Indonesian Journal of Education Research (IJoER)
Vol. 7, No. 3, June 2026, pp. 329~337
ISSN: 2722-1326, DOI: 10.37251/ijoer.v7i3.2903

An Empirical Evaluation of Generative AI Integration in Instructional Material Development: Its Impact on Teacher Performance and the Moderating Role of Digital Literacy

Muhammad Dhuha Masyhuri[1], Muhammad Ilham[2]
[1,2]Department of Islamic Education Management, Faculty of Tarbiyah and Teacher Education, Universitas Islam Negeri Sultanah Nahrasiyah Lhokseumawe, Lhokseumawe, Indonesia.

Article Info

Article history:

Received Mar 5, 2026
Revised May 2, 2026
Accepted May 12, 2026
Online First Jun 13, 2026

Keywords:

Digital Literacy
Educational Evaluation
Generative AI
SEM-PLS
Teacher Performance
Teaching Materials

ABSTRACT

Purpose of the study: The use of generative artificial intelligence (AI) in education is growing rapidly, particularly in the development of instructional materials. However, research providing an empirical evaluation of its effectiveness on teacher performance—taking digital literacy into account as a readiness factor—remains limited. This study is an evaluative research aimed at assessing the effectiveness of using generative AI in instructional material development on teacher performance, as well as evaluating the moderating role of digital literacy within the framework of educators' professional accountability.

Methodology: This study employs a quantitative approach using an explanatory survey design involving teachers from formal educational institutions in Lhokseumawe City. Data were collected via a Likert-scale questionnaire and analyzed using Partial Least Squares-Structural Equation Modeling (SEM-PLS) through SmartPLS 4 software to evaluate the structural relationships among variables.

Main Findings: The analysis results provide evaluative evidence that the use of generative AI significantly contributes to improving teachers' performance in the aspect of instructional material development. Digital literacy was also found to have a positive and significant effect on performance, with a more dominant influence. However, the evaluation results indicate that digital literacy does not moderate the relationship between the use of generative AI and teacher performance, suggesting that the effectiveness of AI is independent of the level of digital literacy in this sample.

Novelty/Originality of this study: This study contributes to the field of educational evaluation by offering a framework for assessing evidence-based technology integration. The implications for evaluation practice are the need to develop teacher performance assessment standards that include digital technology competencies as part of professional accountability. These results can serve as a policy foundation for educational institutions in evaluating the effectiveness of technology training programs to ensure the adoption of AI that impacts instructional quality.

Corresponding Author:
Muhammad Dhuha Masyhuri
Department of Islamic Education Management, Faculty of Tarbiyah and Teacher Education, Universitas Islam Negeri Sultanah Nahrasiyah Lhokseumawe, Jalan Medan-Banda Aceh Km. 275, No. 1, Lhokseumawe, Indonesia
Email: muhammaddhuha1105@gmail.com

1. INTRODUCTION

The development of artificial intelligence technology, particularly generative AI (Artificial Intelligence), has brought significant changes to learning practices, especially in the process of developing teaching materials by teachers. Generative AI enables teachers to produce text, images, and learning material designs more quickly, variably, and contextually, thereby potentially improving work efficiency and learning quality [1], [2]. A number of studies show that the use of generative AI serves as a teacher support tool that can reduce teachers' administrative workload, enhance creativity in material design, and open up broader opportunities for pedagogical innovation [3], [4]. However, the implementation of this technology does not necessarily result in improved teacher performance if it is not accompanied by adequate professional capacity to manage and utilize the technology appropriately.

Teacher performance itself is a manifestation of the success of educators in carrying out planning, implementation, and evaluation of learning professionally, which is influenced by the interaction between personal factors, behavior, and work environment as described in Social Cognitive Theory [5]. In the context of technology-based learning, the Technological Pedagogical Content Knowledge (TPACK) framework emphasizes that the effective use of technology, including generative AI, is highly dependent on teachers' ability to integrate technological knowledge, pedagogy, and content in a coherent manner [6], [7]. Thus, generative AI can be positioned as a technological environmental factor that has the potential to support teacher performance when used strategically in the development of teaching materials, rather than merely as a substitute for conventional work. The SAMR model also emphasizes that technology will have a significant impact on learning practices when it is able to encourage meaningful modification and redefinition of learning processes [8].

In the context of educational effectiveness, the adoption of technologies such as generative AI should not be viewed merely as a trend, but must be systematically evaluated to measure their actual contribution to the instructional process [9], [10]. Evaluating the integration of these technologies is crucial to ensuring that digital tools truly provide added value for educators, rather than simply increasing their administrative burden [11]. This study views the use of AI as an intervention that requires empirical evidence regarding its effectiveness in supporting teachers' critical tasks, so that the results can serve as a foundation for future professional development policies [12], [13].

Furthermore, teacher performance is viewed as a key element within the framework of educational accountability. Measuring teacher performance amid the widespread use of generative AI involves more than simply examining the results of their work; it is an assessment of the extent to which their professional competencies can adapt to changes in teaching tools [14]. By focusing on performance as the subject of evaluation, this study aims to provide an overview of educators' accountability in producing innovative and effective teaching materials, which will ultimately impact the overall quality of educational outcomes [15].

On the other hand, digital literacy is seen as a key competency for teachers in facing the transformation of digital education. Digital literacy not only includes technical skills in using digital devices, but also the ability to evaluate information, understand the context of technology use, and act critically and ethically in the digital space [16], [17]. Previous studies have shown that digital literacy contributes positively to teachers' attitudes and acceptance of generative AI [18], [19]. However, most studies still focus on the direct influence of technology or digital literacy separately, while empirical testing of the role of digital literacy as a moderating variable in the relationship between generative AI use and teacher performance is still limited and shows mixed results. This condition indicates a relevant research gap that needs to be further explored.

Based on the perspective of Program Evaluation Theory [20], there is a gap in the literature regarding comprehensive evaluations of how digital literacy moderates the effectiveness of new technology adoption on performance. Most previous studies have focused solely on direct effects, without conducting an in-depth evaluation of individual readiness variables [21], [22]. The novelty of this study lies in its evaluative approach, which combines AI adoption with digital literacy to provide a comprehensive picture of institutional readiness. The urgency of this research is heightened by the need for schools to adopt evidence-based policies in establishing new standards for teacher performance in the digital age [23].

Given this gap, this study was conducted as an empirical evaluation to analyze the effectiveness of using generative AI in the development of instructional materials on teacher performance, as well as to examine the role of digital literacy both as a direct predictor and as a moderating variable. The novelty of this study lies in its critical examination of the moderating role of digital literacy to determine the actual position of digital competence within the model of teacher professional accountability. Thus, this study makes a scientific contribution to the field of

educational evaluation by clarifying the role of digital literacy as a core teacher competency amidst the integration of generative AI into teaching practices to ensure sustainable educational quality.

2. RESEARCH METHOD

2.1. Type of Research

This study employs a quantitative approach with an explanatory survey design to evaluate the causal relationship among the variables [24]. This approach focuses on an empirical evaluation of the effectiveness of integrating generative AI technology into educational practice.

2.2. Research Subject

The study population consisted of teachers at formal educational institutions (elementary schools/MI, junior high schools/MTs, and senior high schools/MA/SMK) in the city of Lhokseumawe. The sample was selected using purposive sampling, with the criteria being active teachers who had experience using digital technology, resulting in a total of 100 respondents [25].

2.3. Data Collection Instruments and Techniques

Data were collected using a structured questionnaire with a Likert scale developed based on prior theoretical studies. This instrument was designed to measure the variables of generative AI use, teacher performance, and digital literacy with a high level of internal consistency.

2.4. Data Analysis Techniques

Data analysis was conducted using Partial Least Squares-Structural Equation Modeling (SEM-PLS) with SmartPLS 4 software. This technique was chosen for its ability to test complex structural models and moderation effects with a relatively small sample size [26]. The model evaluation includes testing the measurement model (validity and reliability) and the structural model (hypothesis testing) [20].

2.5. Research Procedures

The research procedure began with the formulation of an evaluative framework, followed by the digital distribution of the survey instruments, data processing using a bootstrapping algorithm, and concluded with the interpretation of the results to provide evidence-based educational policy recommendations.

3. RESULTS AND DISCUSSION

This section reports the findings obtained from the data analysis using the Partial Least Squares Structural Equation Modeling (SEM-PLS) technique. The analysis was conducted in stages through the evaluation of the measurement model (outer model) to ensure the validity and reliability of the constructs, followed by the evaluation of the structural model (inner model) to test the relationships between variables and the moderating role of digital literacy in strengthening or weakening the influence of generative AI use on teacher performance. The results presented in this section form the basis for drawing conclusions about the hypotheses that were formulated earlier.

3.1. Evaluation Model Measurement (Outer Model)

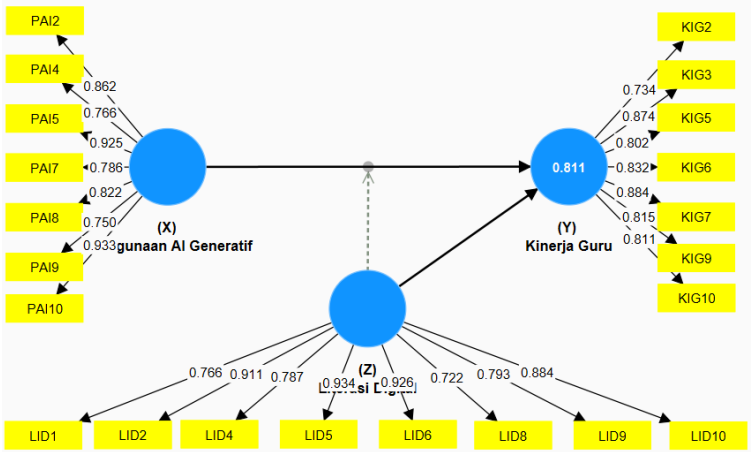

Figure 1. Outer Loadings Indicator Values

The measurement model assessment indicates that all retained indicators exhibit outer loading values above the recommended threshold of 0.70. This indicates that each indicator is able to adequately represent its construct and meets the convergent validity criteria.

Table 1. Cronbach's Alpha, Composite Reliability, and AVE

	Cronbach's alpha	Composite reliability	AVE
(X)_Use of Generative AI	0.928	0.942	0.701
(Y) _Teacher Performance	0.920	0.936	0.677
(Z)_Digital Literacy	0.941	0.952	0.712

Table 1 above shows that the Cronbach's Alpha and Composite Reliability values for all constructs are above 0.70, indicating excellent internal consistency of the instrument. In addition, the AVE values for each construct exceed those indicating valid indicators.

Table 2. Discriminant Validity (HTMT)

Relationships Between Constructs	HTMT value
(Y) _Teacher Performance <-> (X)_Use of Generative AI	0.836
(Z)_Digital Literacy <-> (X)_Use of Generative AI	0.704
(Z)_Digital Literacy <-> (Y) _Teacher Performance	0.904

According to Table 2 above, the results of the discriminant validity test using HTMT show that all values are below the threshold of 0.95. Although the HTMT values between digital literacy and teacher performance are relatively high, these values are still acceptable and reflect the contextual proximity between constructs without showing measurement overlap.

The evaluation model measurement was conducted to ensure the validity and reliability of the constructs used in the study. The analysis results show that all retained indicators have an outer loading value ≥ 0.70, thus meeting the convergent validity criteria. In addition, the Average Variance Extracted (AVE) value for each construct was above 0.50, namely the use of generative AI at 0.701, teacher performance at 0.677, and digital literacy at 0.712. These results suggest that each construct sufficiently captures the variance represented by its indicators.

In terms of reliability, all constructs show excellent internal consistency. The Composite Reliability and Cronbach's Alpha values for each construct are above the analysis threshold of 0.70, which indicates that the research instrument is reliable and suitable for further use. Thus, the measurement model in this study is declared to meet the validity and reliability criteria.

3.2. Structural Model Evaluation (Inner Model)

Table 3. Variance Inflation Factor (VIF) Value

Structural Path	VIF
(X)_Use of Generative AI -> (Y) _Teacher Performance	1.851
(Z)_Digital Literacy -> (Y) _Teacher Performance	1.877
(Z)_Digital Literacy x (X)_Use of Generative AI -> (Y) _Teacher Performance	1.076

Before testing the hypothesis, multicollinearity was examined using the Variance Inflation Factor (VIF) value. The analysis results showed that all structural paths had VIF values below 3, with the VIF value of generative AI use on teacher performance at 1.851, digital literacy on teacher performance at 1.877, and the interaction of digital literacy and generative AI use on teacher performance at 1.076. These findings indicate that there are no multicollinearity issues in the structural model, allowing the testing of relationships between variables to proceed.

3.3. Hypothesis Testing (Bootstrapping)

Table 4. Hypothesis Testing Results

Hypothesis	Path	β	t-statistic	p-value	Decision
H1	X → Y	0,428	3,917	0,000	Accepted
H2	Z → Y	0,548	5,045	0,000	Accepted
H3	Z × X → Y	−0,099	1,832	0,067	Rejected

According to Table 4 above, hypothesis testing was conducted using the bootstrapping technique, where the use of Generative AI in developing teaching materials was proven to have a positive effect on teacher performance, as was the digital literacy hypothesis, which was also proven to have a positive and significant effect on teacher performance ($\beta = 0.548$; $t = 5.045$; $p < 0.001$). This effect is the strongest in the model, indicating that digital literacy is the dominant factor contributing to the improvement of teacher performance.

Results from the interaction analysis demonstrate that digital literacy does not significantly alter the effect of generative AI use on teacher performance ($\beta = -0.099$; $t = 1.832$; $p = 0.067$). In other words, digital literacy does not act as a moderating factor in this relationship.

Overall, the two main hypotheses in this study were accepted, namely the effect of generative AI use on teacher performance and the effect of digital literacy on teacher performance. Meanwhile, the hypothesis stating that digital literacy moderates the effect of generative AI use on teacher performance was rejected. These results indicate that digital literacy plays a significant direct role in predicting teacher performance, but does not function as a factor that strengthens or weakens the effect of generative AI use.

The findings of this study show that the integration of generative AI in the development of teaching materials contributes positively to improving teacher performance, in line with the assumption that artificial intelligence-based technology can improve the efficiency and quality of professional work. Digital literacy has also been proven to have a significant effect on teacher performance. However, contrary to initial expectations, digital literacy does not play a significant role in strengthening the relationship between the use of generative AI and teacher performance. This condition indicates that the effect of generative AI on teacher performance is more direct than through the mechanism of digital competency interaction. Therefore, this section will outline the theoretical and empirical implications of these findings.

3.4. The Effect of Generative AI Use in Teaching Material Development on Teacher Performance

The test results show that the use of generative AI in developing teaching materials has a positive and significant effect on teacher performance. These findings indicate that the use of generative AI can improve teacher efficiency, particularly in lesson planning, material preparation, and administrative tasks directly related to pedagogical activities. Generative AI acts as a tool that speeds up work processes, allowing teachers to allocate their time and energy more optimally to core learning activities.

These findings are in line with Blake [27], which confirms that generative AI can support the teaching process by providing adaptive and varied learning materials, thereby improving the quality of pedagogical practices. Baskara [28] also found that the use of generative AI encourages increased effectiveness in learning communication and teacher creativity in designing teaching strategies. In addition, MacDowell et al. [29] showed that generative AI contributes to reducing teachers' administrative workload, which indirectly impacts on improved professional performance.

These findings provide evaluative evidence that the integration of generative AI into instructional material development serves as an effective technological intervention for enhancing educators' productivity [30], [31]. The success of this implementation demonstrates that AI is not merely a technical tool, but rather a catalyst for instructional effectiveness that enables teachers to allocate more time to high-quality pedagogical interactions [32]. From the perspective of Educational Effectiveness, these results confirm that appropriately adapted technology can redefine the standards of professional performance for teachers in the digital age [33], [34].

Thus, the findings of this study support the view that generative AI should be regarded not only as a technological innovation but also as a practical tool that can contribute to enhancing teacher performance. These findings confirm that the integration of AI in the development of teaching materials has real practical implications for teacher productivity and work quality.

3.5. The Impact of Digital Literacy on Teacher Performance

The results of the analysis reveal that digital literacy exerts a positive and significant effect on teacher performance, with a larger path coefficient than that of generative AI. These findings underscore that teachers' ability to critically understand, manage, and effectively utilize digital technologies constitutes a foundational driver of professional performance in the digital era.

This outcome aligns with previous studies indicating that digital literacy directly enhances teacher performance by fostering creativity, professionalism, and work effectiveness. For instance, Wilujeng and Setiyawan [35], Mao et al. [36] demonstrated that digital literacy significantly improves teachers' innovative capacity and overall effectiveness. Similarly, Widowati and Purbojo [7] emphasized that technology integration competence is a critical determinant of teacher performance, particularly within technology-enhanced learning environments.

More importantly, these results reposition digital literacy not merely as a supporting variable, but as a core competency for teachers in the digital age. Teachers with strong digital literacy tend to be more adaptive, reflective, and effective in fulfilling their professional responsibilities—regardless of the specific technology employed [37]. In this context, digital literacy functions as an enabling foundation that allows teachers to harness generative AI (and other emerging technologies) more critically, ethically, and productively. Rather than competing with AI, high digital literacy amplifies its benefits, creating a synergistic effect on teaching quality and professional efficacy [38].

Overall, these findings highlight that investing in digital literacy should remain a strategic priority in teacher professional development. In an era of rapid technological advancement, digitally literate teachers are better equipped to integrate, critique, and maximize the potential of generative AI, thereby ensuring more sustainable, meaningful, and effective educational practices.

3.6. The Role of Digital Literacy Moderation on the Relationship between Generative AI Use and Teacher Performance

The test results show that digital literacy does not moderate the effect of generative AI use on teacher performance. The interaction coefficient is negative and insignificant, indicating that teachers' digital literacy levels neither strengthen nor weaken the relationship between generative AI use and teacher performance. These findings are important and cannot be considered a failure of the model. Contrary to the common assumption that digital literacy always strengthens the impact of technology, the results of this study show that the influence of generative AI on teacher performance is relatively direct. Generative AI, as an intuitive and easy-to-use interface-based technology, can be utilized by teachers with varying levels of digital literacy without a significant difference in performance.

These results differ from the findings of Sergeeva et al. [39], which show the moderating role of digital literacy in the context of attitudes and acceptance of generative AI. This difference can be explained by the different focus of the dependent variables. Sergeeva et al.'s research focuses on affective aspects and attitudes toward technology, while this study measures teacher performance as actual work output. Thus, digital literacy plays a greater role as a factor that influences readiness and attitudes toward AI, rather than as a reinforcer of the relationship between AI use and actual work performance. These findings confirm that digital literacy and the use of generative AI are two factors that work in parallel, rather than interactively. Digital literacy improves teacher performance directly, while generative AI contributes as a work tool that has a direct impact on performance without relying on the level of digital literacy as a reinforcing factor.

The finding that digital literacy does not act as a moderating variable offers a new perspective on the evaluation of technology integration in schools. These results indicate that the effectiveness of generative AI on teacher performance is universal and does not depend on a specific threshold of digital competence [40], [41]. This can be explained by the characteristics of generative AI, which features a highly intuitive natural language interface, thereby minimizing the technical barriers typically found in conventional educational technology [42]. Within the framework of educational accountability, this phenomenon indicates that AI has acted as an instrument for the equalization of productivity, whereby educators with varying levels of digital literacy can achieve similar performance standards in the development of instructional materials [43], [44].

Overall, this study shows that teacher performance is influenced by two main factors, namely the use of generative AI and digital literacy, with different mechanisms of influence. Generative AI acts as a work instrument that improves teacher efficiency and productivity, while digital literacy is a basic competency that directly

determines the quality of professional performance. The absence of a moderating effect of digital literacy indicates that the successful use of generative AI does not entirely depend on the level of digital literacy, but rather on the characteristics of AI itself, which is becoming increasingly user-friendly.

3.7. Implications and Limitations

In practical terms, the findings of this evaluation suggest that educational institutions adopt new standards for teacher performance evaluations that integrate AI competencies as part of professional accountability [45], [46]. The government needs to develop training curricula that focus not only on the technical aspects of AI use but also on ethics and the validation of machine-generated content [45], [47].

However, this study has limitations due to a sample size restricted to a single geographic region, so generalizing the results must be done with caution [48]. Further research is recommended to involve a broader sample and use longitudinal methods to evaluate the long-term impact of AI on educational success in a systemic manner [49], [50].

These findings provide important implications for both theory and practice. At the theoretical level, the study advances the discussion in educational technology by offering a clearer understanding of how digital literacy relates to the link between AI-driven technology use and teacher performance. The finding that digital literacy does not act as a moderator but has a significant direct effect enriches the literature, which has tended to assume the normative moderating role of digital literacy. This study shows that digital literacy is an independently established foundation of teachers' professional competence, not merely a situational factor that reinforces the influence of certain technologies.

In practical terms, the results of this study have implications for policy makers and education administrators. Efforts to improve teacher performance are not sufficient if they only encourage the adoption of generative AI in learning, but must be accompanied by the systematic and continuous strengthening of teachers' digital literacy. Teacher training programs should focus on developing comprehensive digital competencies so that teachers are able to utilize various learning technologies critically, effectively, and responsibly. In addition, the development and implementation of generative AI in education needs to be directed as a pedagogical tool that supports teacher performance, not as a substitute for the professional role of teachers.

4. CONCLUSION

This evaluative study concludes that the integration of generative AI into instructional material development is an effective technological intervention that significantly contributes to improving teachers' professional performance. The findings indicate that the use of AI directly accelerates instructional processes and educator productivity, while digital literacy serves as a crucial readiness factor in supporting such performance. However, the analysis results demonstrate that digital literacy does not act as a moderating variable, suggesting that the intuitive nature of generative AI allows the benefits of this technology to be experienced equally by teachers with varying levels of digital competence. Overall, the integration of AI has redefined standards of professional accountability within the framework of educational quality assurance in the digital age. As a recommendation for future research, it is suggested that future researchers explore institutional support and teacher workload as potential moderating factors, and employ a longitudinal research design to systematically evaluate the long-term impact of AI use on student learning outcomes.

ACKNOWLEDGEMENTS

The author would like to thank Sultanah Nahrasiyah State Islamic University in Lhokseumawe for its institutional support for this research. The author also extends gratitude to the teachers in Lhokseumawe who participated as respondents, as well as to all those who contributed to the smooth collection of this evaluative data.

REFERENCES

[1] S. Zaimoğlu and A. Dağtaş, "Teacher Cognition and Practices in Using Generative AI Tools to Support Student Engagement in EFL Higher-Education Contexts," *Behav. Sci. (Basel).*, vol. 15, no. 9, p. 1202, Sep. 2025, doi: 10.3390/bs15091202.

[2] A. Yadav, M. Lachney, A. Hu, and L. Tavernier, "Integrating Generative AI in Teacher Education: Pre-Service Teachers' Perspectives, Attitudes, and Design Challenges," *J. Res. Child. Educ.*, pp. 1–22, Dec. 2025, doi:

10.1080/02568543.2025.2581712.
[3] K. Acevedo, "Exploring the Impact of Generative AI to Mitigate Educator Burnout," Abilene Christian University, 2025.
[4] R. C. Kerr and H. Kim, "From Prompts to Plans: A Case Study of Pre-Service EFL Teachers' Use of Generative AI for Lesson Planning," *English Teach.*, vol. 80, no. 1, pp. 95–118, Mar. 2025, doi: 10.15858/engtea.80.1.202503.95.
[5] M. Nelly and Yusdiana, "Application of Albert Bandura's Social-Cognitive Theories in Teaching and Learning," *Edukasi Islam. J. Pendidik. Islam*, vol. 12, no. 02, p. 2131−2146, 2023, doi: 10.30868/ei.v12i02.4585.
[6] I. P. Soko and D. D. Samo, "The Analysis of In-Service Teachers' Practices of Implementing Technological Pedagogical Content Knowledge (TPACK)," *Eur. J. Educ. Pedagog.*, vol. 4, no. 2, pp. 64–71, Mar. 2023, doi: 10.24018/ejedu.2023.4.2.585.
[7] P. N. Widowati and R. Purbojo, "Pengaruh Kompetensi Integrasi Teknologi, Konten Dan Pedagogik (TPACK), Motivasi Kerja Dan Teachers' Work Engagement Terhadap Kinerja Guru SD XYZ Cabang Bekasi," *Cetta J. Ilmu Pendidik.*, vol. 7, no. 3, pp. 216–226, Jul. 2024, doi: 10.37329/cetta.v7i3.3137.
[8] L. Chang, "Reconstruction of Writing instruction with Generative AI in SAMR Framework: A Multimodal Empirical Study," in *Proceedings of the 2nd Guangdong-Hong Kong-Macao Greater Bay Area Education Digitalization and Computer Science International Conference*, New York, NY, USA: ACM, Apr. 2025, pp. 877–881. doi: 10.1145/3746469.3746605.
[9] M. Cheng, "Quality in higher education: Developing a virtue of professional practice," *Qual. High. Educ. Dev. a Virtue Prof. Pract.*, pp. 1–104, 2016, doi: 10.1007/978-94-6300-666-8.
[10] I. Celik, M. Dindar, H. Muukkonen, and S. Järvelä, "The Promises and Challenges of Artificial Intelligence for Teachers: a Systematic Review of Research," *TechTrends*, vol. 66, no. 4, pp. 616–630, Jul. 2022, doi: 10.1007/s11528-022-00715-y.
[11] OECD, *OECD Digital Education Outlook 2023*. in OECD Digital Education Outlook. OECD Publishing, 2023. doi: 10.1787/c74f03de-en.
[12] R. Luckin, *Machine Learning and Human Intelligence: The Future of Education for the 21st Century.* 2018.
[13] O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education – where are the educators?," *Int. J. Educ. Technol. High. Educ.*, vol. 16, no. 1, p. 39, Dec. 2019, doi: 10.1186/s41239-019-0171-0.
[14] L. Darling-Hammond, *Empowering Teachers: Lessons from Five High-Performing Systems.* San Francisco, CA / New York: Jossey Bass, 2017.
[15] A. Adnan, A. Zohriah, and A. Muín, "Evaluasi Kinerja Tenaga Pendidik," *JIIP - J. Ilm. Ilmu Pendidik.*, vol. 7, no. 2, pp. 1463–1468, 2024, doi: 10.54371/jiip.v7i2.3446.
[16] C. Dalsgaard and T. Ryberg, "A theoretical framework for digital learning spaces: learning in individual spaces, working groups, communities of interest, and open connections," *Res. Learn. Technol.*, vol. 31, Sep. 2023, doi: 10.25304/rlt.v31.3084.
[17] E. Yeşilyurt and R. Vezne, "Digital literacy, technological literacy, and internet literacy as predictors of attitude toward applying computer-supported education," *Educ. Inf. Technol.*, vol. 28, no. 8, pp. 9885–9911, Aug. 2023, doi: 10.1007/s10639-022-11311-1.
[18] N. Hidayati and F. Nugrahani, "Pengaruh Kemampuan Berpikir Kritis dan Minat Baca Terhadap Kemampuan Literasi Digital Pendahuluan," vol. 13, no. 3, pp. 3201–3212, 2024, doi: 10.58230/27454312.760.
[19] D. T. K. Ng, J. Su, J. K. L. Leung, and S. K. W. Chu, "Artificial intelligence (AI) literacy education in secondary schools: a review," *Interact. Learn. Environ.*, vol. 32, no. 10, pp. 6204–6224, Nov. 2024, doi: 10.1080/10494820.2023.2255228.
[20] Daniel L. Stufflebeam and Chris L. S. Coryn, *Evaluation theory, models, and applications*, Edition-2. San Francisco: San Francisco : Jossey-Bass & Pfeiffer Imprints, Wiley, 2014. Accessed: Apr. 26, 2026.
[21] A. Tlili *et al.*, "What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education," *Smart Learn. Environ.*, vol. 10, no. 1, p. 15, Feb. 2023, doi: 10.1186/s40561-023-00237-x.
[22] R. Scherer, S. K. Howard, J. Tondeur, and F. Siddiq, "Profiling teachers' readiness for online teaching and learning in higher education: Who's ready?," *Comput. Human Behav.*, vol. 118, p. 106675, May 2021, doi: 10.1016/j.chb.2020.106675.
[23] C. Lang, G. Siemens, A. F. Wise, D. Gasevic, and A. Merceron, *Handbook of Learning Analytics*, Second. Society for Learning Analytics Research (SoLAR), 2022. doi: 10.18608/hla17.
[24] J. W. Creswell and D. C. J, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. Los Angeles: SAGE Publications, 2018.
[25] J. F. Hair, J. J. Risher, M. Sarstedt, and C. M. Ringle, "When to use and how to report the results of PLS-SEM," *Eur. Bus. Rev.*, vol. 31, no. 1, pp. 2–24, Jan. 2019, doi: 10.1108/EBR-11-2018-0203.
[26] H. Latan and I. Ghozali, *Partial Least Squares: Concepts, Methods and Applications using WarpPLS 4*. 2021.
[27] J. Blake, "Unleashing the Potential," in *Generative AI in Teaching and Learning*, Japan: IGI Global, 2023, ch. 2, pp. 31–45. doi: 10.4018/979-8-3693-0074-9.ch002.
[28] C. L. M. FX. Risang Baskara, "Mengoptimalkan Reciprocal Teaching Dengan Generative AI: Kerangka Teori ... - FX. Risang Baskara, Concilianus Laos Mbato - Google Buku," in *E Book*, M. Budiraharjo, Ed., Yogyakarta: Sanata Dharma University Press, 2024. Accessed: Dec. 20, 2025.
[29] P. MacDowell, K. Moskalyk, K. Korchinski, and D. Morrison, "Preparing Educators to Teach and Create With Generative Artificial Intelligence," *Can. J. Learn. Technol.*, vol. 50, no. 4, pp. 1–23, Nov. 2024, doi: 10.21432/cjlt28606.
[30] I. Molenaar, "Towards hybrid human-AI learning technologies," *Eur. J. Educ.*, vol. 57, no. 4, pp. 632–645, Dec. 2022, doi: 10.1111/ejed.12527.
[31] C. N. Prilop, D.-K. Mah, L. J. Jacobsen, R. R. Hansen, K. E. Weber, and F. Hoya, "Generative AI in teacher education: Educators' perceptions of transformative potentials and the triadic nature of AI literacy explored through AI-enhanced methods," *Comput. Educ. Artif. Intell.*, vol. 9, p. 100471, Dec. 2025, doi: 10.1016/j.caeai.2025.100471.

[32] W. Holmes and I. Tuomi, "State of the art and practice in AI in education," *Eur. J. Educ.*, vol. 57, no. 4, pp. 542–570, Dec. 2022, doi: 10.1111/ejed.12533.
[33] F. Miao, W. Holmes, R. Huang, and H. Zhang, *AI and education: guidance for policy-makers*. UNESCO, 2021. doi: 10.54675/PCSP7350.
[34] A. Matere, "Effectiveness of Artificial Intelligence Tools in Teaching and Learning in Higher Education Institutions in Kenya," *J. Kenya Natl. Comm. UNESCO*, vol. 5, no. 1, Dec. 2024, doi: 10.62049/jkncu.v5i1.177.
[35] F. A. Wilujeng and Setiyawan, "The Effect of Digital Literacy on Teacher Performance With Creativity and Professionality As An Intervening Variable Fitri," *IJAEM*, vol. 5, no. 12, pp. 328–336, 2023, doi: 10.35629/5252-0512328336.
[36] Z. Mao, S. Tong, C. Jiang, S. Yan, and Y. Bai, "How university teachers' digital literacy influences their innovative ability: a system dynamics theoretical modeling and simulation study," *Front. Psychol.*, vol. 16, Feb. 2026, doi: 10.3389/fpsyg.2025.1665337.
[37] K. Sperling, C.-J. Stenberg, C. McGrath, A. Åkerfeldt, F. Heintz, and L. Stenliden, "In search of artificial intelligence (AI) literacy in teacher education: A scoping review," *Comput. Educ. Open*, vol. 6, p. 100169, Jun. 2024, doi: 10.1016/j.caeo.2024.100169.
[38] H. Du, Y. Sun, H. Jiang, A. Y. M. A. Islam, and X. Gu, "Exploring the effects of AI literacy in teacher learning: an empirical study," *Humanit. Soc. Sci. Commun.*, vol. 11, no. 1, p. 559, May 2024, doi: 10.1057/s41599-024-03101-6.
[39] O. V. Sergeeva, A. R. Masalimova, M. R. Zheltukhina, L. S. Chikileva, L. Y. Lutskovskai, and A. Luzin, "Impact of digital media literacy on attitude toward generative AI acceptance in higher education," *Front. Educ.*, vol. 10, Jun. 2025, doi: 10.3389/feduc.2025.1563148.
[40] F. ul Haq, M. Asim, N. M. Suki, N. Zakaria, and S. Hussain, "AI Adoption and Educational Effectiveness in Emerging Higher Education Institutions: The Moderating Role of Digital Literacy and Institutional Support," *J. Inf. Knowl. Manag.*, vol. 25, no. 03, Mar. 2026, doi: 10.1142/S021964922550090X.
[41] H. Yaseen, A. S. Mohammad, N. Ashal, H. Abusaimeh, A. Ali, and A.-A. A. Sharabati, "The Impact of Adaptive Learning Technologies, Personalized Feedback, and Interactive AI Tools on Student Engagement: The Moderating Role of Digital Literacy," *Sustainability*, vol. 17, no. 3, p. 1133, Jan. 2025, doi: 10.3390/su17031133.
[42] C. K. Lo, "What Is the Impact of ChatGPT on Education? A Rapid Review of the Literature," *Educ. Sci.*, vol. 13, no. 4, p. 410, Apr. 2023, doi: 10.3390/educsci13040410.
[43] D. Siahaan, A. N. Azhari, and D. S. Soegoto, "Transformasi Digital dalam Pendidikan dan Produktivitas Kerja Pendidik : Peran Artificial Intelligence sebagai Enabler Efisiensi Pedagogi efisiensi pedagogi dalam hubungan antara transformasi digital pendidikan dan produktivitas menyeluruh terhadap metode," *J. Ilm. Manaj. dan Kewirausahaan*, vol. 5, 2026, doi: 10.55606/jimak.v5i2.6730.
[44] T. Rachbauer, J. Graup, and E. Rutter, "Digital literacy and artificial intelligence literacy in teacher training," *Forum Educ. Stud.*, vol. 3, no. 1, pp. 1842–1842, Mar. 2025, doi: 10.59400/FES1842.
[45] F. Miao and M. Cukurova, *AI competency framework for teachers*. France: UNESCO, 2024. doi: 10.54675/ZJTE2084.
[46] X. Tan, G. Cheng, and M. H. Ling, "Enhancing teachers' AI competency: A professional development intervention study based on intelligent-TPACK framework," *Comput. Educ. Artif. Intell.*, vol. 9, p. 100521, Dec. 2025, doi: 10.1016/j.caeai.2025.100521.
[47] I. Tenberga and L. Daniela, "Artificial Intelligence Literacy Competencies for Teachers Through Self-Assessment Tools," *Sustainability*, vol. 16, no. 23, p. 10386, Nov. 2024, doi: 10.3390/su162310386.
[48] E. Tipton, K. Hallberg, L. V. Hedges, and W. Chan, "Implications of Small Samples for Generalization: Adjustments and Rules of Thumb," *Eval. Rev.*, vol. 41, no. 5, pp. 472–505, Oct. 2017, doi: 10.1177/0193841X16655665.
[49] L. Parker, A. J. Loper, C. W. Carter, J. Hayes, and A. Karakas, "Longitudinal insights into AI in education: Usage, ethics, and policy development in higher education," *Comput. Educ. Open*, vol. 10, p. 100329, Jun. 2026, doi: 10.1016/j.caeo.2025.100329.
[50] McGehee Nikolas, "Artificial Intelligence and Student Usage in Online Learning: A Longitudinal Analysis of Usage Patterns, Achievement, and Perceptions in K-12 Virtual Education | Michigan Virtual," Michigan Virtual Learning. Accessed: May 01, 2026.