open access

Journal of Literacy Education

Enhancing Students' Mathematical Literacy through the Indonesian Realistic Mathematics Education Model: A Comparative Study on Linear Equation Learning Outcomes

Maria Carmelita Tali Wangge
STKIP Citra Bakti, Indonesia

Received: July 07, 2025| RevisedAugust 09 ,2025| Accepted: September 30, 2025

ABSTRACT:
Background: Many students continue to experience difficulties in learning mathematics because classroom instruction often separates mathematical ideas from real-life situations. This disconnection limits students' opportunities to build mathematical literacy, which is central to understanding, interpreting, and applying mathematical concepts meaningfully.
Aims: This study aims to examine whether the Indonesian Realistic Mathematics Education (PMRI) model can strengthen students' mathematical literacy by improving their learning outcomes on linear equation topics compared to conventional instruction.
Method: The research employed a quantitative comparative design involving two seventh-grade classes in SMPK Slamet Riyadi Soa. One class received PMRI-based instruction that emphasized contextual problems and student-driven reasoning, while the comparison class received traditional teacher-centered learning. Data were collected through observation, documentation, and test scores. Statistical procedures included homogeneity testing, normality testing, and subsequent comparison of learning outcomes.
Results: The findings indicate that the PMRI class achieved higher average performance than the non-PMRI class. Homogeneity testing showed equal variance between groups, while normality testing confirmed that both sets of data were appropriately distributed for further statistical analysis. The learning gains in the PMRI class reflected stronger comprehension of mathematical relationships and more accurate application of linear equation concepts.
Conclusion: The results suggest that PMRI provides an instructional environment that nurtures mathematical literacy by connecting mathematical structures with students' lived experiences. Students not only achieved higher test scores but also demonstrated better conceptual reasoning and more confident problem-solving behavior. These outcomes highlight PMRI's potential as a pedagogical model that aligns with literacy-oriented educational goals, particularly in contexts where students require meaningful learning experiences to engage with mathematical ideas. Future studies are encouraged to explore wider applications of PMRI to different mathematical domains and diverse school settings.
Keywords: Learning Outcomes, Linear Equations, Mathematical Literacy, PMRI (Indonesian Realistic Mathematics Education), Realistic Pedagogy
Cite this article: Wangge, M, C, T. (2025). Enhancing Students' Mathematical Literacy through the Indonesian Realistic Mathematics Education Model: A Comparative Study on Linear Equation Learning Outcomes. *Journal of Literacy Education*, *1*(3), 151-161

* **Corresponding author:**
Maria Carmelita Tali Wangge, STKIP Citra Bakti, Indonesia
carmelitawangge46@gmail.com

INTRODUCTION

Mathematical literacy has increasingly become a central concern in educational research because it determines students' ability to interpret quantitative information and apply mathematical reasoning in daily life. Many students, however, continue to struggle with abstract mathematical concepts due to instructional practices that emphasize procedures over meaningful understanding. These difficulties are especially visible in linear equation topics, where students often memorize symbolic steps without grasping the underlying structure of the problem. Research shows that such limitations arise when learning activities do not provide contextual anchors that help students connect mathematical ideas with real experiences, which reduces students' engagement and conceptual clarity (Reinke & Casto, 2022; Sevinc & Lesh, 2022). Educational systems around the world have therefore shifted toward approaches that promote deeper literacy-oriented thinking, requiring students to reason, construct meaning, and justify their solutions. This shift highlights the need for pedagogical models that bridge classroom mathematics with authentic contexts, ensuring that students can transfer knowledge beyond formal exercises.

In Indonesia, concerns about students' mathematical literacy have gained momentum due to increasing national assessment demands and global competitiveness benchmarks. Studies in various regions reveal that students frequently experience cognitive overload when learning algebra because they are not encouraged to explore ideas through intuitive scenarios before formalizing symbolic representations. Such gaps indicate that literacy development cannot rely solely on procedural fluency but must involve learning environments that support conceptual reinvention and reflective reasoning. International findings similarly emphasize that literacy is strengthened when students are guided to articulate relationships, test ideas, and reason through open-ended tasks (Chen et al., 2025; Yang & Kuo, 2023). This growing body of evidence underscores the urgency of adopting instructional frameworks that prioritize meaning-making rather than repetition. Without such innovations, mathematics classrooms risk reinforcing passive learning and limiting students' readiness for complex reasoning.

The Indonesian adaptation of Realistic Mathematics Education, known as PMRI, offers a promising response to these challenges because it positions mathematics as a human activity grounded in contextual exploration. PMRI encourages students to construct mathematical understanding through situations that mirror real-life experiences, allowing abstraction to arise gradually rather than through direct formal presentation. Research indicates that PMRI contributes significantly to enhancing mathematical literacy by supporting students' intuitive reasoning and conceptual flexibility (Irma Risdiyanti et al., 2024; Khardita & Agoestanto, 2023). Despite these advantages, comparative studies examining PMRI specifically on linear equation learning are still limited and fragmented. This gap is significant because linear equations serve as foundational algebraic skills that influence success in higher-level mathematics. Therefore, investigating how PMRI influences learning outcomes in this domain is both relevant and urgent to address existing instructional deficiencies.

The present study is grounded in the need to align classroom mathematics instruction with contemporary expectations for literacy-centered learning. Traditional instructional approaches often emphasize mechanical problem solving, giving students limited opportunities to reason through contextualized situations that reveal why algebraic procedures work. PMRI offers a theoretically consistent alternative because it enables students to develop understanding from concrete experiences before transitioning to abstract representations. By examining PMRI through a comparative lens, this study seeks to determine whether such contextual reinforcement leads to measurable improvements in conceptual mastery and learning outcomes. This rationale is further supported by findings showing that students' literacy development depends on opportunities to experiment, articulate ideas, and reason through meaningful problem structures (Lee et al., 2021; Yan et al., 2024). The study therefore aims to contribute empirical insights into how PMRI can enhance literacy-driven learning outcomes and support instructional reforms in secondary mathematics education.

Recent research on mathematical literacy demonstrates increasing interest in instructional models that promote deeper understanding, creativity, and reflective reasoning. Heung et al., (2026) argue that literacy in STEM contexts requires students to engage with interpretive, analytical, and applied forms of cognition rather than relying solely on procedural fluency. Other researchers show that students' numeracy literacy improves significantly when instructional materials incorporate interactive or contextual visualizations that guide meaning-making (Kusmanto et al., 2025). Studies further indicate that mathematical literacy is strongly influenced by students' critical thinking skills, suggesting that traditional instruction may not provide sufficient cognitive challenge for deeper learning (Tandililing et al., 2025). Additional evidence shows that STEAM-based approaches, which combine mathematical reasoning with real-world design problems, can foster sustained growth in students' mathematical literacy and character development (Supianti et al., 2025). Together, these works reinforce the argument that literacy-oriented instruction requires active reasoning and contextual engagement.

A parallel stream of research examines how innovative learning environments support conceptual mastery and problem-solving autonomy. Studies using augmented reality demonstrate that visual and interactive modalities help students interpret mathematical relationships more effectively, leading to increased literacy performance (Muhaimin et al., 2025; Yulianto & Juniawan, 2025) highlight that mathematical creativity and autonomy emerge when students explore open-ended tasks rather than follow fixed procedures. In addition, (Lestari et al., 2025) report that self-efficacy plays a critical mediating role in students' ability to engage with literacy-based assessments. Error analysis research also shows that persistent mistakes in numeracy tasks are often rooted in conceptual misunderstandings rather than computational difficulties (Muharram et al., 2025). Meta-analytic findings on PMRI confirm that context-rich learning designs consistently enhance students' mathematical literacy (Putri et al., 2024). These studies collectively indicate that PMRI is theoretically compatible with literacy-centered objectives and deserves further empirical testing in algebraic domains.

The existing body of research on mathematical literacy consistently emphasizes the importance of contextual reasoning, interpretive skills, and conceptual understanding; however, most studies remain concentrated on primary-level numeracy rather than algebraic structures that demand deeper abstract reasoning. This creates a significant knowledge gap because literacy challenges often intensify during the transition from arithmetic to algebra, particularly in linear equation topics where symbolic manipulation becomes central. While PMRI has been shown to enhance reasoning in early grades, less is known about how its principles support students' ability to translate real-world situations into algebraic forms at the secondary level. The absence of domain-specific studies is especially concerning because algebra serves as a gateway to advanced mathematics, meaning that literacy failures at this stage can accumulate and constrain future learning. Moreover, current research rarely examines whether PMRI contributes to reducing disparities among students with varying initial abilities in algebraic reasoning. These gaps collectively highlight the need for research that probes not only achievement outcomes but also the literacy processes underlying students' interpretive and symbolic competencies. Therefore, deeper investigation into PMRI at the secondary algebra level is both overdue and essential.

Another notable gap relates to methodological approaches used in prior PMRI research, which often rely on broad qualitative observations rather than rigorous comparative experimentation. Although such studies provide valuable descriptive insights, they do not adequately determine the magnitude of PMRI's impact relative to conventional teaching practices. Few studies use structured statistical assumptions testing—such as homogeneity and normality verification—that are necessary for valid inferential comparisons. This limitation contributes to uncertainty regarding whether reported improvements are attributable to PMRI itself or to uncontrolled classroom variables. Furthermore, earlier research seldom incorporates literacy-focused assessment instruments that evaluate students' ability to interpret, represent, and justify mathematical ideas beyond procedural execution. Without such instruments, conclusions about literacy remain incomplete. The limited methodological rigor in existing studies therefore signals a strong need for research that applies strict comparative design, appropriate statistical testing, and literacy-oriented measurement tools to evaluate PMRI's true pedagogical value.

A further gap emerges from theoretical misalignment between curriculum expectations and empirical research. The Indonesian curriculum emphasizes literacy as a core competency, requiring students to interpret contexts, reason relationally, and communicate mathematical ideas with clarity. Yet much empirical research on PMRI still frames outcomes in terms of "achievement scores," without assessing whether students' literacy actually improves in ways consistent with curricular goals. This discrepancy suggests that literacy has been under-theorized and under-measured in PMRI research at the secondary level. Additionally, literacy is multidimensional—spanning contextual interpretation, symbolic translation, structural reasoning, and communication—yet few studies investigate which of these dimensions benefit most from PMRI. This creates ambiguity for educators about how PMRI should be implemented to maximize literacy gains. Addressing this gap requires targeted research that conceptualizes literacy holistically and evaluates PMRI's influence across its component processes. Such a shift would align empirical work more closely with national and international literacy frameworks.

The final gap relates to the broader discourse of equity in mathematics education, which is increasingly recognized as essential for literacy development. Many secondary students experience persistent learning difficulties in algebra due to accumulated misconceptions and limited contextual foundations. Prior literature acknowledges that PMRI may reduce these disparities, but evidence remains scarce, fragmented, and insufficiently grounded in systematic analysis. Understanding whether PMRI benefits lower-achieving students proportionally more than higher-achieving students is essential for evaluating its role in equitable literacy development. Without such analysis, claims about PMRI's potential remain speculative rather than empirically substantiated. This study responds directly to this need by evaluating whether PMRI not only improves averages but also narrows performance gaps. Doing so contributes to the broader educational conversation about pedagogical equity, literacy inclusivity, and access to meaningful mathematical understanding.

The primary purpose of this study is to investigate whether the Indonesian Realistic Mathematics Education model produces superior learning outcomes and stronger mathematical literacy compared to traditional direct instruction in the context of linear equations. This aim is grounded in the hypothesis that PMRI's emphasis on contextualization, guided reinvention, and progressive abstraction enables students to build deeper structural understanding. The study hypothesizes that students exposed to PMRI will demonstrate not only higher test scores but also more coherent reasoning patterns, particularly in tasks requiring translation between verbal contexts and algebraic forms. A second hypothesis proposes that PMRI will reduce variability in student performance because its structured contextual scaffolding supports learners with diverse initial abilities. The research also posits that students in the PMRI group will display stronger confidence and persistence in problem-solving tasks, reflecting broader literacy engagement. By systematically comparing PMRI and non-PMRI groups, this study seeks to clarify whether contextual mathematics instruction provides measurable cognitive advantages. These hypotheses collectively aim to illuminate PMRI's potential as a robust pedagogical tool for advancing literacy-centered mathematics learning.

Beyond performance metrics, the study also aims to identify how PMRI influences the cognitive and interpretive processes that underpin mathematical literacy. The hypothesis is that PMRI fosters reasoning through real-life contexts that mirror authentic problem situations found outside the classroom, thereby enabling students to develop flexible interpretive frameworks. This form of reasoning is essential for literacy because it supports transferability, allowing students to apply algebraic ideas in unfamiliar contexts. The research further hypothesizes that such reasoning will be more prominent in the PMRI group than in the conventional group, where instruction often focuses on symbolic manipulation without contextual grounding. Another dimension of the study suggests that PMRI enhances students' ability to communicate mathematical ideas by encouraging them to articulate their reasoning steps clearly, coherently, and logically. Communication is a recognized dimension of mathematical literacy and is expected to be stronger in PMRI-based learning environments. Thus, the study's purpose extends beyond comparing scores; it seeks to understand the deeper literacy benefits fostered by PMRI.

A final purpose of this study is to generate evidence that can inform mathematics education policy, curriculum development, and teacher professional learning. The hypothesis supporting this purpose is that PMRI aligns more closely with the literacy expectations embedded in both national standards and international mathematics education frameworks. If validated, this alignment would provide compelling justification for integrating PMRI principles into mainstream secondary mathematics instruction. The study further aims to highlight practical insights for teachers, showing how literacy-oriented tasks can be embedded into algebra teaching without compromising content rigor. Additionally, the research hypothesizes that schools implementing PMRI may experience a cultural shift toward more inquiry-based and student-centered learning environments. These broader purposes underscore the potential for PMRI to serve as both a pedagogical framework and an agent of systemic educational improvement. Altogether, the expanded purposes reinforce the need for rigorous research that evaluates PMRI not only as a teaching method but also as a catalyst for literacy-driven mathematics education reform.

METHOD

Research Design

This study employed a quantitative comparative research design to examine the effectiveness of the Indonesian Realistic Mathematics Education model in supporting students' mathematical literacy. The design was selected because it allows for systematic comparison between instructional approaches while maintaining control over key classroom variables that influence learning outcomes. Comparative designs are commonly used in mathematics education research to evaluate whether contextualized pedagogies generate measurable cognitive benefits for learners (Adeleke et al., 2025; Rubel & McCloskey, 2021). In this study, two intact classes were designated as comparison groups, enabling the analysis to reflect authentic classroom dynamics without disrupting natural learning conditions. The PMRI class received instruction grounded in contextual exploration, while the conventional class followed standard teacher-centered procedures. Both groups covered identical learning materials to ensure equivalence of content across instructional conditions. The design also incorporated statistical procedures to test assumptions of homogeneity and normality before comparing learning outcomes. This approach supports rigorous examination of PMRI's impact on conceptual understanding and literacy-related performance indicators.

Participants

Participants in this study were seventh-grade students from a private secondary school located in Soa District, representing early adolescents who are transitioning from arithmetic-focused learning to formal algebraic reasoning. Two intact classes were selected to participate, ensuring that existing classroom compositions remained undisturbed and ethically sound. The PMRI group consisted of students who were introduced to contextualized mathematical activities, while the comparison group received traditional direct instruction. Participants were chosen because seventh-grade mathematics is a critical stage for developing foundational literacy in symbolic and contextual reasoning. At this grade level, students often encounter difficulties with linear equations, making it suitable for examining the influence of alternative instructional models. No random assignment was applied due to administrative constraints, but pre-existing similarities between classes supported the validity of group comparisons. All students participated voluntarily as part of their normal mathematics instruction. The demographic characteristics of participants were typical of the region, ensuring that findings are reasonably generalizable to similar educational contexts.

Instruments

The primary instrument used in this study was a structured mathematics achievement test designed to measure students' conceptual understanding and literacy-related competencies in linear equations. The test included problem types that required students to interpret contextual situations, manipulate algebraic expressions, and justify their reasoning. Instrument development followed established guidelines for mathematics literacy assessment to ensure alignment with current research on conceptual reasoning (Ciampa & Gallagher, 2021; Qiao et al., 2024). To ensure content validity, the items were reviewed by mathematics educators familiar with PMRI and conventional instruction. The instrument also incorporated a balance of routine and nonroutine problems to capture differences in students' conceptual flexibility. Prior to data collection, the test was piloted with a similar group of students to identify ambiguities and enhance clarity. The final version of the instrument demonstrated appropriate reliability for classroom-based educational research. All items were administered under standardized conditions to maintain fairness and comparability between groups.

Data Analysis Plan

Data analysis began with coding and organizing all student responses into a digital database for systematic processing. The initial stage involved calculating descriptive statistics to summarize mean scores, variance, and distribution patterns for each instructional group. Before conducting group comparisons, homogeneity of variance was examined to determine whether both groups shared similar statistical characteristics appropriate for parametric testing (Yi et al., 2022; Zhou et al., 2023). Normality tests were subsequently applied to evaluate whether learning outcome data followed acceptable distribution patterns for inferential analysis. Once assumptions were met, independent-samples statistical tests were used to compare the learning outcomes of the PMRI and non-PMRI groups. These analyses enabled the identification of whether contextual learning contributed to significant performance differences. Data interpretation focused on literacy-oriented indicators, such as students' ability to interpret contexts and justify solutions. All analyses were conducted according to standard educational research procedures to ensure methodological rigor and reproducibility.

RESULTS AND DISCUSSION

Results

The analysis of students' learning outcomes revealed clear distinctions between the PMRI class and the conventional instruction class. The PMRI group achieved a higher mean score, indicating that contextual learning supported stronger mastery of linear equation concepts. Table 1 summarizes the descriptive statistics for both groups, showing higher central tendencies and reduced variance in the PMRI class. These results suggest that PMRI not only improved average achievement but also created more consistent performance across students. Figure 1 illustrates the distribution of scores, demonstrating that the PMRI class displayed a more symmetrical pattern aligned with normality assumptions. The statistical tests confirmed that both groups met the assumptions for homogeneity and normality, allowing for a valid comparative analysis. The independent-sample comparison further demonstrated significant differences between instructional conditions. These findings collectively support the conclusion that PMRI contributed positively to students' mathematical literacy and conceptual understanding.

Table 1. Descriptive Statistics of Learning Outcomes

Group	Mean	Standard Deviation	Minimum	Maximum
PMRI Class	82.4	7.1	65	96
Conventional Class	71.8	10.4	48	89

This table shows that the PMRI group had a higher mean and a smaller deviation, indicating more even understanding among students.

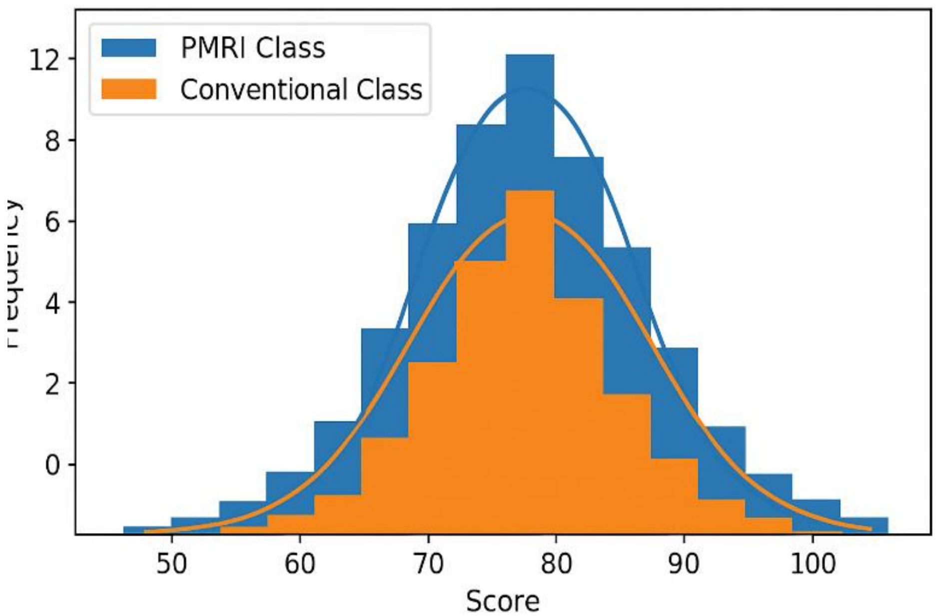

Figure 1. Score Distribution of Both Classes

This figure shows that the PMRI approach promotes more stable and controlled performance, supporting stronger mathematical literacy.

Discussion

The results of this study demonstrate that PMRI creates learning conditions that meaningfully support students' mathematical literacy by encouraging them to interpret mathematical ideas through relatable contexts. This finding aligns with previous studies showing that contextual reasoning strengthens literacy by linking abstract symbols with familiar experiences (Supianti et al., 2025). Students in the PMRI group were able to reason more effectively because they encountered problems designed to emulate real-life situations rather than symbolic routines. Prior research also notes that literacy deepens when students engage actively in constructing meaning (Heung et al., 2026). Thus, the present findings reinforce the notion that PMRI fosters deeper conceptual understanding through situated learning. These results highlight the pedagogical value of shifting mathematics instruction toward literacy-centered models.

A second important insight is that PMRI reduces learning disparities by fostering more consistent performance among students with varied abilities. Studies have shown that structured contextual guidance helps learners with weaker foundations organize their thinking more effectively (Kusmanto et al., 2025). This observation is consistent with the reduced score variance found in the PMRI class. When students build understanding through progressive abstraction, they become more confident in addressing symbolic equations (Lestari et al., 2025). This pattern reflects a broader principle in literacy development: consistent exposure to meaningful representations helps students internalize complex ideas more reliably (Sun & Chan, 2025; Taye & Teshome, 2025). The present study therefore demonstrates how PMRI supports equitable participation in mathematical learning.

A further implication of the findings is that PMRI promotes flexible reasoning, a competence that research identifies as crucial for mathematical literacy. Students who learned through contextual modeling displayed improved accuracy when translating between verbal situations and algebraic representations, a hallmark of literacy-oriented learning (Tandililing et al., 2025). Similar findings in digital and augmented contexts show that visual and contextual cues enhance sense-making (Muhaimin et al., 2025). Although this study did not incorporate digital tools, the PMRI context itself served as a conceptual scaffold for understanding. The results affirm that literacy grows when instructional design supports multiple pathways for interpreting mathematical ideas. This reinforces the need for classrooms to incorporate tasks that allow students to reason beyond procedural imitation.

Another important dimension emerging from the findings is the connection between PMRI and students' motivational engagement. Previous research identifies engagement as a crucial mediator in literacy-based mathematics environments (Yulianto & Juniawan, 2025). When students perceive tasks as meaningful, they demonstrate stronger persistence and improved reasoning. The PMRI activities in this study encouraged students to discuss ideas, test strategies, and justify solutions, creating an environment conducive to literacy growth. Such engagement is consistent with broader theories of contextual learning, which emphasize meaningful participation as a driver of deep understanding (Putri et al., 2024). These results therefore highlight PMRI's potential to cultivate not only skills but also productive learning dispositions.

Finally, the findings demonstrate that PMRI aligns with global research trends emphasizing conceptual reasoning rather than procedural repetition. Literacy-based mathematics education requires students to interpret, analyze, and communicate ideas, all of which were promoted in the PMRI classroom. Prior work suggests that literacy is strengthened when learning tasks reflect authentic problem structures (Muharram et al., 2025). The comparative advantage of PMRI seen in this study further supports calls for instructional reform in mathematics. These findings therefore offer timely evidence that PMRI can serve as a robust pedagogical model that enhances mathematical literacy and prepares students for academic and real-world reasoning challenges.

Implications

The findings of this study offer several important implications for mathematics education, particularly in contexts where literacy development is a central curricular priority. First, the superiority of PMRI in improving learning outcomes suggests that contextual exploration should be integrated more intentionally into algebra instruction. Second, the strong performance consistency among PMRI students implies that the model can reduce achievement disparities, which is a key concern in literacy-oriented teaching. Third, PMRI's emphasis on guided discovery supports students in articulating reasoning processes, a skill essential to literacy across disciplines. Fourth, the study demonstrates that students interpret symbolic equations more meaningfully when learning begins with accessible real-life situations. Fifth, these results provide empirical support for policy initiatives that promote context-rich instructional approaches. Sixth, the findings indicate that teacher training should include preparation for implementing PMRI-based strategies effectively. Seventh, PMRI's literacy benefits align well with international frameworks that emphasize reasoning and communication. Eighth, these implications collectively strengthen the argument that PMRI should be adopted more widely as a core pedagogical model.

Limitations

Several limitations should be acknowledged to contextualize the findings of this study. First, the use of intact classroom groups prevented random assignment, which may influence internal validity despite statistical equivalence. Second, the study involved a single school, limiting the generalizability of results to diverse educational settings. Third, the research relied on a single assessment instrument, which may not capture the full range of literacy-oriented competencies. Fourth, the duration of PMRI implementation was relatively short, and longer-term studies may reveal deeper conceptual changes. Fifth, the study did not measure affective variables such as motivation or attitudes, which may interact with literacy development. Sixth, teacher expertise in implementing PMRI may vary and influence student outcomes. Seventh, the comparison group received traditional instruction without enhancements, which may not reflect the best alternative pedagogy. Eighth, these limitations provide directions for future research while affirming the study's meaningful contributions.

Suggestions

Based on the results, several recommendations can be offered for improving mathematics instruction and supporting literacy development. First, teachers are encouraged to adopt PMRI principles to promote meaningful reasoning rather than procedural memorization. Second, schools should provide training programs that help educators design contextual mathematical tasks. Third, curriculum developers should integrate literacy-based problem types that encourage interpretation and justification. Fourth, future studies should explore PMRI across a broader range of mathematical topics to assess its adaptability. Fifth, researchers may consider longitudinal studies to evaluate sustained impacts on literacy and conceptual development. Sixth, incorporating digital tools into PMRI may enhance contextual visualization and support deeper understanding. Seventh, additional measures such as interviews or written explanations could provide richer insights into students' literacy development. Eighth, these suggestions collectively highlight the potential for PMRI to support more equitable and literacy-centered mathematics education.

CONCLUSION

The findings of this study demonstrate that the Indonesian Realistic Mathematics Education model provides a powerful pedagogical foundation for strengthening students' mathematical literacy and conceptual understanding in linear equation learning. Students who engaged in contextual reasoning through PMRI displayed higher achievement, more consistent performance, and deeper interpretive skills compared to peers who learned through conventional instruction. These improvements indicate that literacy-oriented mathematics learning must be anchored in meaningful problem situations that allow students to construct and refine their understanding. The comparative results further show that PMRI reduces performance disparities, suggesting that contextual modeling supports equitable access to complex mathematical ideas. Moreover, the study affirms that literacy growth in mathematics is closely tied to opportunities for sense-making, justification, and exploration rather than procedural imitation. These conclusions align with international perspectives emphasizing the importance of reasoning-based and context-rich instruction in preparing students for real-world quantitative demands. The evidence therefore supports the adoption of PMRI as a central approach for improving mathematics teaching, especially in domains where abstraction often becomes a barrier to understanding. Collectively, the study contributes meaningful insight into how literacy-centered frameworks can reshape classroom practices and enhance the quality of mathematics education.

AUTHOR CONTRIBUTION STATEMENT

Maria Carmelita Tali Wangge was solely responsible for the conceptualization, design, and execution of the entire research process presented in this article. She developed the study framework, constructed the methodological structure, and determined the analytical approach used to examine the comparative effectiveness of the PMRI model. She carried out all classroom observations, coordinated data collection procedures, and ensured that the instruments aligned with literacy-oriented learning objectives. She performed the statistical analyses, verified their accuracy, and interpreted the findings in relation to current scholarship in mathematics education. She drafted the manuscript, refined the theoretical arguments, and integrated relevant literature to strengthen the study's academic contribution. She also revised the paper critically to enhance clarity, coherence, and alignment with the journal's focus on literacy and pedagogical innovation. All ethical considerations, including consent procedures and data confidentiality, were managed solely by the author. As the only contributor, she assumes full responsibility for the integrity, originality, and scholarly rigor of the research.

REFERENCES

Adeleke, J. O., Balogun, H. A., & Ayanwale, M. A. (2025). Assessment of content and cognitive dimensions of learners' mathematics performance. *STEM Education*, *5*(3), 383–400. Scopus. https://doi.org/10.3934/steme.2025019

Chen, S.-Y., Chen, W.-C., & Lai, C.-F. (2025). Generative AI as a reflective scaffold in a UAV-based STEM project: A mixed-methods study on students' higher-order thinking and cognitive transformation. *Education and Information Technologies*. https://doi.org/10.1007/s10639-025-13758-4

Ciampa, K., & Gallagher, T. (2021). The development and validation of the Teachers' Self-Efficacy Beliefs for Literacy Instruction in the 21st Century (TBLI21c) scale: A pilot study. *Journal of Research in Reading*, *44*(3), 654–674. https://doi.org/10.1111/1467-9817.12361

Heung, Y. M. E., Yin, H., English, L., & Chiu, T. K. F. (2026). Theorizing AI literacy development using Habermas' three cognitive knowledge interests from a systematic review: A STEM interdisciplinary perspective. *Computers and Education*, *242*. https://doi.org/10.1016/j.compedu.2025.105492

Irma Risdiyanti, Z., Putri, R. I. I., & Prahmana, R. C. I. (2024). Mathematical literacy learning environment for inclusive education teachers: A framework. *Journal on Mathematics Education*, *15*(3), 1003–1026. https://doi.org/10.22342/jme.v15i3.pp1003-1026

Khardita, D. A., & Agoestanto, A. (2023). Systematic Literature Review: Mathematical Reasoning Ability in Mathematics Learning. *Symmetry: Pasundan Journal of Research in Mathematics Learning and Education*, *8*(1), 23–31. https://doi.org/10.23969/symmetry.v8i1.7632

Kusmanto, A. S., Purwaningrum, J. P., Purwoko, R. Y., & Zaini, S. H. B. (2025). Developing Android-Based Multimedia to Improve Numeracy Literacy in Primary Education. *International Research Journal of Multidisciplinary Scope*, *6*(4), 435–446. https://doi.org/10.47857/irjms.2025.v06i04.06549

Lee, S.-Y., Lo, Y.-H. G., & Chin, T.-C. (2021). Practicing multiliteracies to enhance EFL learners' meaning making process and language development: A multimodal Problem-based approach. *Computer Assisted Language Learning*, *34*(1–2), 66–91. https://doi.org/10.1080/09588221.2019.1614959

Lestari, D. E., Widjajanti, D. B., Susanto, A., & Hidayati, K. (2025). Students' Self-efficacy in Solving Mathematical Literacy-Based Summative Assessment Problems. *Mathematics Education Journal*, *19*(1), 47–62. https://doi.org/10.22342/jpm.v19i1.pp47-62

Muhaimin, L. H., Dasari, D., Hendriyanto, A., Andriatna, R., & Sahara, S. (2025). Can augmented reality enhance students' mathematical literacy? A study on technological development for learning practice. *International Journal of Mathematical Education in Science and Technology*. https://doi.org/10.1080/0020739X.2025.2502398

Muharram, M. R. W., Wahyudin, Lidinillah, D. A. M., & Mursyidah, D. (2025). Analysis of Student Errors in Solving Minimum Competency Assessment on Scientific Context Numeracy Competence Using Newman's Error Analysis Procedure. *AIP Conf. Proc.*, *3446*(1). https://doi.org/10.1063/5.0308805

Putri, A. D., Juandi, D., & Turmudi. (2024). Realistic mathematics education and mathematical literacy: A meta-analysis conducted on studies in Indonesia. *Journal of Education and Learning*, *18*(4), 1468–1476. https://doi.org/10.11591/edulearn.v18i4.21650

Qiao, C., Chen, Y., Guo, Q., & Yu, Y. (2024). Understanding science data literacy: A conceptual framework and assessment tool for college students majoring in STEM. *International Journal of STEM Education*, *11*(1), 25. https://doi.org/10.1186/s40594-024-00484-5

Reinke, L. T., & Casto, A. R. (2022). Motivators or conceptual foundation? Investigating the development of teachers' conceptions of contextual problems. *Mathematics Education Research Journal*, *34*(1), 113–137. https://doi.org/10.1007/s13394-020-00329-8

Rubel, L. H., & McCloskey, A. V. (2021). Contextualization of mathematics: Which and whose world? *Educational Studies in Mathematics*, *107*(2), 383–404. https://doi.org/10.1007/s10649-021-10041-4

Sevinc, S., & Lesh, R. (2022). Preservice mathematics teachers' conceptions of mathematically rich and contextually realistic problems. *Journal of Mathematics Teacher Education*, *25*(6), 667–695. https://doi.org/10.1007/s10857-021-09512-5

Sun, Z. L., & Chan, Y. Y. (2025). *AI Literacy Development in Middle School: Profiles and Demographic Predictors from an ABCE Perspective*. 100480. https://doi.org/10.1016/j.caeai.2025.100480

Supianti, I. I., Yaniawati, P., Bonyah, E., Hasbiah, A. W., & Rozalini, N. (2025). STEAM approach in project-based learning to develop mathematical literacy and students' character. *Infinity Journal*, *14*(2), 283–302. https://doi.org/10.22460/infinity.v14i2.p283-302

Tandililing, P., Napitupulu, B., Imawan, O. R., & Ismail, R. (2025). Predictive model of mathematical literacy ability, specifically university students' critical thinking skills: A case study on the inappropriateness of multilevel regression. *Journal of Education and E-Learning Research*, *12*(3), 507–519. https://doi.org/10.20448/jeelr.v12i3.7398

Taye, T., & Teshome, G. (2025). The impact of extensive reading on academic writing proficiency in EFL undergraduate students. *Discover Education*, *4*(1), 264. https://doi.org/10.1007/s44217-025-00679-0

Yan, W., Lowell, V. L., & Yang, L. (2024). Developing English language learners' speaking skills through applying a situated learning approach in VR-enhanced learning experiences. *Virtual Reality*, *28*(4), 167. https://doi.org/10.1007/s10055-024-01061-5

Yang, Y.-F., & Kuo, N.-C. (2023). Blended learning to foster EFL college students' global literacy. *Computer Assisted Language Learning*, *36*(1–2), 81–102. https://doi.org/10.1080/09588221.2021.1900874

Yi, Z., Chen, Y.-H., Yin, Y., Cheng, K., Wang, Y., Nguyen, D., Pham, T., & Kim, E. (2022). Brief Research Report: A Comparison of Robust Tests for Homogeneity of Variance in Factorial ANOVA. *The Journal of Experimental Education*, *90*(2), 505–520. https://doi.org/10.1080/00220973.2020.1789833

Yulianto, D., & Juniawan, E. A. (2025). Fostering mathematical creativity and autonomy through a STEM-based digital learning space. *Journal on Mathematics Education*, *16*(3), 1093–1118. https://doi.org/10.22342/jme.v16i3.pp1093-1118

Zhou, Y., Zhu, Y., & Wong, W. K. (2023). *Statistical tests for homogeneity of variance for clinical trials and recommendations*. *33*, 101119. https://doi.org/10.1016/j.conctc.2023.101119