JPPIPA 12(5) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of PBL-Based E-Modules to Enhance Numerical Problem-Solving Skills among Vocational High School Students

Eky Putri Prasanti[1*], Ahmad Fauzan[1], Yerizon[1], Yarman[1]

[1] Universitas Negeri Padang, Padang, Indonesia.

Received: February 09, 2026
Revised: April 28, 2026
Accepted: May 25, 2026
Published: May 31, 2026

Corresponding Author:
Eky Putri Prasanti
ekiputri87@gmail.com

DOI: 10.29303/jppipa.v12i5.15240

Abstract: This study developed a Problem-Based Learning (PBL)-based e-module to enhance Numerical problem-solving skills among Grade X vocational high school students. Using the Plomp research and development model, the product underwent preliminary research, prototyping, and assessment phases, evaluated for validity, practicality, and effectiveness. Results indicated the e-module achieved a validity score of 3.36 (valid category) and the accompanying student worksheet scored 3.68 (very valid). Practicality assessments from students and teachers averaged 80.00%, confirming usability and accessibility via smartphones. Effectiveness testing demonstrated 76% average achievement in Numerical problem-solving, with 79.16% of students reaching minimum competency thresholds. Students showed notable improvement in problem comprehension and strategic planning, though reflective verification required further instructional scaffolding. The findings confirm that the PBL-based e-module meets established quality criteria and offers a replicable, curriculum-aligned framework for fostering active, student-centered Numericals learning in vocational education contexts.

Keywords: E-module; Numerical problem-solving; Problem-based learning; Vocational education

Introduction

Numerical problem-solving is a foundational competency explicitly prioritized within Indonesia's Merdeka Curriculum, particularly for vocational high school students who must apply quantitative reasoning to real-world and technical contexts (Luengo-Aravena et al., 2024). Despite its curricular emphasis, classroom observations and preliminary diagnostics consistently indicate that many learners struggle to navigate the structured cognitive processes required for effective problem-solving (Wang & Cao, 2025). Students frequently demonstrate difficulty in comprehensively understanding problem statements, formulating strategic solution plans, executing accurate Numerical procedures, and critically verifying their outcomes (Zuo et al., 2025). These challenges are often exacerbated by instructional practices that remain heavily teacher-directed and reliant on static, print-based materials, which limit opportunities for active exploration, self-regulated learning, and contextual engagement (Metreveli et al., 2025).

The rapid integration of digital technologies into education offers a strategic avenue to address these pedagogical gaps (Qu et al., 2024). Interactive e-modules can deliver flexible, multimedia-supported learning environments that enable self-paced study, provide immediate feedback, and align with contemporary students' digital literacy (Su, 2024). However, technological tools alone do not guarantee improved cognitive outcomes; their impact is maximized when embedded within instructional models that actively stimulate higher-order thinking (Wang et al., 2023). Problem-Based Learning (PBL) is particularly well-suited for Numericals education, as it organizes learning around authentic, open-ended challenges that require students to collaboratively investigate, construct knowledge, and iteratively refine their reasoning (Muliyadi et al., 2026). By merging the affordances of digital e-modules with the inquiry-driven structure of PBL, educators can create learning experiences that

How to Cite:
Prasanti, E. P., Fauzan, A., Yerizon, & Yarman. (2026). Development of PBL-Based E-Modules to Enhance Numerical Problem-Solving Skills among Vocational High School Students. *Jurnal Penelitian Pendidikan IPA*, *12*(5), 403–409. https://doi.org/10.29303/jppipa.v12i5.15240

closely mirror the sequential demands of Numerical problem-solving (Ruzicic et al., 2026).

This study aims to develop a comprehensive learning package centered on a PBL-based e-module specifically designed to strengthen the Numerical problem-solving abilities of vocational high school students. The work is guided by three primary objectives: (1) to design and construct an interactive e-module that systematically integrates PBL phases with established problem-solving indicators, (2) to evaluate the developed product's validity and practicality through expert validation and iterative field testing, and (3) to assess its effectiveness in enhancing students' capacity to understand problems, plan solution strategies, execute Numerical procedures, and verify results. By aligning innovative digital media with a research-backed pedagogical framework, this research seeks to produce a scalable, curriculum-aligned instructional resource that supports meaningful, student-centered Numericals learning in vocational education settings.

Method

Research Design

This study employed a Research and Development (R&D) approach, which is specifically designed to produce and validate educational products through systematic procedures (Sugiyono, 2012). The primary objective was to develop a Problem-Based Learning (PBL)-based e-module aimed at enhancing Numerical problem-solving skills among vocational high school students. The research followed the development model proposed by Plomp et al. (2013), which emphasizes iterative design cycles and formative evaluation to ensure product quality in terms of validity, practicality, and effectiveness.

Development Model and Procedures

The Plomp development model consists of three interconnected phases: (1) preliminary research, (2) prototyping phase, and (3) assessment phase. Each phase incorporates systematic activities and formative evaluation layers to refine the product progressively.

Phase 1: Preliminary Research

This phase focused on contextual analysis and needs assessment to establish the foundational requirements for the e-module development. Activities included, Needs Analysis: Conducted through classroom observations, teacher interviews, and student questionnaires to identify gaps in current instructional practices and students' problem-solving difficulties; Curriculum Analysis: Examined the Merdeka Curriculum's Capaian Pembelajaran (CP) and Alur Tujuan Pembelajaran (ATP) for Phase E (Grade 10) to ensure alignment of learning objectives, content scope, and assessment strategies; Concept Analysis: Mapped essential statistical concepts (frequency distribution, measures of central tendency, quartiles, and dispersion) to ensure logical sequencing and conceptual coherence and Student Characteristic Analysis: Assessed students' academic readiness, learning preferences, and digital literacy through surveys to inform the e-module's design features, language level, and interactive elements.

Phase 2: Prototyping Phase

This phase involved the iterative design, development, and formative evaluation of the e-module prototype. The process included, Initial Design (Prototype 1): Developed the e-module structure using Lumi Education, integrating PBL syntax (orientation, organization, investigation, presentation, and evaluation) with Polya's problem-solving indicators (understanding, planning, executing, and reviewing). The module included interactive features such as embedded videos, adaptive quizzes, and process-tracking capabilities; Self-Evaluation: The researcher conducted an internal review using a structured checklist to identify typographical errors, instructional inconsistencies, and alignment issues before external validation; Expert Review: Four validators (two Numericals education experts, one language specialist, and one educational technology expert) evaluated the prototype using validated instruments assessing content validity, construct validity, linguistic clarity, and graphical design. Revisions were made based on quantitative scores and qualitative feedback; One-to-One Evaluation: Three students representing low, medium, and high ability levels tested the revised prototype. Semi-structured interviews gathered feedback on usability, comprehensibility, and engagement, leading to further refinements (Prototype 3); and Small-Group Evaluation: Six students (two per ability level) participated in a trial implementation. Data were collected through observation, worksheets, and practicality questionnaires to assess ease of use, time efficiency, and instructional clarity. Results informed the development of Prototype 4.

Phase 3: Assessment Phase

The final phase evaluated the practicality and effectiveness of the refined e-module through field testing, Field Test: Implemented in one Grade 10 class (n=24) at SMKN 11 Sarolangun over four instructional sessions. The teacher facilitated PBL-based lessons using the e-module while researchers observed instructional fidelity; Practicality Assessment: Measured via questionnaires completed by students and the teacher, evaluating dimensions of usability, comprehensibility, appeal, time efficiency, and perceived usefulness. Data were analyzed using descriptive statistics and categorized based on predefined thresholds (≥75% = practical); and Effectiveness Assessment: Assessed through a post-test measuring students' Numerical problem-solving performance across four Polya-based indicators. Scores were analyzed using rubric-based scoring (Hendriana & Soemarmo, 2014) and categorized as effective if ≥75% of students achieved the minimum competency threshold.

Research Subjects

Participants were selected purposively based on the development phase requirements, Validation phase: Four subject-matter experts with relevant academic credentials; One-to-one evaluation: Three Grade 10 students stratified by Numerical ability; Small-group evaluation: Six Grade 10 students (two per ability stratum); and Field test: One intact class of 24 Grade 10 students and one Numericals teacher at SMKN 11 Sarolangun.

Data Collection Instruments

Multiple instruments were employed to ensure triangulation and comprehensive evaluation: Validity Instruments: Expert validation sheets assessing content, construct, language, and graphical aspects using a 4-point Likert scale; Practicality Instruments: Student and teacher questionnaires measuring usability, clarity, engagement, and time efficiency; observation checklists for instructional implementation fidelity; Effectiveness Instruments: A five-item problem-solving test aligned with Polya's indicators, scored using a validated analytic rubric (0–4 points per indicator); and Qualitative Instruments: Semi-structured interview guides for needs analysis and formative feedback collection.

Data Analysis Techniques

Validity Analysis: Mean scores from expert ratings were calculated and interpreted using predefined criteria: 3.50–4.00 = very valid; 3.00–3.49 = valid; 2.00–2.99 = less valid; 1.00–1.99 = invalid. Practicality Analysis: Questionnaire responses were converted to percentages using the formula P = (R/SM) × 100%, where R = obtained score and SM = maximum score. Categories: ≥75% = practical; 50–74% = fairly practical; <50% = impractical. Effectiveness Analysis: Problem-solving test scores were aggregated by indicator and overall performance. Classical effectiveness was determined if ≥75% of students achieved the minimum competency score (≥75). Qualitative Data: Interview and observation notes were analyzed thematically to complement quantitative findings and inform iterative revisions.

Result and Discussion

This study produced a Problem-Based Learning (PBL)-based e-module learning package designed to enhance Numerical problem-solving skills among Grade X vocational high school students. The development followed the Plomp model through three phases: preliminary research, prototyping, and assessment. Key findings are presented according to the three quality criteria: validity, practicality, and effectiveness.

Validity

The developed e-module and student worksheet (LKPD) were validated by four experts (two Numericals education specialists, one language expert, and one educational technology expert). Results indicated that both products met the validity criteria.

Table 1. Results of Validity Assessment by Experts

Product	Average Validity Score	Category
PBL-based E-module	3.36	Valid
Student Worksheet (LKPD)	3.68	Very Valid

The e-module demonstrated systematic alignment between PBL syntax (orientation, organization, investigation, presentation, evaluation) and Polya's problem-solving indicators (understanding, planning, executing, reviewing). Key validated features included smartphone compatibility, interactive multimedia elements, and activity-tracking capabilities that enable teachers to analyze both final answers and students' cognitive processes.

Practicality

Practicality was assessed through questionnaires completed by students (n=24) and the implementing teacher during field testing, alongside observation of instructional fidelity. Results are summarized in Table 2.

Qualitative feedback indicated that the e-module’s clear navigation, contextual problem scenarios, and immediate feedback features supported independent and collaborative learning. The teacher noted improved classroom management and student engagement compared to conventional print-based materials.

Table 2. Practicality Assessment Results from Student and Teacher Perspectives

Aspect	Student Response (%)	Teacher Response (%)	Category
Ease of Use	79.00	91.67	Practical
Comprehensibility	77.67	87.50	Practical
Visual Appeal	80.33	100.00	Practical
Time Efficiency	81.00	75.00	Practical
Perceived Usefulness	82.00	–	Practical
Overall Average	80.00	91.67	Practical

Effectiveness

Effectiveness was measured through a post-test assessing students' Numerical problem-solving performance across four Polya-based indicators. Results from the field test (n=24) are presented in Table 3.

Table 3. Effectiveness of the PBL-Based E-Module on Numerical Problem-Solving Indicators

Problem-Solving Indicator	Average Achievement (%)	Category
Understanding the Problem	88	Very Effective
Planning the Solution	86	Very Effective
Executing the Plan	69	Effective
Reviewing the Solution	59	Less Effective
Overall Average	76	Effective

Classical learning completeness was achieved by 19 of 24 students (79.16%), exceeding the 75% threshold for effectiveness. Students demonstrated notable improvement in identifying relevant information and formulating solution strategies; however, verification and reflective checking remained areas requiring further scaffolding.

The development of a Problem-Based Learning (PBL)-based e-module for vocational high school Numericals represents a meaningful response to persistent challenges in fostering students' Numerical problem-solving competencies. The findings—demonstrating validity, practicality, and effectiveness—carry several implications that extend beyond the immediate metrics of product quality (Tian, 2026).

First, the systematic alignment between PBL syntax and Polya's problem-solving indicators proved instrumental in scaffolding students' cognitive processes (Zhou et al., 2025). Rather than merely presenting content digitally, the e-module structured learning as an iterative inquiry cycle: orienting students to authentic problems, supporting collaborative investigation, and prompting reflective verification. This design directly addresses the observed tendency among vocational students to approach Numerical tasks procedurally rather than strategically (Sarkar et al., 2026). By embedding prompts that explicitly guide learners through understanding, planning, executing, and reviewing, the module cultivates metacognitive habits essential for transferable problem-solving skills. The relatively lower performance on the "reviewing solutions" indicator (59%) suggests that reflective verification remains a developmental area requiring further instructional emphasis—a finding consistent with broader research on novice problem solvers (Liang, 2025).

Second, the practicality outcomes underscore the importance of accessibility and user-centered design in educational technology adoption (Morgan et al., 2025). The e-module's compatibility with smartphones, intuitive navigation, and immediate feedback features resonated with both students and teachers, facilitating integration into existing classroom routines without demanding extensive technical infrastructure (Metlek & Çetiner, 2026). This is particularly significant in vocational contexts where resource constraints and diverse learner profiles are common. The high teacher-rated practicality (91.67%) indicates that the module supports, rather than displaces, the educator's facilitative role—a critical consideration for sustainable implementation (Thanailaki, 2024).

Third, the effectiveness results invite reflection on the conditions under which digital PBL environments yield measurable gains. The overall effectiveness score of 76%, with classical mastery achieved by 79.16% of students, suggests that the intervention successfully shifted learning dynamics toward active knowledge construction (Zhang, 2025). However, the variability across problem-solving indicators reveals that skill development is non-uniform: students demonstrated stronger gains in problem comprehension and strategic planning than in solution verification. This pattern implies that while contextualized, technology-mediated problems effectively engage learners in initial sense-making, deliberate practice in argumentation and self-monitoring may require additional scaffolding—perhaps through structured peer review protocols or embedded reflective prompts (Shi et al., 2026).

The study also highlights synergies between curriculum policy and pedagogical innovation. By anchoring the e-module content to Phase E of Indonesia's Merdeka Curriculum and embedding Profil Pelajar Pancasila values, the development process ensured alignment with national educational priorities while preserving disciplinary rigor (Hsu et al., 2025). This dual focus—on both competency development and character formation—reflects an integrated vision of vocational education that prepares students not only for technical proficiency but for adaptive, ethical engagement with workplace challenges (Rott et al., 2022).

Nevertheless, several limitations temper the generalizability of these findings. The field test was conducted with a single class in one vocational school, limiting insights into how the module performs across diverse institutional contexts, student backgrounds, or subject-matter domains (Hu, 2025). Additionally, the reliance on short-term post-test measures captures immediate learning gains but does not address retention or transfer to novel problem contexts. Future iterations could benefit from longitudinal designs and cross-school replication to strengthen evidence of sustained impact (Vitti et al., 2025).

In practical terms, the developed e-module offers a replicable framework for educators seeking to blend inquiry-based pedagogy with digital tools. Its modular architecture—separating lesson planning (modul ajar) from student-facing activities (LKPD)—allows for contextual adaptation while preserving core instructional principles (Lohakan & Seetao, 2024). For curriculum developers, the study demonstrates how formative evaluation cycles (self-review, expert validation, iterative piloting) can systematically enhance product quality without compromising developmental timelines (Hvidman et al., 2024).

Ultimately, this work contributes to ongoing conversations about the role of technology in transformative Numericals education. The e-module does not merely digitize traditional instruction; it reconfigures the learning environment to position students as active investigators of meaningful problems. As vocational education continues to evolve in response to technological and societal change, such approaches—grounded in sound pedagogy, responsive design, and empirical validation—offer promising pathways for cultivating the adaptive problem-solving capacities that learners will need beyond the classroom (Reddy et al., 2024; Silva et al., 2025).

Conclusion

This study successfully developed a Problem-Based Learning (PBL)-based e-module learning package designed to enhance Numerical problem-solving skills among Grade X vocational high school students. The product met all three quality criteria established for educational development research: validity, practicality, and effectiveness. Expert validation confirmed the e-module's systematic alignment between PBL syntax and Polya's problem-solving indicators, with average validity scores of 3.36 (Valid) for the e-module and 3.68 (Very Valid) for the accompanying student worksheet. Practicality assessments from both students and teachers yielded an average score of 80.00%, indicating that the module is accessible via smartphones, features intuitive navigation, and supports independent and collaborative learning without demanding extensive technical infrastructure. The effectiveness of the developed e-module was demonstrated through post-test results showing an average problem-solving achievement of 76%, with 79.16% of students reaching the minimum competency threshold. Students exhibited notable improvement in understanding problems and planning solution strategies, although reflective verification remained an area requiring further instructional scaffolding. These findings suggest that integrating inquiry-based pedagogy with interactive digital media can meaningfully support vocational students' development of transferable Numerical reasoning skills. The PBL-based e-module thus offers a replicable, curriculum-aligned framework for educators seeking to foster active, student-centered Numericals learning in resource-diverse vocational education contexts.

Acknowledgments

Thank you to all parties who have helped in this research so that this article can be published.

Author Contributions

All authors contributed to writing this article.

Funding

No external funding.

Conflicts of Interest

No conflict interest.

References

Hsu, T. C., Wen, W. N., Liao, C. S., Tu, Y. F., & Lee, M. J. (2025). Virtual reality in P-12 education for improving presence, immersion, and 4C skills: A systematic review of empirical research. *Thinking Skills and Creativity*, *58*. https://doi.org/10.1016/j.tsc.2025.101918

Hu, Z. (2025). A method for generating personalized learning content based on AIGC. *Sustainable Futures*, *10*, 101331. https://doi.org/10.1016/j.sftr.2025.101331

Hvidman, C., Koch, A. K., Nafziger, J., Nielsen, S. A., & Rosholm, M. (2024). An intensive, school-based learning camp targeting academic and non-cognitive skills evaluated in a randomized trial. *Labour Economics*, *88*. https://doi.org/10.1016/j.labeco.2024.102535

Liang, G. (2025). Constructing Chinese online course learning system based on deep learning. *Procedia Computer Science*, *262*, 1424–1431.

https://doi.org/10.1016/j.procs.2025.05.191
Lohakan, M., & Seetao, C. (2024). Large-scale experiment in STEM education for high school students using artificial intelligence kit based on computer vision and Python. *Heliyon*, *10*(10). https://doi.org/10.1016/j.heliyon.2024.e31366
Luengo-Aravena, D., Cabello, P., & Rodriguez-Milhomens Bachino, B. (2024). Online collaborative problem-solving as a tangible outcome of digital skills in technical and vocational higher education. *Computers and Education*, *218*. https://doi.org/10.1016/j.compedu.2024.105079
Metlek, S., & Çetiner, H. (2026). SeqAttention-SH: Sequence attention module based convolution neural network for multiclass leaf features classification. In *Computers and Electronics in Agriculture* (p. 246). https://doi.org/10.1016/j.compag.2026.111609
Metreveli, A., Chen, X., Hedman, A., & Sergeeva, A. (2025). Who will be left behind?": A Swedish case of learning AI in vocational education. *International Journal of Educational Research*, *133*. https://doi.org/10.1016/j.ijer.2025.102697
Morgan, N., Yaqoob, M., & Jones, M. A. (2025). Using digital escape rooms to enhance data analysis skills and student experience in a higher education human physiology module. *Current Research in Physiology*, *8*. https://doi.org/10.1016/j.crphys.2025.100165
Muliyadi, L., Hamidi, H., Islami, A. V., Rizaldi, D. R., Hasanah, R., Yadaeni, A., Hariadi, M. H., Hanafi, M., & Wathoni, H. (2026). Analysis Validation of Physics Learning Devices Based on Problem Based Learning Assisted by PhET Simulation to Improve Students' Creativity and Critical Thinking. *Indonesian Journal of Science Education and Applied Research*, *1*(1), 27–31. Retrieved from https://journals.balaipublikasi.id/index.php/ijosear/article/view/743
Qu, F., Jiang, M., & Qu, Y. (2024). An intelligent recommendation strategy for integrated online courses in vocational education based on short-term preferences. *Intelligent Systems with Applications*, *22*. https://doi.org/10.1016/j.iswa.2024.200374
Reddy, V. N., Gandikota, J., Lella, R., Pydala, B., & Vatambeti, R. (2024). Enhancing anomaly detection: A comprehensive approach with MTBO feature selection and TVETBO[sbnd]Optimized Quad-LSTM classification. *Computers and Electrical Engineering*, *119*. https://doi.org/10.1016/j.compeleceng.2024.109536
Rott, K. J., Lao, L., Petridou, E., & Schmidt-Hertha, B. (2022). Needs and requirements for an additional AI qualification during dual vocational training: Results from studies of apprentices and teachers. *Computers and Education: Artificial Intelligence*, *3*. https://doi.org/10.1016/j.caeai.2022.100102
Ruzicic, N., Schullerus, G., & Braun, A. (2026). Integrating Circular Economy into Engineering Curricula: A Modular and Interdisciplinary Educational Concept. *Procedia Computer Science*, *277*, 3123–3132. https://doi.org/10.1016/j.procs.2026.02.348
Sarkar, S., Vajpayee, A., & Thurber, B. B. (2026). Investigating learning in an iSTEAM project in astronomy. *Social Sciences and Humanities Open*, *13*. https://doi.org/10.1016/j.ssaho.2026.102803
Shi, Y., Goh, W. W., & Jhanjhi, N. Z. (2026). A roadmap to implement Metaverse in education field based on ADDIE model: A systematic review. *Computers and Education Open*, *10*. https://doi.org/10.1016/j.caeo.2026.100365
Silva, R. M., Martins, P., & Rocha, T. (2025). Impact of virtual reality learning environments on skills development in students with ASD. *Computers and Education Open*, *9*. https://doi.org/10.1016/j.caeo.2025.100298
Su, K. D. (2024). Integrating STEM interdisciplinary design into hospitality education to investigate students' learning effectiveness: Taking a biscuit-baking activity with problem-based learning. *Journal of Hospitality, Leisure, Sport and Tourism Education*, *35*. https://doi.org/10.1016/j.jhlste.2024.100512
Thanailaki, P. (2024). Gender-related differences and social entanglements in mathematics education during 19th century: The subject of geometry. *Journal of Mathematical Behavior*, *76*. https://doi.org/10.1016/j.jmathb.2024.101209
Tian, L. (2026). A comprehensive evaluation system for vocational skills supported by multimodal graph neural networks. *Systems and Soft Computing*, *8*. https://doi.org/10.1016/j.sasc.2026.200451
Vitti, M., Trevisan, A. H., Ocampo, H. R., Cuentas, V. K., Sarbazvatan, S., Terzi, S., & Sassanelli, C. (2025). A competency map for circular economy education. *Procedia Computer Science*, *253*, 336–345. https://doi.org/10.1016/j.procs.2025.01.096
Wang, Q., Mousavi, A., Lu, C., & Gao, Y. (2023). Examining adults' behavioral patterns in a sequence of problem solving tasks in technology-rich environments. *Computers in Human Behavior*, *147*. https://doi.org/10.1016/j.chb.2023.107852
Wang, X., & Cao, K. (2025). Personalized learning effect evaluation model for vocational education with cloud computing technology. *Systems and Soft Computing*, *7*. https://doi.org/10.1016/j.sasc.2025.200264

Zhang, X. (2025). Research on the application of big data learning recommendation model driven by knowledge graph algorithm in educational information platform optimization. *Systems and Soft Computing*, *7*. https://doi.org/10.1016/j.sasc.2025.200298

Zhou, Z., Tian, Q., Alcalá, J., & Yepes, V. (2025). Research on the coupling of talent cultivation and reform practice of higher education in architecture. *Computers and Education Open*, *9*. https://doi.org/10.1016/j.caeo.2025.100268

Zuo, H., Zhang, M., & Huang, W. (2025). Lifelong learning in vocational education: A game-theoretical exploration of innovation, entrepreneurial spirit, and strategic challenges. *Journal of Innovation & Knowledge*, *10*(3), 100694. https://doi.org/10.1016/j.jik.2025.100694