

The Effects of GeoGebra-Assisted Local Context-Based PBL on Vocational Students' Mathematical Problem-Solving Skills

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ABSTRACT

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Developing students' mathematical problem-solving abilities (MPSA) remains a persistent challenge in vocational mathematics education. Although Problem-Based Learning (PBL), GeoGebra, and local context approaches have demonstrated positive effects on learning outcomes individually, evidence of their integrated implementation remains limited. This study examined the effects of GeoGebra-Assisted Local Context-Based Problem-Based Learning (GLoC-PBL) on vocational students' MPSA. A quasi-experimental, non-equivalent control-group design was conducted with 70 vocational high school students selected through cluster random sampling. The experimental group received GeoGebra-assisted local context-based PBL, while the comparison group received conventional instruction. Data were collected using a 5-item open-ended mathematics problem-solving test. Descriptive statistics, assumption testing, independent-samples t-test, and Hedges' g effect size analysis were used to analyze the data. The findings indicated that students in the experimental group achieved significantly higher performance on MPSA tasks than those in the comparison group. Specifically, the independent-samples t-test revealed a significant difference between the two groups, $t(68) = 4.42$, $p < 0.001$, with the experimental group obtaining a higher mean score ($M = 78.46$, $SD = 8.21$) than the comparison group ($M = 69.17$, $SD = 9.34$). Furthermore, the intervention demonstrated a large practical effect (Hedges' $g = 1.03$, 95% CI [0.53, 1.53]). The results showed that integrating problem-based learning, GeoGebra, and a culturally relevant local context fostered active engagement, collaborative knowledge construction, and deeper conceptual understanding, thereby improving students' MPSA. This study contributes to the growing literature on technologically enhanced and culturally responsive mathematics education by providing empirical evidence that integrating pedagogy, technology, and local culture offers an effective framework for improving MPSA in vocational education.



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A. INTRODUCTION

Problem-solving skills are essential competencies that vocational high school (SMK) students must possess to face the challenges of the workplace and real life (Ningsih, 2022). Ideally, vocational high school students are expected to identify problems, formulate problem-solving strategies, and evaluate results reflectively. This ability relates not only to conceptual mastery but also to higher-order thinking skills such as analysis, synthesis, and evaluation. In the context of mathematics learning, problem-solving is a key indicator of successful learning. Students with strong problem-solving skills tend to be more adaptable in complex situations

(Cantillo-Rudas et al., 2024). Furthermore, these skills also support rational, data-driven decision-making (Rezaei & Asghary, 2025). Therefore, developing MPSA should be a priority in vocational high school learning.

However, on the ground, students' PSA are still suboptimal. This is reflected in PISA results, which ranked Indonesian students relatively low (OECD, 2021). These results indicate that students still experience difficulties in solving non-routine and contextual problems (Jacinto & Carreira, 2023; Rezaei & Asghary, 2025). This limitation indicates a gap between curriculum expectations and classroom learning practices. Many students tend to rely on mechanistic procedures without a deep understanding of concepts (Sridana et al., 2025). Furthermore, memorization-oriented learning still dominates educational practice (Bhattacharya, 2022). This situation demands learning innovations that can significantly improve students' PSA.

To address these issues, a more innovative and student-centered learning approach is needed. Learning should be designed to encourage students to actively identify and solve problems, both independently and collaboratively (Chen et al., 2024; Loyens et al., 2023). A contextual and life-relevant approach is also crucial for increasing learning motivation (Tamur, Jehadus, et al., 2020; Tamur, Kurnila, et al., 2021; Tamur, Ndiung, Weinhandl, et al., 2023). Furthermore, the use of technology can facilitate more dynamic exploration of concepts (Juandi et al., 2021, 2022; Tamur, Juandi, et al., 2020; Tamur et al., 2022; Tamur, Wijaya, et al., 2024). Teachers need to integrate various learning strategies that can develop higher-order thinking skills (Tamur, Kusumah, et al., 2021). Effective learning must also connect mathematical concepts to real-world situations (Tamur et al., 2025; Turmuzi et al., 2023). Therefore, a learning model that can comprehensively accommodate these needs is needed.

One potential approach that aligns with these learning recommendations is the implementation of PBL combined with technology and local context. PBL provides students with opportunities to learn through authentic, meaningful problem-solving (Jacinto & Carreira, 2023; Jamaluddin et al., 2022; Sridana et al., 2025). The use of technology, such as GeoGebra, enables interactive and in-depth visualization of mathematical concepts (Bedada & Machaba, 2024; Delima & Elfandi, 2025; Tamur, Ndiung, Kurnila, et al., 2023). Meanwhile, integrating local context helps students understand the relevance of mathematics in their daily lives. The combination of these three aspects is believed to increase student engagement and understanding. Furthermore, this approach also supports the development of 21st-century skills. Thus, integrating PBL, technology, and local context is a relevant strategy for mathematics learning in vocational schools.

Various studies have shown that PBL is effective in improving students' mathematical PSA (Cantillo-Rudas et al., 2024; Jacinto & Carreira, 2023; Jamaluddin et al., 2022; Rezaei & Asghary, 2025; Sridana et al., 2025). Other studies have also shown that the use of technology, such as GeoGebra, can improve understanding of mathematical concepts and representations (Awaji et al., 2025; Delima & Elfandi, 2025; Lutfiatussolihah et al., 2025; Pratama, 2024). Furthermore, a local context-based approach, or ethnomathematics, has been shown to increase student motivation and engagement. However, most studies still examine these three aspects separately. Research integrating PBL, technology, and local context within a single learning framework is still limited. This integration, however, has the potential to significantly impact

students' PSA. Therefore, this study seeks to fill this gap by developing an integrative learning approach.

Based on this background, this study aims to analyze the effect of GLoC-PBL on the mathematical PSA of vocational high school students. To achieve this goal, this study focuses on testing the effectiveness of the proposed learning model. Furthermore, this study aims to compare learning outcomes between students who received the intervention and those who did not. The research question posed was whether there was a significant difference in MPSA between the two groups. Furthermore, this study examined the extent of the approach's influence using effect sizes. This analysis is crucial for determining the strength of the intervention. Thus, the research results are expected to provide a strong empirical contribution

B. METHODS

This study used a quantitative, quasi-experimental design to test the effects of the treatment. The research design used a non-equivalent control group design involving two groups. The first group served as the experimental class, receiving the treatment, and the second group served as the comparison class, receiving conventional learning. This research was conducted at SMK Santo Aloisius Ruteng in the even semester of the 2025/2026 academic year. The independent variable in this study was GLoC-PBL. Meanwhile, the dependent variable was students' ability to solve mathematical problems.

The population in this study was all students in six second-grade classes. The sampling technique used was cluster random sampling, randomly selecting two classes from the six available classes. These two classes were then randomly reassigned as the experimental and comparison classes. The total sample size was 70 students, with each class consisting of 35 students. The experimental class received a problem-based learning treatment integrated with the local Manggarai context and supported by GeoGebra. The comparison class was taught using a conventional approach commonly used in schools. Treatment was administered over several sessions according to a predetermined lesson plan.

The research instrument used was an MPSA test in the form of descriptive questions. This test consisted of five items designed to comprehensively measure problem-solving indicators, using local contexts such as markets and Manggarai culture as stimulus questions. Prior to use, the instrument underwent validation by experts to ensure its content and construct suitability. Content validity was analyzed based on the suitability of the items to the ability indicators being measured. Furthermore, a pilot test of the instrument was conducted to determine the empirical quality of the questions. Instrument reliability was calculated using a reliability coefficient to measure the internal consistency of the items. The analysis indicated that the instrument had adequate validity and reliability for research use.

Data collection was conducted by administering a post-test to both groups after treatment. The data obtained were then analyzed quantitatively to test the research hypotheses. Test score data were first analyzed descriptively to determine the mean and standard deviation. Next, prerequisite analysis tests were conducted, including a normality test using the Kolmogorov-Smirnov test and a homogeneity test using the Levene test. After the data met the assumptions of normality and homogeneity, the analysis continued with a two-sample independent t-test. This test was used to determine the difference in means between the experimental and control

classes. The entire analysis process was carried out systematically to ensure the accuracy of the research results.

In addition to inferential analysis, this study also calculated effect sizes to determine the magnitude of the treatment's influence. Effect size calculations were performed using the Hedges' *g* formula and calculated using CMA software to obtain more accurate estimates in relatively small sample sizes. Effect size values were interpreted based on the criteria of Cohen et al. (2018), namely, an effect size less than 0.20 is categorized as very low, $0.20 \leq ES < 0.50$ is categorized as low, $0.50 \leq ES < 0.80$ is categorized as medium, $0.80 \leq ES < 1.30$ is categorized as high, and $ES \geq 1.30$ is categorized as very high. This analysis provides additional information that focuses not only on statistical significance but also on practical significance. Effect sizes are used to strengthen the interpretation of the hypothesis tests. Thus, data analysis was conducted comprehensively by combining descriptive, inferential, and effect size approaches. This approach ensures that the research findings are highly valid and strongly relevant to mathematics learning.

C. RESULT AND DISCUSSION

1. Result

As a first step in data analysis, descriptive statistics were used to provide an overview of the distribution of students' mathematical problem-solving abilities in both study groups. The statistics presented included measures of central tendency and dispersion, such as the mean, median, standard deviation, minimum, and maximum scores. This information enabled the initial identification of differences in student performance between the experimental and control classes before hypothesis testing. A summary of the results of these descriptive statistics is presented in Table 1.

Table 1. Descriptive Statistics of Students' Mathematical Problem-Solving Skills (MPSS)

Group	N	Mean	SD	Min	Max	Skewness
Experimental	35	78.46	8.21	62	94	-0.31
Comparison	35	69.17	9.34	50	86	-0.18

As shown in Table 1, students in the experimental group achieved a higher mean score ($M = 78.46$, $SD = 8.21$) than those in the comparison group ($M = 69.17$, $SD = 9.34$). Although both groups showed a similar distribution of scores, the experimental group demonstrated superior performance in mathematical problem-solving. These preliminary findings indicate that implementing GeoGebra-assisted, locally context-based PBL can positively contribute to students' mathematical problem-solving achievement, which was subsequently tested through inferential statistical analysis. Before conducting the hypothesis testing, the data were examined to ensure they met the analysis requirements. Normality tests were conducted using the Kolmogorov-Smirnov test for each group. Table 2 shows the results of the normality test.

Table 2. Results of Normality Test

Group	N	Kolmogorov-Smirnov Statistic	Sig. (p)	Decision
Experimental	35	0.112	0.200	Normal
Comparison	35	0.105	0.214	Normal

The data presented in Table 2 indicate that the Kolmogorov–Smirnov normality test yielded p-values of 0.200 for the experimental group and 0.214 for the comparison group. Since both values exceed the predetermined threshold of 0.05, the assumption of normality is satisfied. In other words, the distribution of MPSA scores across the two groups does not deviate significantly from normality. The findings of the homogeneity analysis are subsequently summarized in Table 3.

Table 3. Results of the Homogeneity of Variance Test

Levene Statistic	df1	df2	Sig. (p)	Decision
1.284	1	68	0.261	Homogeneous

The results displayed in Table 3 indicate that Levene's test produced a significance value of 0.261, exceeding the criterion level of 0.05. This finding suggests that the variability of scores in the experimental and comparison groups is statistically comparable, implying that the assumption of equal variances is satisfied. When considered alongside the normality test results, which confirmed that the data follow a normal distribution, the parametric assumptions are met. Consequently, an independent-samples t-test was conducted to determine whether there were differences in mathematical PSA between students exposed to the GLoC-PBL approach and those receiving conventional instruction. The outcomes of this analysis are reported in Table 4.

Table 4. Results of the Independent Samples t-Test on Students' MPSS

Variable	Mean (Experimental)	Mean (Comparison)	t	df	p
MPSS	78.46	69.17	4.42	68	0.000

The findings presented in Table 4 reveal a statistically significant difference in MPSA performance between the experimental and comparison groups, with the independent-samples t-test yielding $t(68) = 4.42$, $p < 0.001$. Students who participated in learning through the GLoC-PBL approach achieved a higher mean score ($M = 78.46$, $SD = 8.21$) than their counterparts in the comparison group ($M = 69.17$, $SD = 9.34$). Given that the obtained probability value was well below the 0.05 threshold, the null hypothesis was not supported. These results suggest that GLoC-PBL provides greater benefits for enhancing students' MPSA than conventional instructional practices.

In addition to testing for statistical significance, this study also calculated effect sizes to determine the practical impact of implementing GeoGebra-Assisted Local Context-Based Problem-Based Learning on students' mathematical problem-solving abilities. The effect size was calculated using Hedges' g , which was chosen because it provides a more accurate estimate in a relatively small sample. Based on calculations using the Comprehensive Meta-Analysis (CMA) software, the Hedges' g value was 1.03, with a 95% confidence interval of [0.53, 1.53]. This value indicates that the average mathematical problem-solving ability of students in the experimental class was approximately 1.03 standard deviations higher than that of students in the comparison class. According to the interpretation criteria of Cohen et al. (2018), the effect size falls in the high category ($0.80 \leq g < 1.30$). These findings indicate that the influence of GeoGebra-Assisted Local Context-Based Problem-Based Learning is not only statistically

significant but also has strong practical significance in improving students' mathematical problem-solving abilities. Thus, a learning approach that integrates Problem-Based Learning, GeoGebra, and local context has been proven to have a substantial impact on the quality of mathematics learning in vocational schools.

2. Discussion

The results of this study indicate that GeoGebra-Assisted Local Context-Based Problem-Based Learning has a significant impact on the mathematical problem-solving abilities of vocational high school students. This finding aligns with the theoretical framework that views problem-solving as the core of meaningful mathematics learning. The application of Problem-Based Learning encourages students to actively engage in the knowledge construction process by solving authentic problems relevant to their lives. The integration of the local Manggarai context also strengthens the meaningfulness of learning, making it easier for students to connect mathematical concepts with their real-life experiences. In addition, using GeoGebra provides visual support that helps students understand abstract concepts more concretely and dynamically. This mechanism is evident during the learning process, where students work in groups, discuss solution strategies, explore alternative solutions, and use GeoGebra to test and verify their thinking (see Figure 1).



Figure 1. Collaborative Mathematical Problem Solving

This type of collaborative activity allows for the exchange of ideas, negotiation of meaning, and reflection on the thought processes involved, so that students not only arrive at final answers but also understand the rationale behind the procedures used. Thus, the combination of problem-based learning, interactive technology, and local context creates a learning environment rich in opportunities to develop higher-order thinking skills, particularly problem-solving skills in mathematics.

The findings of this study are also consistent with various previous studies reporting the effectiveness of problem-based learning in improving students' mathematical problem-solving abilities (Cantillo-Rudas et al., 2024; Jacinto & Carreira, 2023; Jamaluddin et al., 2022; Rezaei & Asghary, 2025; Sridana et al., 2025). Previous research has shown that PBL provides students with opportunities to develop critical thinking skills, identify relevant information, and devise more systematic problem-solving strategies. On the other hand, the use of technology such as GeoGebra has been shown to improve visual representation, conceptual understanding, and dynamic exploration of mathematical objects (Delima & Elfandi, 2025; Pratama, 2024; Santos, 2025). Furthermore, local context-based learning, or ethnomathematics, has been reported to

increase student engagement because the material learned is closer to their experiences and environment (Tamur et al., 2025; Tamur, Komaladewi, et al., 2024; Turmuzi et al., 2023). However, most of these studies examine these three components separately. Therefore, this study makes a new contribution by showing that integrating PBL, GeoGebra, and local context within a single learning framework yields a more comprehensive learning experience and positively affects students' mathematical problem-solving abilities.

The intervention's influence was further strengthened by the effect size analysis, which indicated a high effect size. This finding indicates that the superiority of the experimental class was not only statistically significant but also had substantial practical significance for mathematics learning. The large effect size indicates that students who participated in GeoGebra-Assisted Local Context-Based Problem-Based Learning achieved significantly greater learning benefits than those who participated in conventional learning. This condition can be explained by the learning characteristics that allow students to actively build understanding through problem exploration, group discussions, concept visualization using GeoGebra, and reflection on the resulting solutions (Albaladejo & López, 2024; Awaji et al., 2025; Bedada & Machaba, 2024; Delima & Elfandi, 2025; Lutfiatussolihah et al., 2025). These activities not only help students understand mathematical concepts more deeply but also develop metacognitive skills important to the problem-solving process. Thus, this approach has strong potential for broader implementation as an alternative mathematics learning method designed to develop higher-order thinking skills.

However, several limitations of the study should be considered when interpreting the results. First, this study was conducted in a single school with a relatively limited sample size, so generalizing the findings to a broader population requires careful consideration. Second, the study focused solely on mathematical problem-solving skills, without examining other variables that may be influenced by the intervention, such as critical thinking, mathematical creativity, learning motivation, or students' metacognitive skills. Third, the relatively short treatment duration does not allow for observation of the long-term impact of this learning model. Furthermore, the study's local context was limited to Manggarai culture, so the effectiveness of this approach in other cultural contexts warrants further study. Therefore, future research is recommended to involve a larger, more diverse sample, use a longer intervention period, and explore the effects of this approach on various aspects of mathematical skills to gain a more comprehensive understanding of the effectiveness of problem-based learning integrated with technology and the local context.

D. CONCLUSION AND SUGGESTIONS

This study demonstrates that problem-based learning with a local context, supported by GeoGebra, effectively improves vocational students' mathematical problem-solving skills. Students participating in the intervention achieved significantly higher performance than those receiving conventional instruction, with the observed differences supported by large effect sizes. These findings suggest that integrating problem-based learning, GeoGebra, and a culturally relevant local context provides a meaningful learning experience that encourages active engagement, collaborative knowledge construction, and deeper conceptual understanding. Consequently, this instructional approach offers a promising pathway for

fostering higher-order mathematical thinking and strengthening students' ability to solve authentic mathematical problems.

These findings also contribute to the growing literature on integrating pedagogy, technology, and local culture in mathematics education. From a practical perspective, mathematics teachers are encouraged to incorporate technology-supported problem-based learning and a meaningful cultural context into their classrooms to create more engaging and effective learning environments. Future research should involve larger, more diverse samples, examine additional learning outcomes, such as critical thinking, creativity, and mathematical literacy, and investigate the long-term impact of this teaching approach across different educational settings and cultures.

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