



EFFECTIVENESS OF DESIGN THINKING-BASED PROJECT-BASED LEARNING MODEL ON SENIOR HIGH SCHOOL STUDENTS' NUMERACY SKILLS

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ABSTRACT

This study aims to examine the effect of Project-Based Learning integrated with a Design Thinking approach on senior high school students' numeracy skills in statistics. Although Project-Based Learning has been widely studied in mathematics education, most studies focus on general outcomes such as problem-solving, while research specifically addressing numeracy skills in statistics and its integration with Design Thinking remains limited. This study employed a quasi-experimental design using a posttest-only control group involving experimental and control classes. The sample consisted of eleventh-grade students selected through a non-random sampling technique. The instrument was a numeracy test that had been validated and tested for reliability, and the data were analyzed using ANOVA and effect size calculation. The results indicate that the mean numeracy score of the experimental group ($M = 82.50$) is higher than that of the control group ($M = 70.94$), with a statistically significant difference ($p < 0.05$). The effect size (Cohen's $d = 0.90$) is categorized as large, indicating a strong practical significance of the observed difference. Therefore, the implementation of Project-Based Learning integrated with Design Thinking demonstrates a strong positive effect on students' numeracy skills, supported by a large effect size.

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INTRODUCTION

Numeracy is considered an essential competence in mathematics education, as it extends beyond basic computational skills to include the ability to understand, analyze, and interpret quantitative information in various real-life contexts (Hendrowati & Faelasofi, 2021; Tyaningsih et al., 2023; Merita & Widyasari, 2025). In the current educational landscape, the demand for such competence continues to increase, particularly due to the need for individuals to think critically and make data-driven decisions (Mia Rarasyanti et al., 2025; Owÿyeong et al., 2023).

However, findings from large-scale assessments indicate that Indonesian students' numeracy skills remain relatively low. The results of the Programme for International Student Assessment (PISA) 2022 show a decline in Indonesia's average mathematics score from 379 in 2018

to 366 in 2022 (Wijaya et al., 2024; OECD, 2025) This condition suggests that mathematics instruction has not yet fully supported the development of higher-order thinking skills and the contextual application of mathematical concepts (Sulistiyorini et al., 2025). Consequently, there is a clear gap between the expected learning outcomes and students' actual performance, highlighting the need for more meaningful and context-oriented learning innovations (Dewi, 2019; Khonsa et al., 2024)

Statistics is one of the mathematical topics with strong potential to foster numeracy skills, as it involves collecting, processing, presenting, and interpreting data. Nevertheless, statistics instruction in schools is often dominated by procedural and teacher-centered approaches, which limit students' active engagement and conceptual understanding (Munthe et al., 2023; Sahila et al., 2025; Dhini et al., 2024). As a result, students tend to face difficulties in connecting statistical concepts with authentic real-world problems (Dwijayanti et al., 2020).

To address these challenges, various studies have explored the implementation of Project-Based Learning in mathematics education. Mathematics learning is not only aimed at mastering concepts but also at developing students' problem-solving abilities in real-life situations (Nugroho et al., 2020). Previous studies have reported that Project-Based Learning can enhance students' problem-solving skills and learning motivation (Jatisunda et al., 2024; Wijnia et al., 2024; Fajri et al., 2024). However, most of these studies focus primarily on general learning outcomes and have not specifically examined numeracy as a contextual competence. In addition, the implementation of Project-Based Learning is often not systematically structured to support students' creative thinking processes.

To further enhance the meaningfulness of learning experiences, Design Thinking can be integrated into Project-Based Learning. This approach provides structured stages, including empathizing, defining problems, ideating, prototyping, and testing, which enable students to better understand problems and develop relevant and innovative solutions (Amaral & Gamez, 2018). The integration of these two approaches has the potential to create more contextual, reflective, and student-centered learning environments.

Although the integration of Project-Based Learning and Design Thinking has the potential to create more contextual and meaningful learning experiences, studies examining its implementation in statistics instruction, particularly those focusing on numeracy as a data-driven competence, are still relatively limited. Most previous research has primarily emphasized general learning outcomes such as problem-solving skills or learning motivation, without specifically addressing numeracy within the context of statistics. In addition, earlier studies have generally focused on statistical significance without incorporating effect size analysis, making it difficult to clearly determine the strength of the instructional impact on students' numeracy skills. Therefore, this study aims to specifically investigate the integration of Project-Based Learning and Design Thinking in statistics learning and to examine its effect on students' numeracy skills by considering both statistical significance and effect size as indicators of the strength of the effect.

METHOD

This study employed a quantitative approach using a quasi-experimental method with a posttest-only control group design (Saputri & Mardiaty, 2025). This design was selected because it allows the researcher to examine the effect of the treatment directly without being influenced by pretest effects, such as practice effects or score improvements due to familiarity with the test instrument. In addition, this design is appropriate for the purpose of this study, which focuses on comparing the final numeracy outcomes between the experimental and control groups after the treatment was implemented.

Although a posttest-only design was used, initial equivalence between groups was still considered to ensure internal validity. Students' initial ability was not measured through a pretest but was estimated using secondary data in the form of prior daily test scores relevant to statistics learning. The use of these data is justified by the fact that the daily tests assessed students' understanding of concepts related to the topic under study, thereby providing a preliminary indication of their baseline competencies. However, these scores may not fully represent the same construct as the numeracy test used in this study. Therefore, the results of initial equivalence were interpreted cautiously and were used as a supporting indicator rather than a primary measure of students' initial ability. This approach is considered acceptable in quasi-experimental research where intact classes are used, and random assignment is not feasible.

The study was conducted in the second semester of the 2025/2026 academic year at SMA Institut Indonesia Semarang, Central Java, Indonesia. The population consisted of all eleventh-grade students, with two intact classes selected as the sample, comprising 30 students in the experimental group and 32 students in the control group. A non-random sampling technique was employed. This approach may limit the generalizability of the findings, as the sample may not fully represent the broader population. Therefore, the results of this study should be interpreted with caution, particularly when applied to different contexts.

The experimental group was taught using a Project-Based Learning model integrated with Design Thinking, while the control group received conventional instruction. The research instruments consisted of a numeracy test and an observation sheet. The numeracy test was developed based on several indicators, including: (1) the ability to interpret data, (2) the ability to analyze relationships between variables, (3) the ability to use mathematical representations such as scatter plots and regression, and (4) the ability to draw conclusions based on data. Item validity was assessed using the Pearson product-moment correlation, with items considered valid if the correlation coefficient exceeded the critical value. Reliability was evaluated using Cronbach's Alpha, with a coefficient of 0.70 or higher indicating acceptable internal consistency. In addition, item difficulty and discrimination indices were analyzed to ensure the quality of the instrument.

Data analysis was conducted using normality and homogeneity tests as prerequisites, followed by a one-way ANOVA to examine differences in numeracy skills between the experimental and control groups (Sugiyono, 2020). Although only two groups were involved, one-way ANOVA was used because it is statistically equivalent to an independent samples t-test and ensures consistency in the analytical procedure. To strengthen the interpretation of the findings, the effect size was calculated using Cohen's *d* to determine the magnitude of the treatment effect. The effect size values were then interpreted into small, medium, or large categories (Cohen, 1988).

The effectiveness of the learning model was analyzed using three indicators: differences in learning outcomes between the experimental and control groups, students' learning mastery based on the Minimum Mastery Criterion (KKM), and the magnitude of the effect as indicated by the effect size.

In addition, students' learning mastery was analyzed based on the Minimum Mastery Criterion (KKM) applied in the school, which was set at 75. Students were considered to have achieved mastery if they obtained scores equal to or above the KKM. This study also adhered to ethical research standards. Informed consent was obtained from all participants, and the confidentiality of student data was maintained throughout the research process.

RESULTS

Equivalence of Initial Ability

Before the treatment was implemented, an analysis of students' initial ability was conducted to ensure that the experimental and control classes were equivalent. The analysis included descriptive statistics, normality tests, homogeneity tests, and a one-way ANOVA.

Descriptive Statistics of Initial Ability

To provide an overview of students' initial ability prior to the treatment, descriptive statistical analysis was performed based on students' daily test scores. The results are presented in Table 1.

Table 1. Descriptive statistics of students' initial ability

Class	N	Mean	Std. Deviation	Minimum Score	Maximum Score
Experimental	30	83.17	4.921	76	93
Control	32	82.66	4.783	76	91

Based on Table 1, the mean score of the experimental class was 83.17, while that of the control class was 82.66. The difference between the two means was relatively small.

Normality and Homogeneity Tests of Initial Ability

To determine whether parametric statistical tests could be applied, normality and homogeneity tests were conducted.

Table 2. Results of the normality test (initial ability)

Class	Statistic	Sig.	Description
Experimental	0.961	0.320	Normal
Control	0.937	0.062	Normal

As shown in Table 2, the significance values for both classes were greater than 0.05.

Table 3. Results of the homogeneity test (initial ability)

Levene Statistic	Sig.	Description
0.000	0.984	Homogeneous

Table 3 shows that the significance value was 0.984, which is greater than 0.05.

One-Way ANOVA of Initial Ability

To confirm that there was no significant difference in initial ability between the two groups, a one-way ANOVA was conducted. The results are presented in Table 4.

Table 4. One-way ANOVA results of initial ability

Source of Variation	F	Sig.	Description
Between Groups	0.171	0.680	Not Significant

The significance value of 0.680 was greater than 0.05.

Implementation of Learning

The implementation of the Design Thinking-based Project-Based Learning model was observed during three meetings. The results are presented in Table 5.

Table 5. Implementation of the design thinking-based project-based learning model

Meeting	Percentage	Category
1	97.5%	Very High
2	92.5%	Very High
3	87.5%	Very High
Average	92.5%	Very High

As shown in Table 5, the average implementation percentage reached 92.5%, which falls into the "Very High" category.

Posttest Results of Students' Numeracy Skills

To evaluate the effectiveness of the Design Thinking-based Project-Based Learning model, students in both classes completed a posttest to measure their numeracy skills.

Descriptive Statistics of Posttest

Table 6. Descriptive statistics of posttest scores

Class	N	Mean	Std. Deviation	Min. Score	Max. Score
Experimental	30	82.50	12.16	55	100
Control	32	70.94	13.46	40	95

Based on Table 6, the mean numeracy score of students in the experimental group ($M = 82.50$; $SD = 12.16$) is higher than that of the control group ($M = 70.94$; $SD = 13.46$). The mean difference between the two groups was 11.56 points.

Normality Test of Posttest

Table 7. Results of the normality test (posttest)

Class	Sig.	Description
Experimental	0.099	Normal
Control	0.460	Normal

The significance values were greater than 0.05.

Homogeneity Test of Posttest

Table 8. Results of the homogeneity test (posttest)

Sig.	Description
0.888	Homogeneous

The significance value was greater than 0.05.

One-Way ANOVA of Posttest Scores

Table 9. One-way ANOVA results of posttest scores

Source of Variation	F	Sig.	Effect Size (Cohen's d)	Description
Between Groups	12.534	0.001	0.90	Significant (large)

Based on Table 9, the results of the one-way ANOVA show a significance value of 0.001 ($p < 0.05$). In addition, the effect size calculated using Cohen's d is 0.90, which is categorized as large.

Classical Learning Mastery

Table 10. Classical learning mastery in the experimental class

Category	Number of Students	Percentage
Not Mastered	5	16.7%
Mastered	25	83.3%
Total	30	100%

Based on Table 10, 83.3% of students in the experimental class achieved scores above the minimum mastery criterion.

DISCUSSION

The findings of this study indicate that the integration of Project-Based Learning with a Design Thinking approach is associated with higher numeracy performance among students. Rather than merely reflecting statistical differences, these results suggest that the learning process embedded within this instructional model plays a significant role in shaping students' ability to understand and apply numerical concepts in meaningful contexts.

The improvement in numeracy skills can be explained through the characteristics of the learning process implemented in the experimental group. Project-Based Learning encourages

students to engage actively in solving contextual problems through structured project activities. This active engagement allows students to construct knowledge through exploration, discussion, and reflection, which supports deeper conceptual understanding. In the context of numeracy, such processes enable students not only to perform calculations but also to interpret and analyze data meaningfully. This finding is consistent with previous studies indicating that Project-Based Learning can significantly improve students' numeracy skills and learning outcomes and supports meaningful learning through real-life applications (Panjaitan et al., 2024; Lince et al., 2023).

In addition, the Design Thinking approach provides a systematic framework that guides students through stages such as empathizing, defining problems, ideating, prototyping, and testing. These stages facilitate structured thinking processes, allowing students to approach numerical problems more analytically and reflectively. The combination of these stages with project-based activities helps students organize their reasoning, connect data with real-world contexts, and develop more coherent problem-solving strategies (Fitrah et al., 2025). Moreover, the integration of Design Thinking with Project-Based Learning has been shown to create synergistic effects that enhance students' problem-solving skills and learning engagement (Yu et al., 2024).

Compared to conventional instruction, which tends to be more teacher-centered, the integrated model creates opportunities for students to be more actively involved in the learning process. In the experimental group, students were required to explore problems, collaborate with peers, and apply numerical reasoning in authentic situations, whereas the control group experienced more procedural learning. This supports the view that student-centered learning approaches can enhance student engagement and learning outcomes (Zhang & Ma, 2023).

In addition, the high level of instructional implementation observed in this study indicates that the learning model was applied consistently according to the planned stages. This consistency may contribute to the effectiveness of the learning process in supporting students' numeracy development.

The findings of this study are consistent with previous research showing that Project-Based Learning can enhance students' problem-solving abilities and engagement in mathematics learning (Rosanti et al., 2025; Zhang & Ma, 2023). However, this study extends previous findings by specifically focusing on numeracy skills within a statistical context and by integrating the Design Thinking approach. This finding also differs from some previous studies that primarily emphasized general learning outcomes, as the present study specifically highlights numeracy skills within a statistical context. Therefore, this study provides a more specific contribution by demonstrating how the integration of Project-Based Learning and Design Thinking can support data-based numeracy skills.

Furthermore, the inclusion of effect size analysis provides additional insight into the practical significance of the findings. The large effect size observed in this study suggests that the difference between groups is not only statistically significant but also meaningful in terms of educational practice.

Despite these contributions, several limitations should be considered. The study was conducted within a single school context with a relatively small sample size, which may limit the generalizability of the findings. In addition, the measurement of numeracy skills relied primarily on posttest results, and the relatively short duration of the intervention may not reflect long-term learning outcomes.

Therefore, future research is recommended to involve more diverse samples and longer implementation periods. In addition, incorporating qualitative approaches may provide deeper insights into students' numeracy thinking processes.

CONCLUSION

The results of this study suggest that the integration of Project-Based Learning with a Design Thinking approach contributes positively to the improvement of senior high school students' numeracy skills in statistics. These findings indicate that the integrated learning model can support students in understanding and applying numerical concepts within meaningful contexts. This study contributes to the field of mathematics education by providing empirical evidence on the implementation of Project-Based Learning combined with Design Thinking to enhance data-oriented numeracy skills. From a practical perspective, this approach may be considered an alternative instructional strategy to promote more active and contextual learning in mathematics classrooms. Therefore, future research is recommended to involve larger and more diverse samples and to examine the long-term impact of this learning model on students' learning outcomes.

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INFORMED CONSENT

The authors have obtained informed consent from all participants involved in this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding this research.

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