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Mathematical Numeracy Analysis Based on Learning Style in PBL with Differentiation E-Module

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ABSTRACT

This study aims to examine the effectiveness of Problem-Based Learning assisted by differentiated e-modules in enhancing junior high school students' mathematical numeracy and to analyse numeracy development from the perspective of students' learning styles. A mixed methods approach with a sequential explanatory design was employed. Quantitative data were collected using a quasi-experimental pretest–posttest control group design, followed by qualitative data obtained through classroom observations and semi-structured interviews. Participants consisted of Grade VIII students from a public junior high school in Indonesia. The quantitative results show that the experimental group achieved a higher increase in mathematical numeracy scores (from M = 58.75 to M = 78.63) compared to the control group (from M = 59.21 to M = 69.03). An independent sample t-test revealed a statistically significant difference in posttest scores between the two groups (p = 0.001). In addition, learning mastery in the experimental group (84.37%) exceeded that of the control group (65.62%). Qualitative findings indicate that differentiated e-modules effectively supported engagement and understanding across visual, auditory, and kinesthetic learning styles. This study demonstrates that the integration of PBL, learning-style-based differentiation, and e-module assistance produces a cumulative effect on students' mathematical numeracy. The findings contribute empirical evidence for designing inclusive, problem-oriented, and digitally supported mathematics instruction.

Keywords: differentiated instruction; learning styles; mathematical numeracy; problem-based learning; secondary mathematics education

INTRODUCTION

Learning models are a central component in determining the quality of mathematics instruction at the junior secondary level, particularly in fostering students' ability to understand and apply mathematical concepts meaningfully. Recent studies in mathematics education emphasise that effective learning increasingly relies on student-centred instructional models that promote active engagement, reasoning, and contextual problem-solving rather than on passive knowledge transmission (Aziz et al., 2025; Lestari et al., 2024; Nisaa et al., 2024). Contemporary research highlights that appropriate learning models not only influence students' cognitive achievement but also shape their motivation, participation, and numeracy development, which are essential competencies in the twenty-first-century education (Yuhana, 2025). In this context, the careful selection and implementation of learning models are viewed as a key pedagogical strategy to improve the effectiveness and relevance of mathematics learning in junior high schools. Recent syntheses and empirical studies consistently report that Problem Based Learning promotes higher mathematical competence and numeracy by embedding learning in authentic problem contexts and fostering reasoning and collaboration (Badi'ah et al., 2024; Septian & Rahayu, 2021; Suparman et al., 2021).

Despite the growing body of research recommending student-centred and problem-oriented learning models in mathematics education, classroom implementation has not fully reflected these pedagogical advances. Recent reviews indicate that mathematics instruction in many secondary schools is still dominated by teacher-centred practices, with limited opportunities for students to engage in inquiry, problem solving, and contextual reasoning (Linda Safitri et al., 2025). Empirical studies conducted in Indonesian junior high schools also reveal that teachers often encounter practical challenges when applying innovative learning models, including limited instructional time, insufficient familiarity with model implementation stages, and the reliance on conventional teaching materials (Nofrinaldi Hendriko et al., 2024). As a result, the potential of learning models such as Problem-Based Learning to improve students' higher-order thinking and numeracy skills has not been optimally realised in everyday classroom practice.

Students' mathematical numeracy has emerged as a critical issue in junior secondary mathematics education, particularly regarding their ability to apply mathematical concepts and procedures in real-life contexts. Recent international studies emphasise that numeracy is not limited to computational skills but involves reasoning, problem solving, and decision making based on mathematical information (Voni et al., 2025). However, empirical findings in Indonesian secondary schools consistently show that students' numeracy skills are still developing at a moderate level, especially in number-related topics. Research indicates that limited exposure to contextual and problem-oriented learning environments contributes to students' difficulties in connecting mathematical concepts with everyday problems (Fauziyah & Husniati, 2023). This condition highlights the urgent need for instructional approaches that explicitly strengthen numeracy through meaningful problem-solving activities embedded in authentic contexts. Mathematical numeracy entails reasoning, representation, and decision-making in real-world contexts, and is strengthened when learning tasks connect mathematics to authentic situations and tools (Marks et al., 2021).

Although recent studies have demonstrated the effectiveness of Problem-Based Learning in improving students' numeracy and problem-solving skills, most existing research has focused on the implementation of PBL as a single instructional approach or its integration with specific learning media. Previous studies primarily examine the development or practicality of PBL-based learning tools (Ndia et al., 2025). Similarly, national studies report that the integration of differentiated learning strategies with the PBL model has a significant impact on students' conceptual understanding in mathematics (Ambarini et al., 2024). In parallel, the use of interactive e-modules grounded in differentiated instruction has been shown to support adaptive and inclusive mathematics learning (Ramdhani et al., 2025). However, limited empirical research has examined how these three elements—Problem-Based Learning, learning-style-oriented differentiation, and e-module assistance—are systematically integrated to analyse students' mathematical numeracy. This gap indicates the need for further investigation into an instructional framework that simultaneously addresses pedagogical models, individual learning differences, and digital learning resources. Accordingly, the novelty of this study lies in examining students' mathematical numeracy through the integration of Problem-Based

Learning supported by differentiated e-modules while explicitly considering students' learning styles, particularly in number topics at the junior high school level. Although prior studies validate PBL, differentiated instruction, and digital modules independently, evidence on their integrated application to numeracy remains limited, particularly at the junior secondary level (Voni et al., 2025).

Based on the theoretical framework and empirical findings discussed above, this study addresses the issue of how instructional innovation can effectively enhance students' mathematical numeracy at the junior high school level. Specifically, the research problem concerns whether the implementation of the Problem-Based Learning model, when supported by differentiated e-modules, is effective in improving students' mathematical numeracy skills. Furthermore, this study examines how students' mathematical numeracy abilities are manifested when viewed from different learning styles within the context of Problem-Based Learning assisted by differentiated e-modules, particularly in number topics.

This study aims to provide empirical evidence regarding the effectiveness of the Problem-Based Learning model supported by differentiated e-modules in enhancing junior high school students' mathematical numeracy, particularly in number topics. Beyond measuring learning effectiveness, this research seeks to gain deeper insight into how students' mathematical numeracy develops across different learning styles within the implementation of Problem-Based Learning assisted by differentiated e-modules. Through this analysis, the study is expected to contribute to a more comprehensive understanding of how the integration of pedagogical models, differentiated instructional strategies, and digital learning resources can support inclusive, adaptive, and meaningful mathematics learning.

RESEARCH METHODS

This study employed a mixed methods approach with a sequential explanatory design, in which quantitative data collection and analysis were conducted in the first phase, followed by qualitative data collection and analysis in the second phase. The research was conducted at SMP Negeri 1 Kayen during the 2025/2026 academic year. This design was selected to obtain a comprehensive understanding of students' mathematical numeracy abilities by first examining measurable learning outcomes and subsequently exploring students' learning processes and experiences in depth through the implementation of Problem-Based Learning (PBL)-based e-modules with differentiated learning strategies according to learning styles (visual, auditory, and kinesthetic). The sequential explanatory design is widely recommended for studies that aim to explain and elaborate quantitative findings through qualitative evidence (Creswell, J. W., & Plano Clark, 2025).

This study uses a mixed methods approach with a sequential explanatory design, which is the quantitative stage followed by the qualitative stage. This design was chosen to obtain a comprehensive understanding of students' mathematical numeracy abilities through the application of Problem-Based Learning (PBL)-based e-modules with differentiated learning strategies according to learning styles (visual, auditory, kinesthetic). The sequential explanatory mixed-methods design is recommended to explain quantitative effects through qualitative insights and to enhance rigour in educational research.

This design refers to Creswell (2015) who states that sequential explanatory is effective for deepening quantitative outcomes through qualitative data.

The research was conducted at SMP Negeri 1 Kayen in the 2026/2026 school year. The research procedure includes: (1) identification of learning styles through questionnaires; (2) treatment in the experimental class using PBL-based differentiated e-modules; (3) measurement of numeracy ability through pretest and posttest; (4) the collection of qualitative data through observation and interviews of selected subjects, and, (5) the provision of conventional learning in the control class.

The research population is all grade VIII students of SMP Negeri 1 Kayen as many as 284 students. The sample was determined through proportional random sampling using the Slovin formula at an error level of 12%, so that 64 students, 32 students each for the experimental and control classes, were obtained.

The data source consists of primary data (numeracy test results, learning style questionnaires, interviews, and observations) and secondary data (lesson plans, e-modules, learning scores, and student attendance). Data collection techniques include tests, questionnaires, interviews, observations, and documentation.

Quantitative instruments include validated numeracy questions, learning style questionnaires, and student responses. The qualitative instrument consists of interview guides, observation sheets, and documentation formats. All instruments have gone through a validation process and a reliability test.

Quantitative data were analysed with descriptive and inferential statistics, including normality tests (Kolmogorov-Smirnov), homogeneity (Levene Test), t-test, and proportion tests for learning completeness and numeracy categorisation based on NP values. Qualitative data were analysed using the Miles and Huberman model (data reduction, presentation, and drawing of conclusions). The validity of the data was obtained through triangulation of techniques and sources, validation with member checks and trail audits, and peer discussions to maintain consistency of interpretation

RESULTS AND DISCUSSION

Table 1. Descriptive Statistics of Students' Mathematical Numeracy Scores

Group	Test	Mean	Standard Deviation (SD)
Experimental	Pretest	58.75	7.84
Experimental	Posttest	78.63	6.91
Control	Pretest	59.21	8.12
Control	Posttest	69.03	7.45

Table 1 presents the descriptive statistics of students' mathematical numeracy scores before and after the implementation of the learning intervention. The comparable pretest means scores indicate that both the experimental and control groups had similar initial numeracy abilities. Following the intervention, the experimental group demonstrated a substantially greater improvement in mean score than the control group, indicating a stronger learning gain among students who participated in Problem Based Learning assisted by differentiated e-modules.

Descriptive Statistical Analysis

Descriptive statistics were used to provide an overview of students' mathematical numeracy performance before and after the intervention. This analysis included the calculation of the mean and standard deviation for pretest and post-test scores in both the experimental and control groups. Descriptive statistics served to illustrate initial equivalence between groups and to describe the magnitude of score improvement following the learning intervention. An increase in mean scores in the experimental group compared to the control group provided preliminary evidence of the effectiveness of Problem-Based Learning assisted by differentiated e-modules.

Normality Test

Before conducting inferential analysis, a normality test was performed to examine whether the data followed a normal distribution. The Kolmogorov–Smirnov test was applied to the pretest and post-test scores of both the experimental and control groups. The results indicated that all significance values were greater than 0.05, suggesting that the data were normally distributed. Therefore, the assumption of normality required for parametric statistical testing was fulfilled. Statistical decision rule: $p > 0.05 \rightarrow$ data are normally distributed. $p \leq 0.05 \rightarrow$ data are not normally distributed.

Homogeneity of Variance Test

To ensure that the variance between groups was equivalent, a homogeneity test was conducted using Levene's Test. The results showed that the significance value exceeded 0.05, indicating that the variances of the experimental and control groups were homogeneous. This confirms that both groups had comparable variance and that the independent sample t-test could be appropriately applied. Statistical decision rule $p > 0.05$ $\rightarrow$ variances are homogeneous. $p \leq 0.05 \rightarrow$ variances are not homogeneous.

Independent Sample t-Test

An independent sample t-test was employed to determine whether there was a statistically significant difference in post-test mathematical numeracy scores between the experimental and control groups. The test results revealed a significance value of 0.001 ($p < 0.05$), indicating a significant difference between the two groups. This finding demonstrates that students who participated in Problem-Based Learning assisted by differentiated e-modules achieved significantly higher mathematical numeracy scores than those who experienced conventional instruction. Statistical decision rule $p < 0.05 \rightarrow$ significant difference exists $p \geq 0.05 \rightarrow$ no significant difference.

Proportion Test of Learning Completeness

A proportion test was conducted to examine differences in learning completeness between the experimental and control groups. The results showed that 84.37% of students in the experimental group achieved learning completeness, compared to 65.62% in the control group. This indicates that the learning intervention not only improved average performance but also increased the proportion of students who met the minimum learning criteria.

Numeracy Categorisation Analysis

Students' mathematical numeracy levels were further analysed using categorisation based on numerical proficiency (NP) values. The analysis revealed that a larger proportion of students in the experimental class reached the *proficient* category, while most students in the control class remained within the *adequate* category. This categorisation supports the conclusion that the integrated instructional approach was effective in elevating students from basic to higher levels of numeracy proficiency.

Assumption Testing: Normality and Homogeneity

Before conducting inferential statistical analysis, prerequisite tests were carried out to ensure that the data met the assumptions required for parametric testing. These assumptions include the normal distribution of the data and homogeneity of variance between groups.

Table 2. Normality and Homogeneity Test Results

Statistical Test	Group	Statistic Value	Sig. (p-value)	Interpretation
Kolmogorov–Smirnov (Normality)	Experimental	0.109	0.200	Normally distributed
Kolmogorov–Smirnov (Normality)	Control	0.103	0.200	Normally distributed
Levene's Test (Homogeneity)	Experimental & Control	0.784	0.379	Homogeneous variance

Note: Significance values (p) greater than 0.05 indicate that the assumption is fulfilled.

Table 2 presents the results of the normality and homogeneity assumption tests conducted before hypothesis testing. The Kolmogorov–Smirnov test results indicate that the mathematical numeracy scores in both the experimental and control groups were normally distributed, as all significance values exceeded 0.05. In addition, the Levene's test shows that the variance between the two groups was homogeneous ($p > 0.05$). These findings confirm that the data satisfied the assumptions required for parametric analysis, thereby justifying the use of an independent sample t-test for further statistical testing.

Independent Sample t-Test Results

After the assumptions of normality and homogeneity were fulfilled, an independent sample t-test was conducted to examine whether there was a statistically significant difference in mathematical numeracy achievement between students in the experimental and control groups after the learning intervention.

Table 3. Independent Sample t-Test Results of Posttest Scores

Group	N	Mean	SD	Mean Difference	t-value	Sig. (2-tailed)
Experimental	32	78.63	6.91	\multirow {2}{*}{9.60}	\multirow {2}{*}{3.52}	\multirow {2}{*}{0.001}
Control	32	69.03	7.45			

Note: $p < 0.05$ indicates a statistically significant difference between groups

Table 3 presents the results of the independent sample t-test comparing posttest mathematical numeracy scores between the experimental and control groups. The analysis shows a statistically significant difference between the two groups, as indicated by a significance value of 0.001 ($p < 0.05$). This result demonstrates that students who participated in Problem Based Learning assisted by differentiated e-modules achieved significantly higher mathematical numeracy scores than those who received conventional instruction. Therefore, the learning intervention can be considered effective in improving students' mathematical numeracy abilities.

Proportion Test and Numeracy Categorization Results

To further examine the effectiveness of the learning intervention, a proportion test was conducted to compare learning completeness between the experimental and control groups. Additionally, students' mathematical numeracy abilities were analyzed based on numeracy proficiency (NP) categories.

Table 4. Learning Completeness Proportion

Group	Number of Students	Students Achieving Mastery	Percentage (%)
Experimental	32	27	84.37
Control	32	21	65.62

Table 5. Mathematical Numeracy Category Distribution

Numeracy Category (NP)	Experimental (n)	Experimental (%)	Control (n)	Control (%)
Proficient	18	56.25	10	31.25
Adequate	11	34.37	17	53.12
Basic	3	9.38	5	15.63
Total	32	100	32	100

Note: Mastery learning was determined based on the minimum completion criteria set by the school. Numeracy categories were classified according to numerical proficiency (NP) score intervals.

Table 4 and Table 5 presents the results of the proportion test and the distribution of students' mathematical numeracy categories. The proportion test indicates that a higher percentage of students in the experimental group achieved learning mastery compared to the control group. Furthermore, the numeracy categorisation shows that most students in the experimental class reached the *proficient* category, whereas the majority of students in the control class remained in the *adequate* category. These findings suggest that Problem-Based Learning assisted by differentiated e-modules not only improved average numeracy scores but also increased the number of students who attained higher levels of numeracy proficiency.

Meta-analytic and bibliometric evidence show that PBL yields medium positive effects on mathematical outcomes and supports deeper understanding through inquiry and collaboration (Suparman et al., 2021). The results of this study indicate that Problem-Based Learning (PBL) assisted by differentiated e-modules significantly enhances students' mathematical numeracy. This finding is theoretically grounded in constructivist learning theory, which emphasises that knowledge is actively constructed through meaningful engagement with contextual problems rather than passively received from instruction. PBL provides a learning environment in which students explore authentic mathematical situations, discuss solution strategies collaboratively, and reflect on their reasoning processes. Such features are widely recognised as effective in strengthening mathematical competence, particularly numeracy and problem-solving skills (Gunadi & Dadang Juandi, 2022).

From a numeracy perspective, mathematical competence extends beyond procedural calculation to include reasoning, interpretation, and application of mathematics in real-world contexts. Studies on mathematical literacy and numeracy emphasise the importance of connecting classroom mathematics to everyday situations to develop deeper understanding and decision-making abilities (Bolstad, 2023). The significant improvement observed in the experimental group in this study confirms that embedding mathematical concepts within contextual problems—as facilitated by PBL—effectively supports numeracy development.

The effectiveness of the learning intervention is further explained by the integration of differentiated instruction based on students' learning styles. Differentiated instruction emphasises adaptation of content, instructional processes, and learning media to accommodate learner diversity. Empirical evidence from recent classroom-based studies shows that learning models aligned with students' visual, auditory, and kinaesthetic characteristics significantly improve mathematical understanding and engagement (Hidayati, 2020). Differentiated instruction aligned with learners' visual, auditory, and kinesthetic preferences enhances engagement and achievement in mathematics, particularly when implemented through structured frameworks (Adawiah et al., 2026). In this study, differentiated e-modules allowed students to interact with mathematical content through multiple representations, reducing cognitive barriers and supporting more personalised learning experiences

The role of digital learning resources also contributed substantially to the observed outcomes. E-modules designed with differentiated pathways and interactive features have been shown to promote learning autonomy, motivation, and conceptual clarity in mathematics learning (Ramdhani et al., 2025). Furthermore, systematic reviews confirm that e-modules are particularly effective for junior high school mathematics learning when designed to be interactive, adaptive, and problem-oriented (Adiningsih et al., 2024). The present findings align with these studies, demonstrating that differentiated e-modules function not only as digital materials but also as pedagogical tools that support inclusive numeracy instruction.

These findings support and extend previous research on problem-based and differentiated mathematics instruction. Prior development studies in Indonesia have reported that PBL-based differentiated modules improve students' mathematical problem-solving and literacy skills, but most focused on single dimensions such as conceptual understanding or problem solving (Meriza et al., 2024). In contrast, this study demonstrates that numeracy outcomes can be strengthened more comprehensively when PBL, learning-style-based differentiation, and digital e-modules are integrated within a unified instructional framework

The qualitative findings reinforce these quantitative results. Observations and interviews reveal that students were more engaged, confident in discussing mathematical ideas, and capable of identifying contextual problem patterns. Similar patterns have been reported in previous empirical studies, where PBL environments combined with cooperative and differentiated strategies foster active participation and deeper learning (Ogunsola et al., 2021). These outcomes highlight that learning effectiveness is not solely determined by instructional models but also by how well learning environments respond to students' cognitive and learning style diversity.

The novelty of this study lies in its integrated focus on mathematical numeracy as a holistic competency, examined through the convergence of PBL, differentiated instruction, and e-module assistance. While earlier studies often examined these components separately, this study provides empirical evidence that their integration produces cumulative benefits, both in terms of learning achievement and numeracy proficiency distribution. This contributes to current discussions on innovative mathematics instruction, especially within the context of curriculum reforms emphasizing student-centered and inclusive learning approaches.

CONCLUSION

This study concludes that the integration of Problem Based Learning (PBL) assisted by differentiated e-modules is effective in enhancing junior high school students' mathematical numeracy. The quantitative results demonstrate that students who participated in the integrated learning intervention achieved significantly higher numeracy outcomes than those who experienced conventional instruction, both in terms of average performance and learning completeness. These findings indicate that the learning model not only improves overall achievement but also increases the proportion of students reaching higher levels of numeracy proficiency.

The qualitative analysis strengthens these findings by revealing that differentiated e-modules supported students' engagement and conceptual understanding across diverse learning styles. Visual, auditory, and kinesthetic learners were able to access mathematical content through representations that aligned with their learning preferences, thereby facilitating more meaningful learning experiences. The role of the teacher as a facilitator within the PBL framework further contributed to active participation, collaborative problem solving, and reflective thinking, which are essential components of mathematical numeracy development.

From a theoretical perspective, the findings support constructivist views of learning and contemporary approaches to differentiated instruction, emphasizing that numeracy is best developed through contextual, problem-oriented, and inclusive learning environments. This study extends previous research by demonstrating that the integration of PBL, learning-style-based differentiation, and digital e-modules yields a cumulative pedagogical effect on mathematical numeracy, rather than treating these components as isolated instructional strategies.

The main contribution of this study lies in its integrated instructional framework and its focus on mathematical numeracy as a holistic competency encompassing reasoning, application, and decision making in real-world contexts. Practically, the findings suggest that mathematics teachers and schools are encouraged to adopt problem-based and differentiated digital learning approaches to address learner diversity and improve numeracy outcomes. Nevertheless, this study is limited by its sample size and focus on number topics, and future research is recommended to involve broader samples, longer interventions, and additional mathematical domains to further validate and generalize the findings.

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