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The Effect of Geogebra-Assisted Problem-Based Learning and Motivation on Mathematics Learning Outcomes of SMA Hang Tuah 5 Sidoarjo Students

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A B S T R A C T

The development of digital technology encourages the application of innovative learning models to improve students' mathematics learning outcomes. This study aims to analyze the influence of GeoGebra-assisted Problem-Based Learning (PBLGG), learning motivation, and the interaction of the two on students' mathematics learning outcomes. The study used a quantitative approach with quasi-experimental methods and a non-equivalent control group pretest-posttest design. The research sample consisted of 72 students of Phase E of SMA Hang Tuah 5 Sidoarjo which were divided into experimental classes and control classes. Data was collected through mathematics learning outcome tests and learning motivation questionnaires, then analyzed using the Independent Sample t-test and two-way ANAVA (Two-Way ANOVA). The results showed that there was a difference in mathematics learning outcomes between students who took part in PBLGG and students who participated in Problem-Based Learning (PBL) without the help of GeoGebra. Learning motivation also affects mathematics learning outcomes. There is an interaction between learning model and learning motivation on students' mathematics learning outcomes. These findings show that the integration of PBL, GeoGebra, and learning motivation is an effective learning strategy to improve mathematics learning outcomes and support more active, meaningful, and student-centered learning.

1. Introduction

The development of technology in the era of the industrial revolution 4.0 is characterized by the integration of the Internet of Things (IoT), artificial intelligence, and automation in various aspects of human life. This transformation also affects the world of education which requires a change in the learning paradigm to be in line with the needs of the 21st century. In response to these conditions, the

Ministry of Education, Culture, Research, and Technology implements the Independent Curriculum with a deep learning approach that emphasizes the use of digital technology and meaningful and in-depth learning (Subagyo et al., 2024; Fathimah & Surya, 2026). The curriculum requires students not only to master knowledge procedurally, but also to develop high-level thinking skills (HOTS), creativity, and problem-solving abilities related to real-world situations (Gradini, 2019; Aini & Hikmawan, 2026). Learning innovation is an important need in the educational process, including in mathematics learning at the high school level. Deep learning emphasizes that students not only master the completion procedure but also be able to understand concepts in their entirety, connect between concepts, and apply them in various contextual situations (Husen et al., 2026).

Mathematics learning in high school is no longer oriented towards mastering calculation procedures alone, but on a deep understanding of concepts and the ability to apply these concepts in solving contextual problems. However, conventional learning approaches that are still teacher-centered often cause students to have difficulty in connecting abstract mathematical concepts with real situations (Agustina, 2024). One of the approaches that can bridge these problems is PBL, which is a learning model that places real problems as the starting point of the learning process to encourage students to think critically and be active in finding solutions (Nisa et al., 2022). In addition to the application of the right learning model, the integration of learning technology is also an important factor in helping students understand abstract mathematical concepts. One of the technologies widely used in mathematics learning is GeoGebra, which is dynamic mathematics software that integrates geometry and algebra concepts in the form of interactive visualization. GeoGebra allows students to explore mathematical concepts in a more concrete way through visual representations so that it can help bridge the gap between mathematical abstraction and students' conceptual understanding (Tristanti et al., 2025). The use of GeoGebra in problem-based learning has the potential to enrich students' learning experiences, especially in materials that require graphical visualization and mathematical modeling. The findings strengthen GeoGebra not only to improve students' cognitive aspects but also help visualize abstract mathematical concepts so that they are easier to understand (Tristanti et al., 2025).

One of the mathematics materials that often causes difficulties for high school students is the Two-Variable Linear Inequality System (SPtDLV). This material requires students' ability to identify variables, model contextual problems into the form of inequalities, describe graphs, and determine the area of the solution set (DHP). The completion process that is done manually often leads to errors in drawing lines and determining shade areas so that students' conceptual understanding becomes less than optimal (Utami et al., 2022). This condition can have an impact on students' low mathematics learning outcomes, especially when they are faced with story problems that require mathematical modeling skills. Improving mathematics learning outcomes requires a learning strategy that can help students understand concepts in depth through the presentation of material that is contextual, visual, and in accordance with the characteristics of students (Ningsih & Mawardi, 2024). The use of technology-based media in mathematics learning has also been proven to be able to improve students' mathematical representation skills because it provides an opportunity to connect various forms of representation, such as visual, symbolic, and verbal, in a more meaningful way (Sari et al., 2026). The integration of technology in the learning process has been proven to be able to improve the quality of learning through the provision of teaching materials that are more flexible, interactive, and student-centered (Kristanto et al., 2017). The findings support the use of digital media such as GeoGebra in the Problem-Based Learning model to create more effective learning.

In addition to the learning model factor and the use of technology, the psychological factor of students also plays an important role in the success of mathematics learning. Learning motivation is one of the internal factors that can affect student involvement in the learning process and success in achieving optimal learning outcomes. Students with high motivation to learn tend to be more active, diligent, and have a strong desire to solve the problems given. On the other hand, low motivation to learn often causes students to be passive and give up easily in the face of difficulties in learning mathematics (Sutama et al., 2025). This condition is also strengthened if learning is still dominated by a teacher-centered approach so that students' opportunities to explore and build understanding of concepts are limited (Sutama et al., 2025). Several previous studies have shown that the application of a problem-based learning model combined with GeoGebra technology can improve the quality of mathematics learning. Research at SMA Negeri 1 Mengwi shows that the PBL model assisted by GeoGebra can increase students' learning motivation and mathematics learning outcomes (Juwana et al., 2025). Other research has also shown that the use of GeoGebra in mathematics learning can improve students' learning motivation and mathematical communication skills (Perawansa, 2019). The findings show that the combination of a student-centered learning model and the use of digital technology has great potential in improving the quality of mathematics learning.

Research on spatial ability in three-dimensional materials found that there was no significant relationship between learning models and students' learning motivation (Handayani et al., 2020). The use of PBLGG does not show a significant difference compared to conventional learning in improving spatial skills. The difference in findings shows that the effectiveness of the application of learning and technology models is likely influenced by other factors, including students' psychological characteristics such as learning motivation. The difference in the results of the study shows that the effectiveness of the implementation of PBLGG still requires further study, especially on the materials, student characteristics, and different learning outcomes. The need for research that can provide empirical evidence regarding the influence of learning models, the use of technology, and learning motivation on mathematics learning outcomes (Handayani et al., 2020). Ash Shiddiqi et al. (2023) stated that the development of a systematically designed learning model can improve the quality of learning through more active, creative, and innovative learning activities. Wasesa et al. (2022) explained that the use of digital technology through training can improve students' competence in facing the demands of technology-based learning and the world of work.

Based on these problems, research is needed that examines more comprehensively the influence of the PBLGG model by considering the motivation factors of students to learn mathematics learning outcomes. This research offers a learning approach that integrates PBL, the use of GeoGebra as a visualization medium, and student learning motivation in one learning framework. This approach is expected to be able to provide empirical evidence on the effectiveness of integrating learning models, digital technology, and students' psychological factors in improving mathematics learning outcomes. This study aims to: 1) Examine the difference in mathematics learning outcomes between students who take part in PBLGG learning and students who participate in PBL learning without the help of GeoGebra; 2) Testing the difference in mathematics learning outcomes between students who have high and low learning motivation in PBLGG learning; and 3) To find out the interaction between PBLGG learning and learning motivation on the mathematics learning outcomes of Hang Tuah 5 Sidoarjo High School students. The combination of PBL models, the use of GeoGebra, and student learning motivation is expected to contribute to improving mathematics learning outcomes.

2. Methodology

This study uses a quantitative approach with a quasi-experimental method. The quantitative approach is used because the research focuses on objectively measuring phenomena using numerical data (Sugiyono, 2017). The quasi-experimental method was chosen because the researcher did not randomize the subjects completely but used a pre-formed group (intact group) (Abraham & Supriyati, 2022). This study aims to examine the cause and effect between learning models and learning motivation on students' mathematics learning outcomes in real learning conditions. This design allowed researchers to systematically compare the effects of treatment on experimental and control groups without disrupting the learning process that was already taking place in the school. The use of quasi-experimental provides a more realistic picture of the effectiveness of the learning model in real learning situations so that the research results have high relevance to be applied in the educational environment.

The research design used was a non-equivalent control group pretest-posttest design. This design involves 2 (two) groups, namely the experimental group and the control group. The experimental group was given treatment using the PBLGG model, while the control group was taught using the Problem-Based Learning (PBL) model without the assistance of GeoGebra. Before treatment, both groups were given a pretest to find out the student's initial ability. After the learning process was completed, both groups were given a posttest to measure students' mathematics learning outcomes after treatment. The research was carried out at SMA Hang Tuah 5 Sidoarjo which is located at Jalan M. Ridwan No. 7 Candi Sayang, Sidoarjo in the even semester of the 2025/2026 school year. The research population was Phase E students who participated in mathematics learning at the school. The research sample consisted of two classes selected based on the classes that had been set by the school. Each class has 36 students, so the total research sample is 72 students. Class E7 was designated as an experimental class that obtained PBLGG learning, while class E8 as a control class obtained PBL learning without the help of GeoGebra.

The research instruments used include: 1) Mathematics learning outcome tests are used to measure students' cognitive abilities before and after learning treatment. The test is in the form of a multiple-choice of 20 questions that include SPtLDV material according to learning outcomes in Phase E. Questions are prepared based on indicators of cognitive ability ranging from C2 to C4 that understand concepts, analyze, and solve contextual problems. Before being used in research, the test instrument has gone through empirical validity, reliability, difficulty, and differentiating power so that it is feasible to use as a research instrument.; 2) Student learning motivation questionnaire measured using the Likert Scale consisting of 20 statements. The questionnaire was systematically prepared to measure students' attitudes and perceptions of mathematics learning (Kurniawan, 2021). The Likert scale is used to measure an individual's attitudes, opinions, and perceptions of a social phenomenon through several statements (Sugiyono, 2017). Each statement has 5 (five) answers, namely strongly disagree, disagree, hesitate, agree, and strongly agree (Mawardi, 2019). Scores are given on each answer choice ranging from 1 to 5 so that the data obtained can be analyzed quantitatively (Riyanto & Hatmawan, 2020). The use of the Likert scale allows qualitative attitude data to be converted into quantitative data for the purposes of statistical analysis (Herlina, 2019); and 3) Documentation is used as a complementary technique to obtain research supporting data. The data collected through the documentation includes data on the number of students, a list of grades, and documentation of learning activities during the research.

Data collection is carried out through several stages: 1) Pretest, given to students in the experimental group and control group before the implementation of learning to find out the students' initial ability in SPtLDV material; 2) Treatment delivery, the experimental group followed learning using the PBLGG model, while the control group followed learning using PBL without the help of GeoGebra. The learning process is carried out in accordance with the steps of the PBL model which includes orientation to problems, student organization, independent or group investigation, development and presentation of results, and evaluation of the problem-solving process; 3) Posttest, students in both groups were given a posttest using the same test instrument to find out the results of mathematics learning after treatment; 4) Filling out a learning motivation questionnaire, given to students to find out the level of motivation to learn mathematics possessed by students during the learning process; and 5) Documentation, carried out during the research process to obtain supporting data related to the implementation of learning and the conditions of the research subjects.

Data analysis was carried out quantitatively using inferential statistics with the help of SPSS software version 26. Data analysis includes several stages: 1) Prerequisite tests are carried out before the main analysis to ensure the data meets statistical assumptions, including normality tests are used to find out whether the data is normally distributed or not. The test was conducted using Kolmogorov-Smirnov or Shapiro-Wilk with a significance level of 0.05. The data is declared to be normally distributed if the significance value (Sig.) > 0.05. Meanwhile, the homogeneity test was used to determine the similarity of variance between groups using the Levene test. The data is declared homogeneous if the significance value is greater than 0.05; 2) If necessary, an Independent Sample t-test is carried out to determine the difference in average learning outcomes between the experimental group and the control group before the main analysis is carried out; 3) The main analysis using two-way ANOVA with hypothesis testing was carried out with a significance level of $\alpha = 0.05$. If the significance value is less than 0.05 then the null hypothesis is rejected and the alternative hypothesis is accepted; and 4) If the ANOVA results show a significant difference, then further tests will be carried out to find out the differences between groups more specifically.

3. Results and Discussion

Implementation of Problem-Based Learning Assisted by GeoGebra

In this study, learning in the experimental class was carried out using the GeoGebra-assisted Problem-Based Learning model during several meetings on the Two-Variable Linear Inequality System (SPtLDV) material. The implementation of learning refers to the Problem-Based Learning syntax combined with the use of GeoGebra at each stage of learning. The stages of implementing GeoGebra-assisted Problem-Based Learning during the learning process can be seen in Figure 1.

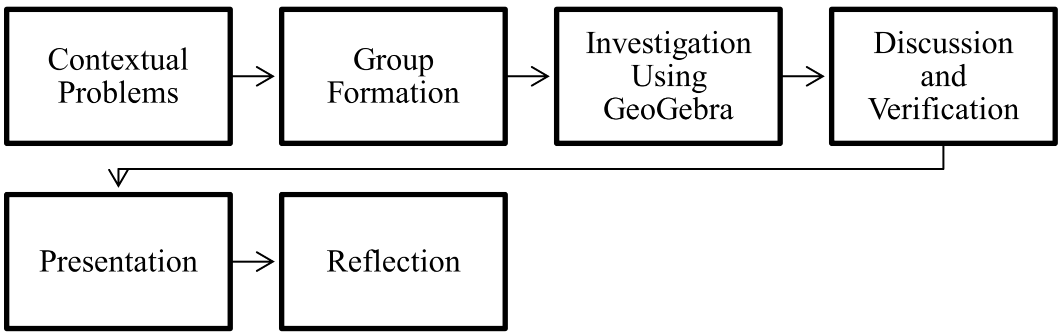

Figure 1. Stages of PBL Assisted by GeoGebra

Based on Figure 1, GeoGebra is integrated mainly at the investigation stage, which is when students visualize the graph of inequality, determine the area of the set of solutions, test their conjectures, and verify the results of the solution before presenting it to other groups. The first stage is problem-orientation. The teacher presents contextual problems related to the determination of the two-variable linear inequality system feasible region so that students are encouraged to identify known information, required information, and possible solution strategies to use. The second stage is to organize students into study groups consisting of 4–5 students. Each group discusses the problem, divides tasks, and formulates initial conjectures for the solution to be obtained. The third stage is the investigation stage. At this stage, students use GeoGebra to draw each boundary line, determine the feasible region, observe the cutoff points between the lines, and re-test the proposed solution that has been obtained manually. The teacher plays the role of a facilitator by providing guidance if the group experiences difficulties. The fourth stage is the development and presentation of results. Each group presented the problem-solving strategy used, showed the results of the visualization using GeoGebra, then the other group gave feedback and had a discussion. The last stage is analysis and reflection. The teacher and the students evaluate the problem-solving process, compare the results of the manual with the results of the GeoGebra visualization, and conclude the mathematical concepts learned.

The implementation of GeoGebra-assisted Problem-Based Learning models is supported by contextual problem delivery designed to encourage students to identify information, construct mathematical models, explore alternative solutions, and verify answers through dynamic visualization using GeoGebra. The problems given are adjusted to the learning objectives in the Two-Variable Linear Inequality System (SPtLDV) material and are taken from a context that is close to the students' daily lives. Two examples of problems used during the learning process are presented as follows: 1) The bazaar committee will make two types of products, namely stickers (x) and pins (y). Each sticker requires a production time of 2 minutes, while each pin requires a production time of 3 minutes. The total available production time is 600 minutes and the number of goods that must be produced is at least 100 pieces. Based on this information, compile a mathematical model in the form of a Two-Variable Linear Inequality System (SPtLDV), then visualize the area of the set of solutions using GeoGebra and determine a set of solutions that meet all constraints; and 2) A culinary business produces two types of menus, namely Menu A and Menu B. Making Menu A takes 40 minutes using the stove and 20 minutes using the oven. Meanwhile, Menu B takes 25 minutes using the stove and 15 minutes using the oven. The time of use of the stove and oven is each limited to a maximum of 120 minutes every day. Construct a mathematical model in the form of a Two-Variable Linear Inequality System (SPtLDV), then use GeoGebra to visualize the area of the set of solutions and analyze alternative production combinations that meet all constraints. An example of the use of GeoGebra in solving one of the contextual problems given to students is presented in Figure 2.

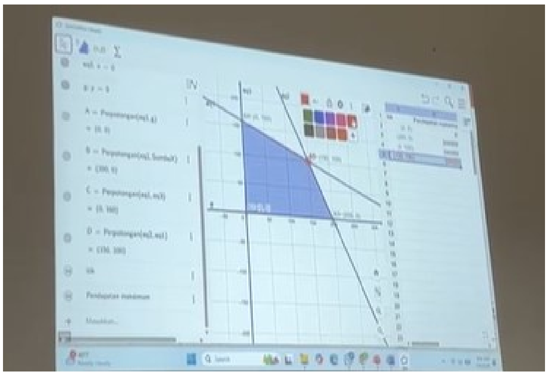

Figure 2. Visualization of SPtLDV Solution Using GeoGebra

In the investigation phase, students use the Input Bar feature to enter a linear inequality system, Graphics View to display graphs and settlement procedureareas, and Intersection Tool to determine point of intersection coordinates. Through this visualization, students can compare the results of manual completion with the results obtained using GeoGebra so that the concept verification process takes place more accurately, as shown in Figure 3.

Figure 3. Students Conducting Problem Solving Using GeoGebra

The relationship between the stages of Problem-Based Learning, student activities, and the use of GeoGebra features during the learning process is presented in Table 1.

Table 1. Student Activities and the Utilization of GeoGebra Feature at Each Stage of Problem-Based Learning

PBL Stages	Student Activities	GeoGebra Features
Problem Orientation	Identifying known and unknown information	–
Group Organization	Discussing problem-solving strategies	–
Investigation	Constructing inequality graphs	Input Bar
Exploration	Observing the feasible region	Graphics View
Verification	Identifying intersection points and verifying solutions	Intersection Tool
Presentation	Presenting problem-solving results	Graphics View
Reflection	Comparing manual and GeoGebra solutions	Graphics View

Table 1 shows that GeoGebra is not only used as a medium for drawing graphs but is also used by students at the exploration and verification stages to analyze the relationships between variables, test conjectures, and ensure the accuracy of the solutions obtained. The integration supports each stage of Problem-Based Learning so that the learning process becomes more active, collaborative, and student-centered.

The Influence of PBLGG on Mathematics Learning Outcomes

The average mathematics learning outcome of students who participated in PBLGG learning was 93.92, higher than the PBL group which obtained an average of 85.00. The average difference of 8.917 shows a tendency to integrate GeoGebra into the PBL model to be able to provide better learning outcomes. The relatively small standard deviation in both groups shows that the distribution of student scores is quite homogeneous so that the learning outcomes obtained are relatively consistent in each of the groups, as in Table 2.

Table 2. Descriptive Statistics of Learning Outcomes Based on Learning Models

Learning Model	N	Mean	Std. Deviation
PBLGG	36	93,92	1,842
PBL	36	85,00	2,151

The results of hypothesis testing using the Independent Sample t-test showed a significance value of 0.000 (<0.05). The first hypothesis is accepted, which means that there is a significant difference in mathematics learning outcomes between students who take PBLGG learning and students who take PBL without the help of GeoGebra. These findings show that the use of GeoGebra as a supporting media makes a positive contribution to improving students' mathematics learning outcomes, as shown in Table 3.

Table 3. Independent Sample T-Test Results

Variable	t	df	Sig. (2-tailed)	Mean Difference
Learning Outcomes	18,890	70	0,000	8,917

These findings indicate that the success of learning is not only influenced by the application of the PBL model but also using digital media that is able to visualize mathematical concepts in a more concrete way. In the SPtLDV material, students are not only required to understand the settlement procedure but also determine the area of the settlement procedure through graphical representation. The visualization allows students to explore independently and collaboratively, so that the learning process becomes more meaningful than learning that only relies on manual completion.

Pedagogically, the results of this research are in line with the theory of constructivism which states that knowledge is actively built through learning experience and interaction with the learning environment (Dewi & Fauziati, 2021). In the PBL model, students are faced with contextual problems that must be solved through discussion, investigation, and reflection. When the process is combined with GeoGebra, students gain the opportunity to test various alternative solutions directly through interactive visualization. The process of forming concepts does not only take place through the teacher's explanation, but also through exploration activities carried out by the students themselves in the learning process. In addition to strengthening conceptual understanding, the use of GeoGebra also increases student engagement during the learning process. When solving SPtLDV problems, students can verify the results of their work directly using graphical representations on GeoGebra. The feedback process obtained quickly helps students find mistakes, improve solving strategies, and increase confidence in solving math problems. This condition makes learning more active, interactive, and student-centered, in accordance with the learning characteristics in the Independent Curriculum that emphasizes deep learning.

The results of this study reinforce the findings Juwana et al. (2025) which states that the application of PBL can improve mathematics learning outcomes through problem-solving activities that encourage students to think critically and actively build knowledge. These findings are also supported by Gurmu et al. (2024) which reports GeoGebra provides dynamic mathematical visualization that helps students understand concepts more deeply. Perawansa (2019) explained that the use of GeoGebra not only improves learning outcomes but also improves students' learning motivation and mathematical communication skills because it is easier for students to connect visual representations with the mathematical concepts, they are learning to support deep learning.

The effectiveness of PBLGG does not solely come from the use of digital technology, but from the synergy between the problem-based learning approach and GeoGebra's ability to visualize mathematical concepts interactively. These findings are in line with the results of studies that show that problem-based learning combined with technological media, including GeoGebra, can improve mathematical representation skills through more meaningful exploration, visualization, and problem-solving processes (Sari et al., 2026). The integration of the two provides a more meaningful learning experience, increases student involvement in the learning process, and results in higher mathematics learning outcomes than the implementation of PBL without the help of GeoGebra. The use of technology-based learning media, such as Android-based e-modules, has been proven to increase students' interest in learning and support the effectiveness of the learning process (Mahardika et al., 2021).

The combination of Problem-Based Learning and GeoGebra works in a complementary way. The PBL model encourages students to actively identify problems, develop solution strategies, discuss, and reflect on the results obtained. GeoGebra provides dynamic visualizations that help students connect algebraic representations with direct graph representations. When students find an alleged solution through a group discussion, GeoGebra is used to verify the accuracy of the guess so that the concept formation process takes place through a more meaningful learning experience. The integration of these two components causes students not only to obtain final answers, but also to understand the relationships between mathematical concepts through simultaneous exploration, visualization, and verification. The improvement in learning outcomes does not only come from the use of technology alone, but also from the synergy between problem solving activities in PBL and the visualization capabilities provided by GeoGebra.

The Effect of Learning Motivation on Mathematics Learning Outcomes

Students who have high learning motivation get an average mathematics learning result of 89.85, while students with low learning motivation get an average of 88.94. The average difference between the two groups is relatively small, as shown in Table 4.

Table 4. Descriptive Statistics of Learning Outcomes Based on Learning Motivation

Learning Motivation	N	Mean	Std. Deviation
Low	31	88,94	4,781
High	41	89,85	5,028
Total	72	89,46	4,910

However, the results of statistical testing showed a significance value of 0.044 (<0.05). The second hypothesis is accepted, which shows that there is a difference in mathematics learning outcomes between students who have high learning motivation and students who have low learning motivation, as shown in Table 5.

Table 5. Independent Sample T-Test Test Results Based on Learning Motivation

Variable	t	df	Sig. (2-tailed)
Learning Outcomes	-0,784	70	0,044

The findings show that learning motivation is one of the internal factors that contribute to students' success in learning mathematics. Students with high learning motivation tend to show greater involvement during the learning process, such as actively asking questions, participating in discussions, completing assignments independently, and trying to find solutions when facing difficulties. Students with low learning motivation generally show more limited involvement so the opportunity to build optimal understanding of concepts is also smaller. Although the difference in average learning outcomes was only 0.91 points, the results of the statistical test showed that the difference was significant. This indicates that learning motivation still contributes to the achievement of mathematics learning outcomes, although it is not the most dominant factor. Learning motivation functions as a supporting factor that helps students make more optimal use of the learning process. These findings also show that the improvement of learning outcomes is not only determined by academic ability but also influenced by students' psychological readiness to be actively involved in the learning process.

This finding can also be explained using the Self-Determination Theory put forward by Deci and Ryan. The theory explains that intrinsic motivation develops when the need for competence, autonomy, and social connectedness is met (Ryan & Deci, 2024). In GeoGebra-assisted PBL learning, students can explore various alternative solutions independently, discuss with their peers, and get direct feedback through GeoGebra visualizations. These conditions support the emergence of confidence and competence so that students with high learning motivation can utilize the learning process more optimally. From the perspective of Expectancy-Value Theory, students who have confidence that they can solve mathematical problems (expectancy) and view the assignments given as having benefits and value (task value) will show greater learning effort. Students with high motivation tend to be more active in using GeoGebra to explore various possible solutions compared to students with low motivation.

The results of this study are in line with the theory put forward by Slameto (2015) which states that learning outcomes are influenced by internal factors and external factors. One of the internal factors that has an important role is learning motivation because it can encourage students to study more diligently, maintain concentration, and not give up easily when facing difficulties. Students who have high learning motivation tend to take advantage of the various learning resources available so that the opportunity to achieve better learning outcomes becomes even greater. The findings of this research can also be explained through constructivism theory which emphasizes knowledge is actively constructed by students through learning experiences (Dewi & Fauziati, 2021). Students who have high learning motivation are generally more active in building their own knowledge through questioning activities, exploring information, connecting the concepts learned, and reflecting on learning outcomes. Students who have low motivation to learn tend to be more passive so that the knowledge construction process takes place less than optimally. This condition causes the conceptual understanding obtained to be relatively lower.

Vygotsky's social theory explains that the learning process develops optimally through social interaction and a supportive learning environment (Kurniati, 2025). In this study, all students obtained the same learning experience through the PBL model, but different levels of motivation caused the intensity of student involvement in the process of discussion, collaboration, and problem solving to be different. Students who are highly motivated are more active in taking advantage of these opportunities so that they have a more meaningful learning experience. The findings of this study strengthen the results of the research Perawansa (2019) The findings of this study strengthen the results of the research Juwana et al. (2025) which explains that PBL can increase student involvement during the learning process. This involvement is one of the factors that encourages increased learning motivation while having a positive impact on mathematics learning outcomes. Gurmu et al. (2024) stated that the use of GeoGebra helps students understand mathematical concepts more deeply through more interactive visualizations so that students who have high learning motivation can make more optimal use of the facility.

However, the results of this study also show that the influence of learning motivation on learning outcomes is not as large as the influence of the learning model. This can be seen from the relatively small difference in average learning outcomes between the high and low motivation groups. This condition indicates that learning motivation is not the only factor that determines the success of learning mathematics. Other factors, such as the quality of the learning model, learning media, students' initial abilities, and the characteristics of the material studied, also contribute to the achievement of learning outcomes. Learning motivation makes a positive contribution to students' mathematics learning outcomes, although the magnitude of the influence is relatively smaller than the influence of the learning model. In addition, learning motivation is one of the factors that supports the understanding of mathematical concepts because students who have high motivation tend to be more active in building knowledge and utilizing various learning resources during the learning process (Nuuryadin et al., 2026). Teachers not only need to implement innovative learning models but also create a learning environment that is able to increase student motivation through the provision of challenges, constructive feedback, and opportunities to actively participate in the learning process.

The Interaction of PBLGG and Learning Motivation on Mathematics Learning Outcomes

The group of students who participated in PBLGG with high learning motivation obtained the highest average learning outcomes, which was 94.38, while the PBL group with low learning motivation obtained the lowest average, which was 84.88, as shown in Table 6.

Table 6. Descriptive Statistics of Learning Outcomes Based on Learning Models and Learning Motivation

Learning Model	Learning Motivation	Mean	Std. Deviation	N
PBLGG	Low	93,27	1,944	15
PBLGG	High	94,38	1,658	21
PBL	Low	84,88	2,419	16
PBL	High	85,10	1,971	20

Meanwhile, the results of the Two-Way ANOVA test showed a significance value of 0.035 (<0.05). The third hypothesis is accepted, which shows the interaction between learning model and learning motivation on students' mathematics learning outcomes, as shown in Table 7.

Table 7. Results of Tests of Between-Subjects Effects

Source of Variation	F	Sig.	Partial Eta Squared
Learning Model	347,568	0,000	0,836
Learning Motivation	1,996	0,023	0,029
Learning Motivation * Learning Model	6,354	0,035	0,013

These results show that the effectiveness of the learning model does not stand alone but is influenced by the level of student learning motivation. The success of the implementation of PBLGG is determined not only by the characteristics of the learning model, but also by the readiness and encouragement of students to be actively involved in the learning process. Students who have high learning motivation tend to take advantage of all stages of PBL, starting from identifying problems, exploring using GeoGebra, discussing, to concluding the results of the solution more optimally than students who have low learning motivation. Although the interaction was statistically significant, the Partial Eta Squared value of 0.013 indicates the relatively small strength of the interaction effect. In contrast, the main influence of the learning model has a Partial Eta Squared value of 0.836, which belongs to the very large category. These findings indicate that learning models are the most dominant factor in improving mathematics learning outcomes, while learning motivation plays a role in strengthening the effectiveness of the model. The use of PBLGG has a positive impact on all students, but the benefits obtained are more optimal when students have high motivation to learn.

Theoretically, the results of this research can be explained through the theory of constructivism which states that knowledge is built through active and meaningful learning experiences (Dewi & Fauziati, 2021). In problem-based learning, students are encouraged to build their own understanding through the activities of identifying problems, developing solution strategies, testing various alternative solutions, and reflecting on the results obtained. GeoGebra reinforces this process through interactive visualization so that abstract mathematical concepts can be observed in a more concrete way. When this process is supported by high learning motivation, students will be more active in exploring concepts, discussing with their classmates, and verifying the solutions obtained. This condition allows for the formation of a deeper conceptual understanding so that it has an impact on improving learning outcomes.

These findings are also in line with the theory Slameto (2015) which Present the problem-solving results are influenced by internal factors and external factors. In this study, learning motivation plays a role as an internal factor that encourages students to actively engage in learning, while the PBLGG model is an external factor that provides a more interactive and contextual learning experience. The interaction of these two factors shows that the success of mathematics learning will be more optimal if innovative learning strategies are supported by good learning motivation.

The results of this study strengthen the research Perawansa (2019) which states that the use of GeoGebra can increase students' learning motivation as well as mathematical communication skills through more interactive learning. These findings are also consistent with research Gurmu et al. (2024) which shows dynamic visualization on GeoGebra helps students understand mathematical concepts more deeply. Juwana et al. (2025) reporting the implementation of PBL encourages students to be more active in solving problems so that they can improve mathematics learning outcomes. In contrast to previous studies that generally examined the influence of each variable separately, this study showed that the combination of learning models and learning motivation contributed to mathematics learning outcomes, although the magnitude of the interaction effect was relatively small.

The findings have practical implications that teachers are not only able to choose innovative learning models but also need to build students' learning motivation during the learning process. Providing contextual problems, opportunities to explore using GeoGebra, group discussions, and constructive feedback can increase student engagement in learning. The application of PBLGG not only serves as a medium to improve understanding of mathematical concepts, but also to create a more active, collaborative, and meaningful learning experience. PBLGG is the main factor that affects mathematics learning outcomes, while learning motivation plays a supporting role as a supporting factor that strengthens the effectiveness of the learning model. The integration of innovative learning models with efforts to increase learning motivation is a relevant strategy to support mathematics learning in the digital learning era.

4. Conclusion

The application of PBLGG provides better mathematics learning outcomes than PBL without the help of GeoGebra. GeoGebra's integration in problem-based learning helps students understand abstract mathematical concepts through more concrete, interactive, and contextual visualizations to support improved learning outcomes. This study also proves that students who have high learning motivation tend to achieve better learning outcomes than students with low learning motivation. There is an interaction between learning models and learning motivation on mathematics learning outcomes, which shows that learning effectiveness will be more optimal if the use of innovative learning models is supported by good learning motivation. These findings confirm that the use of digital technology through GeoGebra can be an effective alternative to support the implementation of more active, meaningful, and student-centered mathematics learning. Teachers and schools need to optimize the use of technology-based learning media while building student learning motivation so that the quality of mathematics learning continues to improve. Further research is suggested to test the application of this model to materials, educational levels, and other variables so that a more comprehensive picture of the effectiveness of technology-based learning is obtained.

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