Attractive : Innovative Education Journal
Vol. 8 No. 1, March 2026

Development of AI-Enhanced Learning-Based Constructivist Training E-Module to Improve The Pedagogic Competence of Junior High School Teachers Through the Professional Learning Community

Berlian Novalita Sigalingging[1*], Bambang Ismanto[1], Stefanus C. Relmasira[1]
[1] *Universitas Kristen Satya Wacana, Indonesia*

Corresponding Author: 942024007@student.uksw.edu*

ARTICLE INFO
Article history:
Received
January 09, 2026
Revised
February 28, 2026
Accepted
March 30, 2026

ABSTRACT

This research is motivated by the low pedagogical competence of teachers in implementing constructivist learning and the minimal use of AI-Enhanced Learning technology at SMP Negeri 4 Sentani. Existing conventional training is considered ineffective in providing practical guidance on technology integration in learning. This study aims to develop a training E-Module that has been tested for validity, practicality, and effectiveness in improving teacher pedagogical competence through the Professional Learning Community (PLC) forum. Using the modified Borg and Gall Research and Development (R&D) model method. Field trial subjects involved 30 teachers. Data collection techniques used interviews, observations, questionnaires, and tests, which were analyzed using quantitative descriptive and inferential statistics (t-test and N-Gain). The results showed that the E-Module met the criteria of very valid (material experts: 3,69; media experts: 3,95) and very practical (91,05%). The effectiveness test showed a significant increase in competence (Sig. 0.000) with an N-Gain score of 0.76 (High category). The AI-Enhanced Learning-Based Constructivism Training E-Module has been proven to be feasible and effective in improving teachers' pedagogical competence and digital literacy, as well as being able to build a collaborative culture in PLC.

Keywords: *E-Modules, Constructivism, AI-Enhanced Learning, Professional Learning Community (PLC), Research & Development (R&D)*

Journal Homepage https://attractivejournal.com/index.php/aj/

Published by CV. Creative Tugu Pena

INTRDUCTION

The rapid advancement of technology in the 21st century has driven various fundamental innovations in the world of education, particularly in the transformation of learning strategies. Education today faces increasingly complex demands, where teachers are not only expected to transfer knowledge but also to prepare students for a dynamic and uncertain future. Responding to this challenge requires a paradigm shift from conventional methods towards a more student-empowering approach. One relevant and increasingly applied approach is constructivism, a learning paradigm that places students as active agents in constructing their own knowledge through experience and social interaction.

From a constructivist perspective, students do not simply sit passively and receive information, but actively explore, collaborate, and solve problems. Piaget, (1976) emphasized the cognitive dimension where individuals construct knowledge independently, while Vygotsky, (1978) complemented it with the social dimension, placing interaction and collaboration as the main foundation of cognitive development. This synergy between personal and social construction is an absolute prerequisite for achieving 21st-century skills, such as critical, creative, and collaborative thinking, which are crucial in the modern world of work. However, the success of this approach heavily relies on the teacher's pedagogical competence in designing learning scenarios that position technology not merely as a tool, but as a catalyst for critical thinking.

As digital technology evolves, expectations for the effectiveness of constructivism learning are increasing with the advent of AI-Enhanced Learning. Artificial intelligence (AI) technology enables more personal, adaptive, and in-depth learning experiences. Holmes et al. (2019) explain that AI can analyze student learning patterns, provide automated feedback, and help teachers design learning tailored to the unique needs of each student. In the context of constructivism, AI acts as a thinking partner and scaffolding tool that expands the Zone of Proximal Development (ZPD) for both students and teachers. This technology enables interactive simulations and virtual experiments that support the discovery learning process, where students can independently explore concepts in a safe environment.

While the potential synergy between constructivism and AI is promising, the reality on the ground reveals a significant gap. In many schools, particularly in regions like Jayapura Regency, the integration of advanced technology still faces multidimensional challenges. Ismanto (2023) highlights that equitable education and sufficient teacher competency in the region remain crucial issues. Many teachers feel overwhelmed when they have to integrate technology into learning, especially when faced with the complexities of AI and constructivist pedagogy. Frequently encountered obstacles include a lack of adequate training, limited access to technology, and minimal conceptual understanding of how AI can be used effectively to support meaningful learning. Consequently, technology integration often stops at the mere use of tools without touching the essence of learning, and teaching methods in the classroom are still dominated by conventional approaches that make students passive.

This competency gap is exacerbated by the fact that training available to teachers is often overly theoretical, administrative, and does not address specific field contexts. Yulianingsih et al. (2024) found that many teachers feel the training they attend does not respond to real classroom challenges nor is it appropriate to Papua's geographic or cultural conditions. Yet UNESCO (2011) stresses that relevant teacher training is much needed to help them leverage AI technology within a constructivist pedagogical context. Without interventions in the form of structured, contextualized training, the risk of widening digital and pedagogical gaps will increase.

To address the challenges of professional isolation and lack of peer support, the concept of a Professional Learning Community (PLC) emerges as a strategic solution. A PLC serves as a forum for teachers to engage in reflective dialogue, share best practices, and collectively solve learning problems. Within the PLC framework, a scaffolding process occurs among teachers; those more proficient in technology can assist their colleagues in achieving new competencies. Studies by Dong et al. (2024), Niyomves et al. (2024) and Pramasari et al. (2025) indicate that collaboration in technology-based professional communities has proven effective in enhancing teaching strategies and 21st-century teacher skills. However, initial observations suggest that a culture of collaboration in the target school is not yet optimal, with teachers still accustomed to working in isolation.

Based on a review of previous literature, there is a considerable research gap regarding AI in education. Research by Eriana & Zein (2023), Handoko et al. (2024) and Russell & Norvig (2016) indicates that AI research predominantly focuses on applications for students, while the role of educators is often overlooked. Similarly, research by Hamida et al. (2025), Shen (2024) and Vebiyanti & Miatun (2025) largely highlights the impact of AI on students' critical thinking, rather than on developing teacher competencies. There is a lack of training modules specifically designed to guide teachers in integrating AI-Enhanced Learning into constructivism learning through PLC mechanisms (Ashari et al., 2025). The absence of this practical guidance hinders teachers from leveraging the potential of technology in creating interactive and adaptive learning experiences.

Stemming from these problems and gaps, this research has a high urgency to develop an AI-Enhanced Learning-Based Constructivism Learning Training E-Module. The development of this module aims to provide practical, easy-to-understand guidelines that are appropriate to field conditions in order to improve teachers' pedagogical competence. This module is designed not only to transfer technical skills in using AI, but also to build a pedagogical framework that is able to synergize artificial intelligence with educational instincts

within a collaborative PLC. Through this integration, it is hoped that teachers will not only become technology users, but also thinking partners who are able to design meaningful, contextual learning scenarios that are in favor of student needs, while also enriching the theory of Intelligence Augmentation and Social Constructivism in the digital age.

METHOD

This research employs a Research and Development (R&D) method adapted from the Borg and Gall development model, simplified into seven stages: potential and problems, data collection, product design, design validation, design revision, product testing, and final revision. The analytical approach used is Mixed Methods to comprehensively examine the data. The research subjects were determined using purposive sampling, involving 7 teachers in a limited trial and 30 teachers from SMP Negeri 4 Sentani who are active in the Professional Learning Community (PLC) for field effectiveness testing.

Data were collected through several instruments, including a pedagogical competence test (pre-test and post-test), validation and practicality questionnaires, observation sheets, interview guidelines, and documentation studies. Quantitative data analysis to examine the effectiveness of the module was conducted using a Paired Sample t-test, preceded by the Shapiro–Wilk normality test, as well as the calculation of the N-Gain to measure the significance of improvement. Meanwhile, qualitative data obtained from observations, interviews, and reflective journals were analyzed using the Miles and Huberman model, which consists of data reduction, data display, and conclusion drawing.

RESULTS AND DISCUSSION

Existing Training Conditions and Modules (Needs Analysis)

The initial stage of the study mapped the factual condition of teachers' pedagogical competence, the patterns of training currently implemented, and the availability of training modules at SMP Negeri 4 Sentani. Most teachers conceptually understood constructivism; however, its classroom implementation remained inconsistent and insufficiently structured. The use of technology was still at a basic level (such as the use of PowerPoint or videos), and there was a significant technical gap related to the utilization of AI. Furthermore, no specific training modules were found that addressed the integration of constructivist learning with AI-Enhanced Learning. The results of this gap analysis are presented in Table 1.

Table 1.
Gap Analysis Between Current Conditions and Expected Conditions

Aspect	Current Condition (Factual)	Expected Condition (Ideal)	Proposed Solution
Pedagogy	The implementation of constructivism is not yet consistent and remains insufficiently structured.	Teachers are able to design systematic and well-structured constructivist lesson plans (RPP).	Provision of sample lesson plans and instructional design templates within the e-module.
Technology (AI)	The use of technology is still limited (e.g., PowerPoint/videos). Teachers do not yet understand how to integrate AI into learning.	Teachers are able to use AI as a scaffolding tool and as a cognitive partner in the learning process.	Step-by-step tutorials on the use of AI tools (e.g., Gemini, ChatGPT, etc.) included in the module.
Accessibility	Training is only incidental (once per semester workshops) and limited to face-to-face sessions.	Teachers are able to learn independently and flexibly (via LMS) alongside their	Development of an LMS based on Google Sites and a Flipbook format to

		professional responsibilities.	enable flexible access.
Instructional Materials	No specific module is available that addresses AI and constructivism.	A comprehensive guide is available containing concise theory, tutorials, and practical activities.	Development of an AI-Enhanced Constructivist Learning Training E-Module.

Field findings revealed a gap between the cognitive domain (*knowing*) and pedagogical skills (*doing*). Theoretically, teachers understand constructivism as articulated by Piaget (1976) and Vygotsky (1978), which emphasizes that students must actively construct their own knowledge. However, teachers experience difficulties in designing practical instructional scenarios that operationalize these principles in classroom practice. The use of technology by teachers remains at the level of substituting conventional tools rather than transforming learning processes.

This finding is consistent with previous research Gede Agung et al. (2024), which emphasizes that technology utilization without structured training tends not to be optimal and merely replaces traditional media. The absence of a specific module has also caused existing In-House Training (IHT) programs to feel overly theoretical and insufficiently practice-oriented. Therefore, an intervention is needed in the form of a Professional Learning Community (PLC), as proposed by Satyawati et al. (2022), which teachers perceive as the most desirable platform for facilitating sustained professional development.

Profile and Specifications of the Developed Training E-Module

The e-module was designed as a web-based digital learning ecosystem using Google Sites to ensure accessibility and ease of use across teachers' devices. The module adopts the MERDEKA learning flow and positions AI as a cognitive partner for teachers in designing and reflecting on instructional practices.

Table 2.
Identity and Specifications of the Developed E-Module

Component	Specification Description
E-Module Title	Teacher Training E-Module: AI-Enhanced Constructivist Learning
Target Users	Junior Secondary School (SMP) teachers across subject areas, particularly members of Subject Teacher Groups/Professional Learning Communities (PLC).
Main Platform	Google Sites (integrated with Google Workspace).
Content Format	Hybrid: Digital text, Flipbook (PDF), videos, and interactive links.
Pedagogical Approach	Social Constructivism (Vygotskian perspective) and AI-Enhanced Inquiry.
Training Flow Model	MERDEKA (Starting from Self, Concept Exploration, Collaborative Space, Contextual Demonstration, Elaboration of Understanding, Interconnection of Concepts, Real Action).
Training Duration	Designed for 2 weeks (8 sessions × 4 lesson hours @ 45 minutes).
AI Tools Utilized	Generative AI (e.g., Gemini/ChatGPT), Wayground (diagnostic tools), and Canva (visual design support).

Table 3.
Implementation of the MERDEKA Flow in the E-Module

MERDEKA Stage	Activities in the E-Module	Pedagogical Purpose

MERDEKA Stage	Activities in the E-Module	Pedagogical Purpose
Starting from Self	Reflective triggering questions delivered through Google Forms or Padlet.	Activating prior knowledge and encouraging reflection on teachers' instructional experiences.
Concept Exploration	Core materials presented through texts, curated videos, and case studies (e.g., Vygotskian theory).	Building independent conceptual understanding of new material.
Collaborative Space	Group discussions analyzing real cases and conducting peer review.	Constructing social knowledge through interaction with colleagues within the PLC.
Contextual Demonstration	Individual practice assignments such as analyzing previous lesson plans or creating a "Scaffolding Map."	Applying concepts within the context of teachers' own instructional documents.
Elaboration of Understanding	Reinforcement sessions through expert videos to address misconceptions (e.g., "The Risk of Using AI as a Shortcut").	Deepening understanding and clarifying inaccurate conceptions.
Interconnection of Concepts	Synthesis tasks (diagrams/ concept maps) linking the current topic with previous modules.	Developing a holistic "big picture" understanding of the entire training sequence.
Real Action	Implementation challenges in real classrooms or dissemination of practices to fellow teachers.	Ensuring the transfer of knowledge into daily professional practice.

The following section presents a visualization of the developed training e-module design in the form of a Learning Management System (LMS).

Table 4.
Visualization Design of LMS

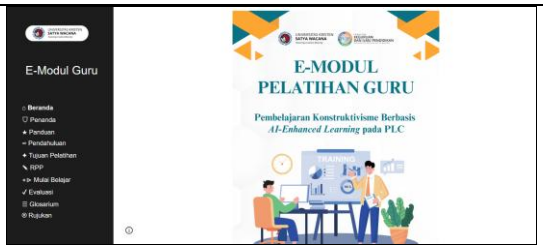

Figure 1. Home page display

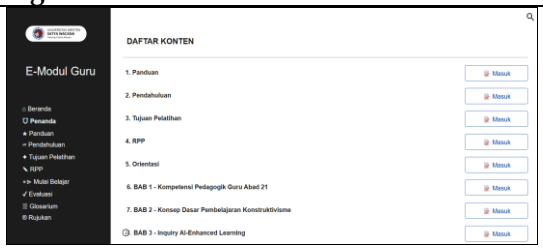

Figure 2. View bookmarks page

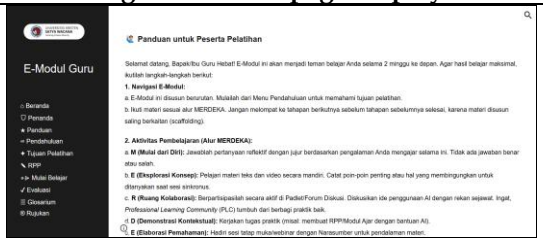

Figure 3. View of the guide page for resource persons, facilitators, and training participants

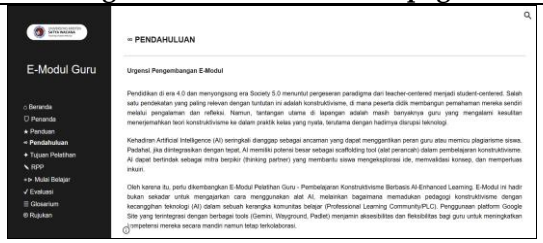

Figure 4. Introduction page display

Figure 5. Display the learning objectives page

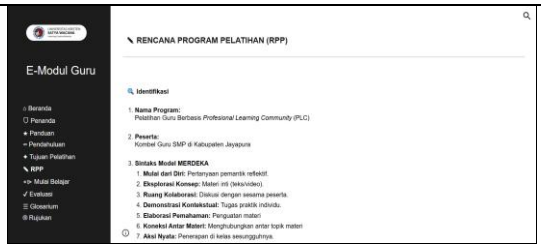

Figure 6. Onboarding page view

Figure 7. View the content page of each learning flow

Figure 8. Display of collaboration space that can be used as an asynchronous or synchronous online discussion space

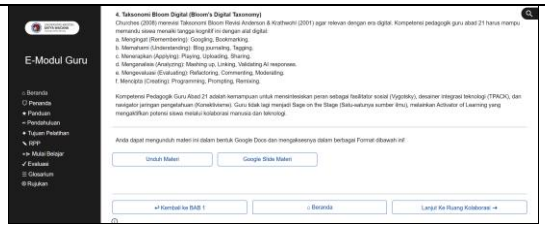

Figure 9. A page view that can be used to download material or view material in other formats.

Figure 10. Assignment page view

Figure 11. View a page that provides media in the form of video

Figure 12. A page view that provides reflection media in the form of a padlet

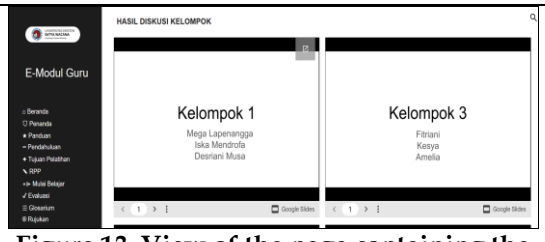

Figure 13. View of the page containing the results of the group discussion

Figure 14. Display of the reflection page that can be filled in directly using Google Forms

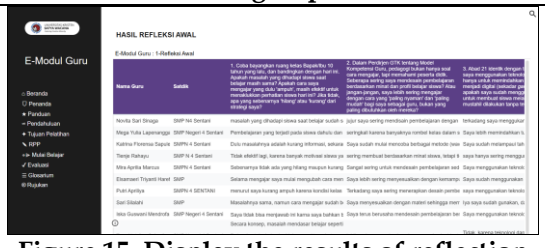

Figure 15. Display the results of reflection

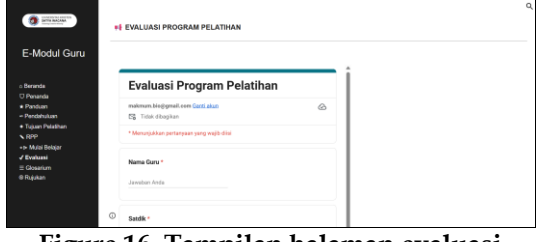

Figure 16. Tampilan halaman evaluasi

answers	program berbasis google form
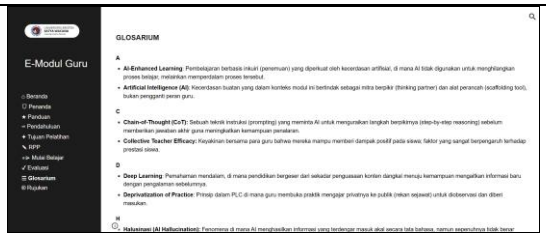	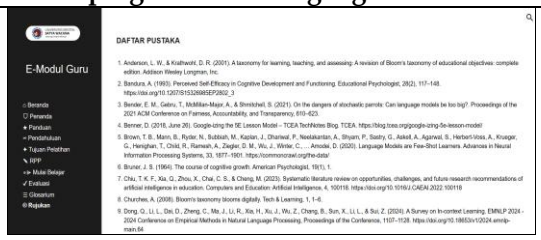
Figure 17. The final section of the LMS looks like a glossary	**Figure 18. Referral page display**

This e-module represents the manifestation of the Technological Pedagogical Content Knowledge (TPACK) framework. The selection of a web-based platform using Google Sites adopts the principle of ubiquitous learning, which addresses issues related to infrastructure accessibility. Theoretically, this development philosophy aligns with the concept of Intelligence Augmentation proposed by Luckin & Holmes (2016), in which AI is positioned not to replace the role of educators, but to extend their capacity as thinking partners. The MERDEKA flow has been shown to stimulate the process of social constructivism as articulated by Lev Vygotsky, guiding teachers from merely operating at the cognitive level toward becoming active practitioners (real action) with peer support in the Collaborative Space.

Results of the Validity and Practicality Test of the E-Module

The e-module was subjected to validity testing by subject-matter experts and media experts. The evaluation covered the accuracy of constructivist theory, the depth of AI literacy content, and the quality of the user interface design.

Table 5.
Expert Validation Results (Content Expert)

Assessment Aspect	Mean Score Validator 1	Mean Score Validator 2	Combined Mean	Category
Content Feasibility	3.57	4.00	3.79	Very Valid
Presentation Feasibility	3.33	3.83	3.58	Very Valid
Language Feasibility	3.60	3.80	3.70	Very Valid
Overall Mean	**3.50**	**3.88**	**3.69**	**Very Valid**

Table 6.
Expert Validation Results (Media Expert)

Assessment Aspect	Mean Score Validator 1	Mean Score Validator 2	Combined Mean	Category
Interface Design	3.86	4.00	3.93	Very Valid
Functionality and Navigation	3.83	4.00	3.92	Very Valid
Multimedia and Technical Quality	4.00	4.00	4.00	Very Valid
Overall Mean	**3.90**	**4.00**	**3.95**	**Very Valid**

Table 7.
Recapitulation of Practicality Test Results by Teachers

No.	Assessment Aspect	Mean Score (%)	Category
1	Ease of Access (Accessibility & Navigation)	92.8%	Very Practical
2	Content Integration (Relevance of Materials & Activities)	89.3%	Very Practical
3	Interactivity (User Engagement & Design)	87.5%	Very Practical

4	Usefulness (Impact on Competence)	94.6%	Very Practical
Overall Practicality Mean		**91.05%**	**Very Practical**

The high validity scores for content (3.69) and media (3.95) indicate that the module meets rigorous academic standards. The module design applies User-Centered Design principles, prioritizing ease of navigation in response to the varying levels of teachers' digital literacy. The practicality level of 91.05% further confirms that the tool is genuinely usable in real educational contexts. The integration of this module is consistent with previous findings Puentedura (2006) and Vieira et al. (2025), which highlight that technology can function as an adaptive scaffolding tool. With the usefulness aspect reaching a practicality level of 94.6%, the module successfully deconstructs the complexity of AI technology into practical steps that teachers can directly apply in developing their instructional designs.

The Effectiveness of the E-Module in Enhancing Teachers' Pedagogical Competence through the PLC

The effectiveness testing involved 30 junior secondary school teachers by comparing their scores before (pre-test) and after (post-test) participating in the training program.

Table 8.
Paired Sample Statistics

Pair	Test Type	Mean	N	Std. Deviation
Pair 1	Pre-Test	50.00	30	16.918
	Post-Test	87.83	30	9.886

Table 9.
Results of the N-Gain Analysis

Indicator	Value	Description
N of Participants	30	-
Mean Pre-Test Score	50	-
Mean Post-Test Score	87	-
N-Gain	0.7	High Effectiveness
% Gain	73%	Effective

The statistical analysis confirmed the effectiveness of the e-module intervention, with a significance value of 0.000 ($p < 0.05$) and an N-Gain of 0.73 (high category). This success is closely linked to the integration of the Professional Learning Community (PLC) approach. As emphasized by DuFour (2004) and Stoll et al. (2006), educational innovation achieves optimal results when supported by a strong collaborative culture. Field observations documented the presence of peer mentoring during the training process, reflecting the application of the Zone of Proximal Development theory proposed by Lev Vygotsky at the level of the teacher community, not only among students. These findings corroborate recent research (Liu et al., 2024), which indicates that technology-based PLCs significantly empower teachers to share challenges and collaboratively design instructional strategies. A shift in teachers' attitudes was also evident; their affective response to technology moved from perceiving AI as a competitive threat to recognizing it as a supportive strategic assistant in creating student-centered learning environments. During the implementation of this research and development process, the adoption of AI-Enhanced Learning encountered several technical and non-technical challenges in the field (Abdennour et al., 2025). The primary technical constraints included unstable internet connectivity and limited availability of adequate hardware within the school environment. In addition, non-technical challenges emerged as teachers faced time constraints in independently learning new technologies and initially expressed concerns that the presence of AI might replace their professional roles or encourage plagiarism among students.

Nevertheless, these challenges were mitigated through the design of the e-module grounded in the Technological Pedagogical Content Knowledge (TPACK) framework, as well as the use of a lightweight web-based format via Google Sites, which could also be accessed

offline through a Flipbook version (Chanwaiwit, 2025). The successful transformation of teachers' apprehension into enthusiasm for collaborating with technology demonstrates the effectiveness of the Zone of Proximal Development (ZPD) theory proposed by Lev Vygotsky, in which the module and AI functioned as adaptive scaffolding tools within the learning ecosystem. This finding also empirically reinforces the theoretical foundation of Intelligence Augmentation (Holmes et al., 2019), emphasizing that artificial intelligence is intended to extend educators' cognitive capacities rather than replace them.

The findings regarding the effectiveness of this e-module are also consistent with numerous previous studies examining the integration of technology in education. The successful incorporation of AI-based learning within a Professional Learning Community (PLC) framework directly confirms the findings of Nugraha et al. (2025), Persada & Heryandi (2026) and Siregar (2025), which demonstrate that digital collaborative platforms significantly empower teachers to design instructional strategies and share solutions with peers. This implementation is likewise aligned with the study of (de Jong et al., 2021), highlighting that inquiry-support technologies play a crucial role as scaffolding tools in fostering deeper and more structured conceptual understanding.

Furthermore, the results of this study address the gap identified by Kurniawan et al. (2023), who noted that the adoption of technological innovation without structured training modules often results in technology being used merely as a substitute for conventional media, without meaningfully transforming pedagogical practice. Given that the present trial was limited to SMP Negeri 4 Sentani, future research and development are recommended to expand the scope of implementation to multiple schools with more diverse demographic and infrastructural characteristics in order to ensure broader generalizability of the product's feasibility. In addition, longitudinal studies are recommended to measure the retention of teachers' pedagogical competence as well as the long-term impact of implementing this e-module approach on students' learning outcomes and 21st-century skills.

DISCUSSION

The main finding of this study demonstrates that the developed AI-Enhanced Learning-Based Constructivism Training E-Module is highly valid, practical, and effective in improving teachers' pedagogical competencies. The validity test results from material and media experts, scoring 3.69 and 3.95 respectively, confirm that the e-module content is robust and technically sound for instructional use. Furthermore, the high practicality score of 91.05% indicates that teachers found the Google Sites-based Learning Management System (LMS) and its integrated tools (such as Gemini, ChatGPT, and Canva) intuitive and highly applicable to their daily teaching routines. This directly addresses the initial needs analysis, which revealed that teachers previously lacked specific, accessible, and practical guidelines for integrating artificial intelligence into their constructivist classrooms.

In terms of effectiveness, the implementation of the e-module yielded a significant improvement in teachers' pedagogical competencies, as evidenced by a Sig. value of 0.000 and a high N-Gain score of 0.76. This significant enhancement proves that transitioning from traditional, passive training methods to a structured, digital ecosystem using the MERDEKA learning flow successfully bridges the gap between knowing constructivist theories and practically implementing them. Compared to previous studies such as Gede Agung et al. (2024), which noted that unstructured technology use merely substitutes traditional media without transforming the learning process, this research proves that structured, AI-integrated training empowers teachers to actively design systemic and adaptive instructional scenarios.

The novelty of this research lies in its specific focus on utilizing Artificial Intelligence to enhance educator competencies, rather than solely focusing on student applications. As highlighted in previous literature by Eriana & Zein (2023) and Handoko et al. (2024), AI research predominantly explores applications for students, often overlooking the critical role of educators. This study shifts the current research paradigm by positioning AI as a cognitive partner and scaffolding tool specifically for teachers. It provides a pioneering pedagogical framework that synergizes generative AI with educational instincts, effectively addressing a

critical gap identified by Sarima et al., (2025) regarding the lack of training modules specifically designed for teachers in this domain.

Another crucial novelty is the contextual integration of this AI-enhanced training within the Professional Learning Community (PLC) framework, specifically tailored to the unique needs of teachers in regions like the Jayapura Regency. Unlike generic, overly theoretical In-House Training (IHT) programs criticized by Yulianingsih et al. (2024), this e-module embeds the MERDEKA learning flow into a collaborative ecosystem. This approach not only facilitates independent concept exploration but also mandates the social construction of knowledge among peers. By merging AI-assisted instructional design with localized peer-to-peer scaffolding, this study introduces a technologically advanced training model that effectively combats professional isolation and builds a sustainable collaborative culture.

This research provides a significant contribution to learning outcomes by empirically demonstrating how enhanced teacher pedagogy directly facilitates more interactive and adaptive student learning environments. By equipping teachers with the ability to leverage AI for diagnostic assessments and customized lesson planning, the study operationalizes Piaget and Vygotsky's constructivist theories for the digital age, significantly advancing the concept of Intelligence Augmentation in education. However, the study is not without limitations. The current research was primarily conducted with a sample of 30 teachers at SMP Negeri 4 Sentani, which may limit the immediate generalizability of the findings across schools with vastly different infrastructural and cultural backgrounds. Furthermore, the e-module relies on stable internet connectivity and access to Google Workspace, which remains a challenge in certain remote geographical areas.

Considering these limitations, it is recommended that school administrators and local education authorities provide stronger infrastructural support, including reliable internet access and institutional AI tool subscriptions, to sustain the integration of this e-module. Additionally, schools should formally integrate this e-module into their continuous professional development programs and allocate dedicated time for PLC meetings. The relevant implication of this research is that educational policies must evolve to recognize AI not just as a student learning aid, but as an essential component of teacher professional development, requiring sustained investment in both digital infrastructure and targeted pedagogical training.

For future researchers, it is highly suggested to expand the scope of this study by conducting longitudinal research to observe the long-term impact of the AI-enhanced e-module on actual student academic performance. While the current study successfully measured the immediate improvement in teacher pedagogical competence, tracking how these acquired skills translate into student learning outcomes over a full academic year would provide deeper insights into the sustained effectiveness of the training. Additionally, expanding the sample size to include a diverse range of schools would help validate the scalability and adaptability of the e-module.

Future studies should also explore the development of offline or low-bandwidth versions of the e-module to accommodate teachers in more remote or underserved areas where internet access is inconsistent. Investigating the integration of other emerging technologies, such as Augmented Reality (AR) or Virtual Reality (VR), combined with AI within the constructivist framework, could further enrich the training modules. Finally, further research could delve into the ethical implications and potential biases of using generative AI in lesson planning, providing a more comprehensive guideline for educators on responsible and culturally sensitive AI utilization.

CONCLUSION

This study produced an AI-Enhanced Constructivist Learning Training E-Module designed to address the limitations of conventional training, which tends to be overly theoretical and has not yet integrated pedagogical AI literacy. The developed e-module, delivered through Google Sites and supported by a Flipbook format, was deemed highly feasible for use. Based on expert evaluations, the product achieved a "Very Valid" category, with an average material validation score of 3.69 and a media validation score of 3.95. Limited

trials also demonstrated a "Very Practical" level of usability, with an implementation percentage reaching 91.05%, indicating that the e-module is easily accessible, user-friendly, and highly relevant to field needs. The developed e-module was proven effective in improving teachers' pedagogical competence. There was a statistically significant increase in learning outcomes, with a significance value of 0.000 and an N-Gain score of 0.76, which falls into the high category. Qualitatively, the training successfully transformed teaching practices from lecture-based methods to a facilitative role in which teachers actively provide scaffolding. Through the Professional Learning Community (PLC), a strong culture of collaboration was established, enabling teachers to utilize AI as a thinking partner in designing interactive, student-centered learning.

REFERENCE

Abdennour, O., Kemouss, H., & Khaldi, M. (2025). Integrating AI Education in Non-Technical Disciplines: Bridging the Gap Between Theory and Practice. In *Ethics and AI Integration Into Modern Classrooms* (pp. 117–146). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-2262-9.ch005

Ashari, M., Susanto, D. A., Susanti, R. S., Pramono, B., Muntazarah, F., Fitriani, A., Desmelinda, E., Miza, L. P., & Riskawati. (2025). *Strategi Mengajar dengan Pendekatan Pembelajaran Mendalam (PM) Pada Pendidikan Dasar dan Menengah*. CV. Edu Akademi.

Chanwaiwit, P. (2025). Influence of teacher dispositions on TPACK: Insights from pre-service EFL teacher education. *Indonesian Journal of Applied Linguistics*, *15*(2), 359–374. https://doi.org/10.17509/tt54xq47

de Jong, T., Gillet, D., Rodríguez-Triana, M. J., Hovardas, T., Dikke, D., Doran, R., Dziabenko, O., Koslowsky, J., Korventausta, M., & Law, E. (2021). Understanding teacher design practices for digital inquiry–based science learning: The case of Go-Lab. *Educational Technology Research and Development*, *69*(2), 417–444. https://doi.org/10.1007/s11423-020-09904-z

Dong, Q., Li, L., Dai, D., Zheng, C., Ma, J., Li, R., Xia, H., Xu, J., Wu, Z., Chang, B., Sun, X., Li, L., & Sui, Z. (2024). A Survey on In-context Learning. *EMNLP 2024 - 2024 Conference on Empirical Methods in Natural Language Processing, Proceedings of the Conference*, 1107–1128. https://doi.org/10.18653/v1/2024.emnlp-main.64

DuFour, R. (2004). *What Is a "Professional Learning Community."* Educational Leadership, 61, 6-11. - References - Scientific Research Publishing. https://www.scirp.org/reference/referencespapers?referenceid=1818223

Eriana, E. S., & Zein, A. (2023). Artificial Intelligence. *Angewandte Chemie International Edition*, *6(11)*, 1. https://doi.org/10.32877/bt.v8i1.2526

Gede Agung, D. A., Nasih, A. M., Sumarmi, Idris, & Kurniawan, B. (2024). Local wisdom as a model of interfaith communication in creating religious harmony in Indonesia. *Social Sciences and Humanities Open*, *9*(July 2023), 100827. https://doi.org/10.1016/j.ssaho.2024.100827

Hamida, L., Albab, M. U., Lestari, W., Rahmah, I., Mayestika, S. S. V. V., Fatawi, N. F., Azizah, L. A., Milandry, A. S., Putri, A. T. U. K., & Amalah, S. F. (2025). Creative and Critical Thinking in Language Education, Literature, and Translation. *Prociding National Seminar Applied Lingustics (NASAL)*.

Handoko, D., Saryoko, A., Aghata, F., Yunita, F., Saputro, I. P., Atho'illah, I., Asnur, P., Rahmah, S. A., Jaya, I., & Siregar, A. M. (2024). Artificial Intelligence: Revolusi Kecerdasan Buatan. *Penerbit Mifandi Mandiri Digital*, *1*(01).

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education promises and implications for teaching and learning*. Center for Curriculum Redesign. https://doi.org/10.58863/20.500.12424/4276068

Ismanto, B. (2023). Kebijakan Pemerataan Pendidikan Melalui Program 3T (Studi Kecukupan Guru Smp Di Kabupaten Seruyan Provinsi Kalimantan Tengah). *Trisala: Jurnal Ilmiah Pendidikan*, *9*(1). https://doi.org/10.54211/trisala.v9i1.94

Kurniawan, M. R., Mustakim, I., Harto, K., & Suryana, E. (2023). Analisis Kritis Teori Belajar Sosiokultural Terhadap Karakter Sosial Komunikatif Siswa di Era Digitalisasi. rtf. *Jurnal Ilmiah Mandala Education*, *9*(3), 2010–2023.

Liu, J., Aziku, M., Qiang, F., & Zhang, B. (2024). Leveraging professional learning communities in linking digital professional development and instructional integration: evidence from 16,072 STEM teachers. *International Journal of STEM Education*, *11*(1), 56.

Luckin, R., & Holmes, W. (2016). *Intelligence unleashed: An argument for AI in education*.

Niyomves, B., Kunacheva, N., & Sutadarat, S. (2024). Hybrid Learning: A combination of face-to-face and online learning. *Journal of Education and Learning Reviews*, *1*(3), 11–20.

Nugraha, N. A. S., Lustyantie, N., & Rafli, Z. (2025). EMPOWERING DIGITAL PEDAGOGY FOR EARLY ENGLISH LEARNERS THROUGH NOTION AI APPLICATION INTEGRATED IN E-MODULE DEVELOPMENT AT KAMPUNG INGGRIS PURBALINGGA. *International Seminar on Humanity, Education, and Language*, 1241–1249.

Persada, A. R., & Heryandi, Y. (2026). Instructional Design of E-Modules and E-Courses for AI Literacy: Enhancing Conceptual, Critical, and Ethical Understanding. *International Journal of Education and Humanities*, *6*(1), 180–193.

Piaget, J. (1976a). Piaget's theory. In *Piaget and his school: A reader in developmental psychology* (pp. 11–23). Springer.

Piaget, J. (1976b). *Piaget's theory*. Springer.

Pramasari, R., Ismanto, B., Satyawati, S. T., Young, J. S., & Hida, E. U. (2025). Development of Peer-Based Academic Supervision Model in Increase Skills Teaching The 21st Century in Elementary Schools. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran, Dan Pembelajaran*, *11*(1), 457–468.

Puentedura, R. (2006). *Transformation, technology, and education*.

Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: a modern approach*. pearson.

Satyawati, S. T., Dwikurnaningsih, Y., Ismanto, B., Iriani, A., Wasitohadi, W., & Waruwu, M. (2022). E-Training penyusunan karya tulis ilmiah best practice bagi guru dan kepala sekolah untuk meningkatkan profesionalitas. *Dinamisia: Jurnal Pengabdian Kepada Masyarakat*, *6*(6), 1440–1453.

Shen, J. (2024). Development of Online and Offline Mixed Teaching Materials for Higher Vocational Education Under the Background of Internet. *International Journal of E-Collaboration*, *20*(1), 1–12. https://doi.org/10.4018/IJeC.342124

Siregar, T. (2025). The Effect of Problem-Based Learning and STEM-Based E-Modules on Students' Mathematical Problem-Solving Skills. *The Effect of Problem-Based Learning and STEM-Based E-Modules on Students' Mathematical Problem-Solving Skills (November 15, 2025)*.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*(4), 221–258.

Unesco. (2011). ICT: Competency framework for teachers. *Paris: United Nations Educational, Scientific and Cultural Organization*.

Vebiyanti, D., & Miatun, A. (2025). Flipbooks' Support Of Problem-Based Learning and Its Impact On Critical Thinking Ability. *Mathline: Jurnal Matematika Dan Pendidikan Matematika*, *10*(2), 387–400. https://doi.org/10.31943/mathline.v10i2.953

Vieira, D., Ismanto, B., & Iriani, A. (2025). Cross Cultural Communication Strategies for Teaching Teams in PKBM Junggel Salatiga, Indonesia. *Jurnal Paedagogy*, *12*(3), 897. https://doi.org/10.33394/jp.v12i3.15712

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (Vol. 86). Harvard university press. https://doi.org/10.2307/j.ctvjf9vz4

Yulianingsih, Y., Ismanto, B., & Wasitohadi, W. (2024). Education Quality and Performance Based on Balanced Scorecard in Junior High School: A Case Study at SMPN 8 Insumbrei Supiori Regency, Papua. *Jurnal Paedagogy*, *11*(1), 156–164. https://doi.org/10.33394/jp.v11i1.9861