problems systematically based on the facts and concepts they have learned (Fauziyah & Sujarwo, 2022; Kotto et al., 2022).

However, various research results show that students' ability to understand concepts and mathematical reasoning is still in the low category. This condition is reflected in the results of the Programme for International Student Assessment (PISA) in 2022 which shows that Indonesia obtained a mathematics score of 366, far below the average of OEC member countries (Salsabilla et al., 2023; Tsani, 2022). These results indicate that most students still have difficulty in understanding mathematical concepts and applying them in solving contextual problems that require high-level thinking skills. Similar problems were also found at SMP Negeri 47 Batam. The results of initial observations show that students still have difficulties in understanding the concept of flat building, especially in distinguishing the concept of wide and circumference and applying the concept in daily life problems. In addition, students also show difficulties in identifying the properties of flat buildings and explaining the logical reasons for the settlement procedures used. The findings were strengthened by the results of the summative assessment of mathematics of grade VIII students which showed that the level of learning achievement was still relatively low. Class VIII.5 is the class with the lowest achievement rate, which is 35% with an average score of 60. This condition indicates that students' understanding of concepts and mathematical reasoning skills have not developed optimally, so it requires improvement efforts in the learning process.

Based on the results of observations and interviews with mathematics teachers, this low ability is suspected to be caused by the learning process that is still centered on teachers. Although it has utilized technology-based presentation media such as PowerPoint, its use is still one-way so that it has not been able to facilitate students to explore mathematical concepts actively and independently. In fact, effective mathematics learning requires the active involvement of students in building knowledge through a meaningful process of investigation, exploration, and problem-solving (Kamsurya & Masnia, 2021; Sakinah et al., 2022). Therefore, learning innovations that are able to create a

more interactive, contextual, and student-centered learning environment are needed.

One of the learning models that has the potential to improve students' understanding of concepts and mathematical reasoning is Project Based Learning (PjBL). This model places students as the main subjects in the learning process through investigation activities and project completion related to real problems (Mulyawati et al., 2018; Suranti et al., 2017). Through these activities, students have the opportunity to develop critical thinking skills, work together, communicate ideas, and construct knowledge independently. Previous research has shown that the application of PjBL has a positive influence on improving students' understanding of concepts and higher-level thinking skills (Béres & Kis, 2018; Puspitasari et al., 2020). In addition, collaborative and reflective activities contained in the PjBL stage can help students develop mathematical reasoning skills more optimally (Amelia et al., 2024).

However, the implementation of PjBL in mathematics learning still faces challenges because many mathematical concepts are abstract so that it is difficult for students to understand if they are only presented verbally. Therefore, it is necessary to support learning media that is able to visualize mathematical concepts in a concrete and interactive manner. One of the medias that can be used is GeoGebra. GeoGebra is a dynamic mathematics software that integrates geometry, algebra, statistics, and calculus in one interactive platform that allows students to visualize mathematical objects more clearly (Afifah, 2024; Septianawati et al., 2025). The use of GeoGebra has been proven to improve understanding of mathematical concepts, learning motivation, and student involvement in the learning process because it is able to connect abstract concepts with visual representations that are easy to understand (Fariana et al., 2025; Aisyah et al., 2025).

The integration of the Project Based Learning model with the help of GeoGebra is seen as able to provide a more meaningful learning experience (Santiyani et al., 2026). Through the projects they work on, students not only engage in investigation and problem-solving, but also gain visual support that helps them understand mathematical concepts in depth. Although much research on PjBL and GeoGebra has been conducted, most previous studies have examined the two approaches separately. Research on PjBL generally focuses on improving learning outcomes, creativity, or problem-solving skills, while research on GeoGebra focuses more on visualizing concepts and improving mathematical understanding. In addition, studies that integrate PjBL and GeoGebra to improve conceptual understanding and mathematical reasoning

simultaneously in junior high school students are still relatively limited, especially in geometry materials. Thus, there is still a research gap related to the effectiveness of integrating GeoGebra-assisted Project Based Learning models in developing the two mathematical abilities simultaneously.

Based on the research gap, the novelty of this research lies in the integration of the Project Based Learning (PjBL) model with GeoGebra media as a learning approach designed to improve students' conceptual understanding and mathematical reasoning simultaneously in geometry materials at the junior high school level. Unlike previous studies that tended to test the influence of PjBL or GeoGebra separately, this study combines the advantages of project-based learning with interactive mathematical visualization in one integrated learning design. This study also provides empirical evidence regarding the effectiveness of integrating the two approaches in the context of junior high school mathematics learning so that it is expected to be an innovative learning alternative that is able to answer the problem of low conceptual understanding and mathematical reasoning of students.

Based on this description, the purpose of this study is to analyze the effectiveness of the GeoGebra-assisted Project Based Learning (PjBL) model on the conceptual understanding and mathematical reasoning of junior high school students. The results of the research are expected to make a theoretical and practical contribution to the development of mathematics learning that is more innovative, interactive, and oriented towards improving students' mathematical thinking skills.

Method

This study uses a quantitative approach with a quasi-experimental research method and applies a pretest-posttest nonequivalent control group design. This design involves two research groups, namely the experimental group and the control group, which are given an initial test (pretest) and a final test (posttest) respectively. The experimental group obtained learning using the Project Based Learning (PjBL) model assisted by GeoGebra, while the control group obtained conventional learning with the help of PowerPoint presentation media (PPT).

Table 1. Research design

Groups	Pretest	treatment	Posttest
Experiment	O1	X	O2
Control	O2	-	O4

The research was carried out at SMP Negeri 47 Batam in the 2025/2026 school year. The research population consists of all students in grade VIII which totals 357 students and is spread across nine classes. The

research sample was selected using the purposive sampling technique based on the similarity of the characteristics of students' initial abilities reviewed from the results of the mathematical summative assessment on the prerequisite material. Based on these criteria, class VIII.5 with 40 students was designated as an experimental group, while class VIII.4 with 40 students was designated as a control group.

The research instruments consist of a mathematical concept comprehension test, a mathematical reasoning test, and an observation sheet on learning implementation. The concept understanding and mathematical reasoning test is prepared in the form of description questions based on indicators that refer to the Regulation of the Director General of Higher Education Number 506/C/PP/2004 concerning the Assessment of the Development of Junior High School Students. The concept comprehension test consists of seven questions that measure students' ability to restate concepts, classify objects based on certain properties, provide examples and non-examples, present concepts in various mathematical representations, develop the necessary and sufficient conditions of a concept, choose and use certain procedures or operations, and apply concepts or algorithms in problem solving. Meanwhile, the mathematical reasoning test consists of seven questions that measure students' ability to present mathematical statements, propose conjectures, perform mathematical manipulations, check the validity of an argument, draw conclusions, find patterns or traits to make generalizations, and formulate mathematical proofs.

Before being used in the study, all learning instruments and tools were validated by experts to ensure the conformity of the content with the measured indicators (Sugiyono, 2018). Furthermore, the instrument was tested on 40 grade IX students who had studied the material of building a flat side room. The validity test of the question item was carried out using Pearson's Product Moment correlation (Arikunto, 2013; Riduwan, 2012) with the formula:

$$r_{xy} = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{[N \sum X^2 - (\sum X)^2][N \sum Y^2 - (\sum Y)^2]}} \quad (1)$$

The results of the validity test showed that all question items met the valid criteria with a validity coefficient ranging from 0.57 to 0.81. Furthermore, the reliability of the instrument is calculated using the Cronbach Alpha coefficient to measure the internal consistency of the instrument (Arikunto, 2013; Sugiyono, 2018), with formula:

$$r_{11} = \frac{k}{k-1} \left(1 - \frac{\sum \sigma_i^2}{\sigma_t^2} \right) \quad (2)$$

The results of the reliability test showed a Cronbach Alpha value of 0.81 for the concept understanding test and 0.81 for the mathematical reasoning test, indicating that both instruments have high reliability and are suitable for use in the study.

Data collection was carried out during six meetings which included the preparation, implementation, and end stages of research. In the initial stage, both groups are given a pretest to determine the students' initial ability in conceptual understanding and mathematical reasoning. Furthermore, the experimental group followed the learning using the GeoGebra-assisted PjBL model, while the control group followed the conventional learning with the help of PowerPoint. During the learning process, observations were made on the implementation of the PjBL model and the use of GeoGebra. After all treatments were given, both groups took a posttest to measure the student's final ability.

Data analysis was carried out using the help of SPSS software version 25. Prior to hypothesis testing, the data were first tested using the Shapiro-Wilk normality test and the Levene homogeneity test to ensure the fulfillment of parametric statistical assumptions. If the data is normally distributed and homogeneous, then hypothesis testing is carried out using an Independent Samples t-test at a significance level of 0.05 to compare the posttest results between the experimental group and the control group. In addition, a descriptive analysis in the form of the percentage of achievement of indicators was carried out to illustrate the effectiveness of the GeoGebra-assisted PjBL model on students' ability to understand concepts and mathematical reasoning in more depth.

Result and Discussion

Research Results

The Influence of GeoGebra's Assisted Project Based Learning Model on the Ability to Understand Mathematical Concepts

Descriptive statistics of students' ability to understand mathematical concepts in the experimental group and the control group are presented in Table 2.

Table 2. Descriptive statistics ability to understand mathematical concepts

Groups	Pretest (Mean $\pm$ SD)	Posttest (Mean $\pm$ SD)
Experiment	44.55 $\pm$ 8.75	86.07 $\pm$ 6.46
Control	40.54 $\pm$ 10.34	65.80 $\pm$ 8.71

Based on Table 2, the initial abilities of the two groups were relatively equal. After treatment, the average posttest score of the experimental group increased to 86.07, while the control group reached 65.80. These results show that students who participated in learning using the Project Based Learning (PjBL)

model assisted by GeoGebra had better understanding of mathematical concepts than students who participated in conventional learning with the help of PowerPoint.

Before hypothesis testing is carried out, the data is first tested using normality and homogeneity tests. Table 3 presents the results of the normality and homogeneity test of the data on the ability to understand mathematical concepts.

Table 3. Normality and homogeneity test results

Statistical Test	Significance Value	Remarks
Shapiro-Wilk	> 0.05	Normal distributed data
Levene	0.064	Varian homogeneous

So that the variance of the two groups is declared homogeneous. Therefore, hypothesis testing is performed using Independent Samples t-test assuming the same variance. The results of the t-test showed a value of $t = -11.821$ with a significance value of 0.000 ($p < 0.05$). These findings show that there is a significant difference between the ability to understand mathematical concepts of students in the experimental group and the control group. Thus, the GeoGebra-assisted PjBL model has a positive influence on students' ability to understand mathematical concepts.

The Influence of GeoGebra's Assisted Project Based Learning Model on Mathematical Reasoning Skills

Descriptive statistics of students' mathematical reasoning abilities are presented in Table 4.

Table 4. Descriptive statistics of mathematical reasoning ability

Groups	Pretest (Mean $\pm$ SD)	Posttest (Mean $\pm$ SD)
Experiment	45.71 $\pm$ 9.91	86.52 $\pm$ 5.75
Control	42.50 $\pm$ 6.56	66.52 $\pm$ 9.25

Based on Table 4, the initial mathematical reasoning abilities of the two groups were relatively equal. After treatment, the experimental group obtained an average posttest of 86.52, while the control group obtained an average of 66.52. These results showed a higher increase in mathematical reasoning ability in the experimental group compared to the control group.

The results of the normality test showed that all data was distributed normally. However, the results of the homogeneity test showed a significance value of 0.009 ($p < 0.05$), so the variance of the two groups was not homogeneous. Therefore, the interpretation of the t-test results refers to the Equal Variances Not Assumed line.

The results of the t-test showed a value of $t = -11.618$ with a significance value of 0.000 ($p < 0.05$). These findings show that there is a significant difference between students' mathematical reasoning abilities in

the experimental group and the control group. Thus, the GeoGebra-assisted PjBL model has a positive influence on students' mathematical reasoning skills.

The Effectiveness of GeoGebra-Assisted Project Based Learning Model

The effectiveness of the GeoGebra-assisted PjBL model was analyzed based on the increase in the average score and percentage of achievement in the experimental group as presented in Table 5.

Table 5. The effectiveness of GeoGebra-assisted PjBL model

Variable	Pretest	Posttest	Improvement	Percentage of Achievement (%)
Understanding of mathematical concepts	45.71 ± 9.91	86.52 ± 5.75	41.52	86.07
Mathematical reasoning	42.50 ± 6.56	66.52 ± 9.25	40.81	86.52

Based on Table 5, the ability to understand mathematical concepts increased by 41.52 points, while the ability to mathematical reasoning increased by 40.81 points. The achievement percentage of the two variables is in the very good category, which is 86.07% and 86.52%, respectively. These results show that GeoGebra's Project Based Learning model is effective in improving students' concept understanding and mathematical reasoning skills.

Discussion

PjBL Assisted by GeoGebra and Mathematical Concept Understanding Ability

The results showed that the ability to understand mathematical concepts of students who participated in learning using the GeoGebra-assisted PjBL model was higher than that of students who participated in conventional PowerPoint-assisted learning. These findings show that students' active involvement in the project-based learning process can help students build a deeper understanding of concepts than teacher-centered learning.

In the perspective of constructivism, knowledge is actively built by students through interaction with the learning environment. The PjBL model provides students with the opportunity to identify problems, design projects, gather information, and evaluate their own work. Through this process, students not only memorize concepts, but also understand the relationships between concepts and their application in various situations. This condition is in line with the theory of constructivism put forward by Piaget and Vygotsky that learning that involves exploratory and collaborative activities allows students to build more meaningful understandings (Piaget, 1952).

The use of GeoGebra further strengthens the process of forming an understanding of these concepts. GeoGebra allows students to visualize geometric objects dynamically so that abstract concepts become more concrete and easier to understand. In the flat-sided space building material, students can observe the relationship between the meshes, surface area, and volume through interactive visual representations. The visualization

helps students build more accurate mental representations and strengthens their conceptual understanding.

The findings of this study are in line with the results of the study by Widyaningrum (2016) which shows that the application of Project Based Learning is able to improve students' understanding of mathematical concepts because it provides opportunities for students to construct knowledge through contextual project completion. Research conducted by Rahayuningsih et al. (2022) also reported that students who learned using the PjBL model obtained higher concept comprehension scores than students who learned using conventional learning.

In addition, the results of this study are supported by the findings of the Mariana et al. (2025) which states that the use of GeoGebra can improve the understanding of geometric concepts through dynamic visualization and self-exploration. Toyib et al. (2026) also explained that GeoGebra helps students connect visual and symbolic representations so that mathematical concepts become easier to understand. Thus, the improvement in the ability to understand mathematical concepts in this study is suspected to occur due to a combination of project activities that demand knowledge construction and interactive visualization support provided by GeoGebra.

The results of this study reinforce previous findings by showing that the integration of PjBL and GeoGebra not only increases student involvement in learning, but also has a significant impact on the ability to understand mathematical concepts in flat side space building materials at the junior high school level.

PjBL Assisted by GeoGebra and Mathematical Reasoning Skills

The results of the study also showed that the mathematical reasoning ability of students who participated in learning using the GeoGebra-assisted PjBL model was higher than that of students who learned through conventional learning. These findings indicate that project-based learning supported by mathematical visualization is able to create a learning

environment that encourages students to think logically, critically, and systematically.

Mathematical reasoning skills develop when students are given the opportunity to make conjectures, analyze information, test the correctness of arguments, and draw conclusions based on available evidence. These activities are facilitated directly in each stage of PjBL. During the project work, students are required to discuss ideas, verify completion procedures, and provide logical reasons for the solutions obtained. Thus, the learning process focuses not only on the end result, but also on the underlying thought process of problem solving.

These findings are in line with Yulianto et al. (2024) which states that Project Based Learning is able to develop high-level thinking skills because students are actively involved in the process of investigation, problem-solving, and decision-making. Research conducted by Abidin et al. (2020) also showed that students who learned using the PjBL model had better mathematical reasoning skills than students who followed conventional learning.

GeoGebra plays an important role in supporting this reasoning process. Through the dynamic visualization feature, students can observe patterns, verify conjectures, and test the relationships between the elements of building spaces more easily. The visualization provided by GeoGebra helps students connect concrete representations with abstract concepts so that the reasoning process becomes more systematic and directed. In addition, the use of GeoGebra allows students to explore independently and obtain direct feedback on the results obtained.

The results of this study are supported by the findings of the Triani et al. (2026) who reported that the use of GeoGebra had a positive influence on students' mathematical reasoning abilities because it helped students explore concepts and find mathematical relationships independently. Other research by Triani et al. (2026) also showed that GeoGebra-assisted learning was able to significantly improve students' critical thinking and mathematical reasoning skills compared to regular learning.

The integration of PjBL and GeoGebra provides a more comprehensive learning experience as students are not only involved in the completion of projects, but also gain technological support that simplifies the process of exploration, verification, and mathematical proof. This condition allows students to develop reasoning skills through investigative activities supported by accurate and interactive visual representations.

Overall, the results show that the integration of Project Based Learning and GeoGebra is able to create more active, meaningful, and effective mathematics learning. These findings also support the results of a

meta-analysis conducted by Ubm et al. (2024) which concluded that the use of dynamic mathematical technology combined with active learning models had a positive impact on students' learning outcomes and mathematical thinking skills. Therefore, the GeoGebra-assisted PjBL model can be recommended as one of the innovative learning alternatives to improve the conceptual understanding and mathematical reasoning skills of junior high school students.

PjBL Assisted by GeoGebra and Comprehension Skills

The results showed that the ability to understand mathematical concepts of students who participated in learning using the GeoGebra-assisted PjBL model was higher than that of students who participated in conventional PowerPoint-assisted learning. These findings show that students' active involvement in the project-based learning process can help students build a deeper understanding of concepts than teacher-centered learning.

In the perspective of constructivism, knowledge is actively built by students through interaction with the learning environment. The PjBL model provides students with the opportunity to identify problems, design projects, gather information, and evaluate their own work. Through this process, students not only memorize concepts, but also understand the relationships between concepts and their application in various situations. This condition is in line with the view that a meaningful understanding of concepts is formed when students are actively involved in the process of knowledge construction.

The use of GeoGebra further strengthens the process of forming an understanding of these concepts. GeoGebra allows students to visualize geometric objects dynamically so that abstract concepts become more concrete and easier to understand. In the flat-sided space building material, students can observe the relationship between the meshes, surface area, and volume through interactive visual representations. The visualization helps students build more accurate mental representations and strengthens their conceptual understanding.

The findings of this study support previous studies that showed that Project Based Learning is able to improve concept understanding through authentic investigative activities, while GeoGebra helps students understand mathematical concepts through interactive visualization. The results of this study expand on previous findings by showing that the integration of PjBL and GeoGebra has a stronger impact on improving understanding of mathematical concepts than using one of the approaches separately.

PjBL Assisted by GeoGebra and Mathematical Reasoning Skills

The results of the study also showed that the mathematical reasoning ability of students who participated in learning using the GeoGebra-assisted PjBL model was higher than that of students who learned through conventional learning. These findings indicate that project-based learning supported by mathematical visualization is able to create a learning environment that encourages students to think logically, critically, and systematically.

Mathematical reasoning skills develop when students are given the opportunity to make conjectures, analyze information, test the correctness of arguments, and draw conclusions based on available evidence. These activities are facilitated directly in each stage of PjBL. During the project work, students are required to discuss ideas, verify completion procedures, and provide logical reasons for the solutions obtained. Thus, the learning process focuses not only on the end result, but also on the underlying thought process of problem solving.

GeoGebra plays an important role in supporting this reasoning process. Through the dynamic visualization feature, students can observe patterns, verify conjectures, and test the relationships between the elements of building spaces more easily. The visualization provided by GeoGebra helps students connect concrete representations with abstract concepts so that the reasoning process becomes more systematic and directed. In addition, the use of GeoGebra allows students to explore independently and obtain direct feedback on the results obtained.

The results of this study are in line with various studies that show that PjBL is able to improve students' high-level thinking and mathematical reasoning skills. Similarly, previous research has reported that GeoGebra can increase students' engagement in math learning and help them develop mathematical thinking skills. The integration of the two approaches provides a more comprehensive learning experience as students are not only involved in the completion of projects, but also gain technological support that facilitates the process of exploration and mathematical proof.

Overall, the results show that the integration of Project Based Learning and GeoGebra is able to create more active, meaningful, and effective mathematics learning. The advantage of this approach lies in its ability to combine student-centered learning activities with the support of interactive mathematical visualizations. Therefore, the GeoGebra-assisted PjBL model can be recommended as one of the innovative learning alternatives to improve the conceptual understanding and mathematical reasoning skills of junior high school students.

Conclusion

Based on the results of the research and discussion, it can be concluded that the Project Based Learning (PjBL) model assisted by GeoGebra has a positive and significant influence on the ability to understand mathematical concepts and mathematical reasoning of junior high school students. The results showed that students who participated in learning using the GeoGebra-assisted PjBL model obtained higher ability to understand mathematical concepts and mathematical reasoning than students who participated in conventional learning with the help of PowerPoint. In addition, the GeoGebra-assisted PjBL model proved effective in improving both abilities, which was shown by the percentage of achievement of mathematical concept comprehension skills of 86.07% and mathematical reasoning skills of 86.52% with the excellent category. These findings show that the integration of project-based learning with the help of interactive mathematical visualization through GeoGebra is able to create more active, meaningful, and student-centered learning, so it can be recommended as one of the innovative mathematics learning alternatives to improve students' concept understanding and mathematical reasoning skills, especially in geometry materials at the junior high school level.

Acknowledgments

The author would like to express his deepest gratitude to Prof. Dr. Darmansyah, S.T., M.Pd., Prof. Dr. Zelhendri Zen, M.Pd., and Dr. Rayendra, M.Pd., for their invaluable guidance, constructive suggestions, and continuous support during the research and writing process of this article. The expertise, direction, and motivation provided have contributed significantly to the successful completion of this research.

Author Contributions

Conceptualization, Y.F. and D.; methodology, software, formal analysis, investigation, resources, data curation, writing original draft preparation, Y.F.; validation, writing—review and editing, D., Z.Z., and R. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

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