Asian Journal of Applied Education (AJAE)
Vol. 5, No. 1, 2026: 79-92

Teachers' Pedagogical Adaptation in the Use of Artificial Intelligence in Secondary School Learning

Syarifuddin[1], Pierre Marcello Lopulalan[2], Rudi Harun[3]
[1]Sekolah Tinggi Ilmu Ekonomi YPUP Makassar, Indonesia
[2,3]Politeknik Pelayaran Banten, Indonesia
Corresponding Author: Syarifuddin, syarif070707@gmail.com

ARTICLE INFO

Keywords: Pedagogical Adaptation, Artificial Intelligence, Secondary School Learning, Teachers.

Received : 28, November
Revised : 29, December
Accepted: 30, January

ABSTRACT

The integration of artificial intelligence (AI) in secondary education requires teachers to adapt pedagogically to sustain meaningful learning. This mixed-methods study examines teachers' pedagogical adaptation in using AI, focusing on learning strategies, assessment, classroom management, and professional readiness. The findings show that effective adaptation is shaped by teachers' digital competence, institutional support, and prior experience. Teachers who successfully integrate AI adopt learner-centered approaches, use AI for personalized learning and formative assessment, and act as learning facilitators. However, limited training, ethical concerns, and unequal access remain challenges. The study highlights the need for continuous professional development, supportive policies, and clear pedagogical frameworks to ensure AI enhances learning quality.

DOI prefix: https://doi.org/10.55927/ajae.v5i1.16040
ISSN-E: 2693-5241
https://journal.formosapublisher.org/index.php/ajae

INTRODUCTION

The development of artificial intelligence (AI) in recent years has brought significant transformations in various aspects of life, including the field of education. AI is now used in the form of adaptive learning systems, learning analytics, virtual assistants, and assessment automation that enable more personalized and data-driven learning. In the context of formal education, the use of AI is no longer seen as an additional innovation, but rather as an integral part of the ever-evolving digital learning ecosystem (Holmes et al., 2022; Zawacki-Richter et al., 2020).

At the secondary school level, AI integration has complex pedagogical implications. Students in this phase are at a stage of cognitive and social development that demands contextual, reflective, and encouraging high-level thinking skills. AI has the potential to support these needs through material personalization, quick feedback, and continuous monitoring of learning progress. However, the effectiveness of the use of AI is highly dependent on the role of teachers as the main actors in the learning process (Kong et al., 2021).

Teachers have a strategic position in determining how AI technology is used in the classroom. AI integration is not only a matter of technology adoption, but also requires teachers' ability to make pedagogical adaptations, namely adjusting learning strategies, assessment methods, and classroom management to be in harmony with the characteristics of technology and the needs of students. Recent research shows that without adequate pedagogical adaptation, the use of AI risks being superficial and not having a significant impact on the quality of learning (Ifenthaler & Schumacher, 2023).

Pedagogical adaptation of teachers in the context of AI includes a paradigm shift in teaching from a teacher-centered approach to student-centered learning. Teachers are required to utilize AI as a tool to support active, collaborative, and reflective learning, not as a substitute for their pedagogical role. Within this framework, teachers play the role of facilitators, learning designers, and pedagogical decision-makers who are critical of the use of technology (Trust et al., 2023).

Although the potential of AI in education is enormous, various studies show that teachers still face significant challenges in their integration process. These challenges include limited digital competencies, lack of ongoing professional training, and lack of clear pedagogical guidance on the use of AI in learning (Hwang & Tu, 2021; Ng et al., 2023). This condition causes considerable variation in the level of readiness and pedagogical adaptation of teachers, especially in secondary schools.

In addition to the technical and pedagogical aspects, AI integration also raises ethical and professional issues that need serious attention. Concerns related to student data privacy, algorithm transparency, AI system bias, and the potential for reduced human interaction in learning are important discourses in contemporary educational literature (Selwyn, 2022; Williamson & Eynon, 2020). Therefore, teachers' pedagogical adaptations need to be accompanied by an ethical and reflective understanding of the use of AI in the classroom.

A number of studies in the past five years have highlighted the importance of teacher professional development focused on AI literacy and digital pedagogy. Teachers who receive relevant institutional support and training tend to be better able to meaningfully integrate AI, including in lesson planning, formative assessment, and instructional differentiation (Kong et al., 2022; Luo et al., 2024). However, empirical studies that specifically examine the pedagogical adaptation of secondary school teachers in the use of AI are still relatively limited.

Based on this presentation, this study aims to examine in depth the pedagogical adaptation of teachers in the use of artificial intelligence in learning in secondary schools. The focus of the research is directed at learning strategies, assessment practices, classroom management, and teachers' professional readiness in integrating AI. This research is expected to fill the existing research gaps and make theoretical and practical contributions to the development of effective, ethical, and sustainable AI-based pedagogy in the context of secondary education.

LITERATURE REVIEW

Artificial Intelligence in Education

Artificial Intelligence (AI) in education is defined as the use of a computational system that is able to perform cognitive functions such as data analysis, decision-making, and providing feedback to support the learning process. In the past seven years, research has shown that AI has played an important role in the development of intelligent tutoring systems, learning analytics, and adaptive learning that are oriented to the individual needs of learners (Chen et al., 2020; Ouyang & Jiao, 2021). The integration of AI in learning allows for the provision of a more personalized, efficient, and responsive learning experience to a variety of students' abilities.

Nevertheless, the researchers assert that the positive impact of AI in education is not automatic. The success of AI implementation is greatly influenced by the pedagogical context and the competence of teachers in utilizing the technology in a meaningful way. AI used without a strong pedagogical foundation has the potential to reinforce learning practices that are mechanistic and purely outcome-oriented (Teräs et al., 2020). Therefore, AI needs to be understood as a pedagogical tool, not just a technological innovation.

Pedagogical Adaptation of Teachers in AI Integration

Teacher pedagogical adaptation refers to the ability to adapt learning strategies, instructional roles, and assessment approaches in line with changes in the technology-based learning environment. In the context of AI, pedagogical adaptation includes the ability of teachers to integrate technology critically, reflectively, and in harmony with learning objectives (Howard & Mozejko, 2022). Recent studies show that teachers who are able to adapt pedagogically tend to use AI to support active, collaborative, and problem-solving-based learning (Celik et al., 2022).

Cross-border research also indicates that teachers' pedagogical adaptation is influenced by individual and institutional factors, such as teaching experience,

confidence in the use of technology, and a school culture that supports innovation (Alam, 2021). Teachers who have pedagogical autonomy and strong managerial support are better able to explore the potential of AI in learning, compared to teachers who are in rigid and administratively oriented systems.

Changing the Role of Teachers in the AI Era

Contemporary literature confirms that the integration of AI is driving significant changes in the professional role of teachers. Teachers no longer function solely as conveyors of information, but as learning facilitators, learning designers, and reflective supervisors for students (Pedro et al., 2019). AI takes over some routine tasks, such as automatic correction and analysis of learning data, so teachers have more room to focus on pedagogical interactions and the development of higher-level thinking skills.

However, this change of role does not always go smoothly. Several studies have found that teachers' resistance to AI is caused by concerns about reduced professional autonomy and the potential replacement of human roles by machines (Bayne et al., 2020). Therefore, teacher pedagogical adaptation needs to be understood as an ongoing process that involves the negotiation of professional identity and the reinterpretation of teaching practice.

Teacher AI Competence and Literacy

AI literacy is a key component in supporting teachers' pedagogical adaptation. This literacy includes not only technical skills using AI tools, but also a conceptual understanding of how AI works, its limitations, and its pedagogical and social implications (Long & Magerko, 2020). Teachers with adequate levels of AI literacy tend to be more critical in choosing and using technology, and are able to integrate it ethically and responsibly.

Recent research shows that teacher professional development programs that emphasize pedagogy-based AI literacy have a positive impact on teachers' readiness to implement AI in the classroom (Zhai et al., 2023). However, there is still a gap between educational technology policy and professional development practices in the field, especially in secondary schools, which causes teachers' pedagogical adaptation to run unevenly.

Ethical Issues and Challenges of AI Implementation

The integration of AI in learning also raises various ethical issues relevant to teachers' pedagogical practices. These issues include the privacy and security of student data, algorithm transparency, and potential bias in AI systems that can reinforce educational inequities (Regan & Jesse, 2019). Teachers are strategically positioned to ensure that the use of AI remains oriented towards pedagogical and humanitarian values. In addition, structural challenges such as limited infrastructure, technology access gaps, and lack of clear policies also affect teachers' ability to optimally adapt AI (Bozkurt et al., 2021). This challenge confirms that teachers' pedagogical adaptation cannot be separated from the context of the education system at large.

Research Synthesis and Gaps

Based on a literature review, it can be concluded that AI has great potential in improving the quality of learning in secondary schools, but its effectiveness is highly dependent on the pedagogical adaptation of teachers. Although many studies have addressed AI in education and changes in the role of teachers in general, empirical studies that specifically examine how secondary school teachers adapt pedagogically in the use of AI are still limited, especially those that comprehensively integrate pedagogical, professional, and ethical dimensions.

Therefore, this study is directed to fill this gap by exploring the pedagogical adaptation of teachers in the use of AI in secondary school learning. This focus is expected to enrich theoretical studies on AI-based pedagogy and provide practical implications for the development of teacher professional development policies and programs.

METHODOLOGY

Research Design

This study uses mixed methods with an explanatory sequential design approach. This approach was chosen to gain a comprehensive understanding of teachers' pedagogical adaptation in the use of artificial intelligence (AI) in secondary school learning, by combining the power of quantitative and qualitative data. Quantitative data is used to identify general patterns of teacher pedagogical adaptation, while qualitative data serves to deepen and explain these quantitative findings (Creswell & Plano Clark, 2018).

Context and Research Participants

This research was carried out in several secondary schools that have begun to integrate digital technology and AI in the learning process. The research participants consisted of high school teachers from various subjects selected using purposive sampling techniques. Participant selection criteria include: (1) having at least three years of teaching experience, (2) having used or been involved in the utilization of AI-based technology in learning, and (3) willing to voluntarily participate in the entire research series. This technique is used to ensure that the data obtained is relevant to the research focus and reflects the teacher's real experience in adapting AI-based pedagogical practices (Palinkas et al., 2015).

Data Collection Techniques and Instruments

Quantitative data was collected through a closed-ended questionnaire designed to measure teachers' level of pedagogical adaptation in the use of AI. The questionnaire instrument covers several main dimensions, namely learning strategies, assessment practices, classroom management, and teacher professional readiness. A five-point Likert scale is used to measure respondents' level of approval of each statement. The development of the instrument is based on a literature review on digital pedagogy and teacher AI literacy, and is tailored to the context of secondary education (Ifenthaler & Schumacher, 2023).

Qualitative data were obtained through semi-structured interviews and limited classroom observations. The interviews were conducted to explore teachers' experiences, perceptions, and challenges in integrating AI into daily learning practices. Classroom observations are used to obtain an empirical picture of how AI is used in the learning process and how teachers adjust their pedagogical roles. This approach allows researchers to obtain more contextual and in-depth data (Merriam & Tisdell, 2016).

Research Procedure

The research was carried out in several stages. The first stage is the collection of quantitative data through the distribution of questionnaires to all participants. The second stage was an initial analysis of quantitative data to identify the tendency and pattern of pedagogical adaptation of teachers. The third stage is the collection of qualitative data through interviews and observations selected based on the results of previous quantitative analysis. This sequential procedure allows qualitative data to serve as an explanatory and reinforcing of quantitative findings (Creswell & Plano Clark, 2018).

Data Analysis Techniques

Quantitative data were analyzed using descriptive statistics to describe teachers' pedagogical adaptation levels and inferential statistics to identify relationships between relevant variables, such as digital competence and professional readiness. The analysis is carried out with the help of statistical software. Meanwhile, qualitative data was analyzed using thematic analysis with stages of open coding, theme grouping, and interpretation of meaning. This analysis aims to identify key themes related to pedagogical adaptation strategies, challenges in AI implementation, and changes in the role of teachers in learning (Braun & Clarke, 2021). The integration of quantitative and qualitative analysis results is carried out at the interpretation stage to produce a holistic understanding.

Data Validity and Reliability

To ensure the validity of the quantitative data, a content validity test was carried out through expert assessment and instrument reliability test using an internal consistency coefficient. In qualitative data, validity is maintained through triangulation techniques of sources and methods, member checking, and the preparation of detailed contextual descriptions (Lincoln & Guba, 1985). This approach is used to increase the credibility and reliability of research findings.

Ethical Considerations

This research is carried out by paying attention to the ethical principles of educational research. All participants were given clear information about the purpose of the research and the data collection procedure, and signed an informed consent. The confidentiality of the participants' identities is maintained, and the research data is used solely for academic purposes. This ethical consideration is important considering that the use of AI in education is closely related to the issue of professionalism and data privacy (Regan & Jesse, 2019).

RESEARCH RESULTS

The Level of Pedagogical Adaptation of Teachers in the Use of AI

The results of quantitative data analysis showed that the level of pedagogical adaptation of teachers in the use of artificial intelligence (AI) in secondary school learning was in the medium to high category. Most of the respondents have utilized AI in learning activities, especially as a supporting tool in the provision of digital materials, the search for learning resources, and the implementation of technology-based formative assessments. These findings suggest that AI has begun to be adopted in daily learning practices by secondary school teachers.

Table 1. The Level of Pedagogical Adaptation of Teachers in the Use of AI Based on Dimensions

Dimensions of Pedagogical Adaptation	Red	SD	Categories
AI-Based Learning Strategies	3.82	0.54	Height
AI-Based Learning Assessment	3.67	0.61	Medium–High
AI-Based Classroom Management	3.21	0.68	Medium
AI-Based Pedagogical Decision-Making	3.08	0.72	Medium
Teacher Pedagogical Adaptation (Total)	**3.45**	**0.59**	**Medium–High**

Based on Table 1, the level of pedagogical adaptation of teachers in the overall use of AI is in the moderate-high category (M = 3.45; SD = 0.59). The AI-based learning strategy dimension obtained the highest average score (M = 3.82), indicating that teachers are relatively more prepared to leverage AI to support learner-centered learning. In contrast, the AI-based classroom management and AI-based pedagogical decision-making dimensions showed lower average scores and were in the medium category. These findings indicate that the use of AI by teachers is still more dominant in the operational aspects of learning than in the aspects of classroom management and data-based decision-making.

However, the results of the analysis also show that the use of AI is still dominated in basic and operational functions. The use of AI in a more strategic and reflective way, such as to support adaptive learning, instructional differentiation, and data-driven pedagogical decision-making, is still limited to a small percentage of teachers. This indicates that there is a variation in the level of pedagogical adaptation between teachers in integrating AI into learning.

Based on the analysis per dimension, the learning strategy is the pedagogical adaptation dimension that obtains the highest score. Teachers are relatively more able to utilize AI to support student-centered learning, such as the use of interactive digital platforms and the preparation of more flexible learning activities. In contrast, the dimensions of AI-based classroom management and the utilization of AI for pedagogical decision-making showed lower scores. These findings show that the use of AI by teachers still tends to be at the operational level, and has not fully developed towards a transformative pedagogical level.

Factors Affecting Teachers' Pedagogical Adaptation

The results of the inferential analysis showed that teachers' digital competence and school institutional support had a significant relationship with the level of pedagogical adaptation of teachers in the use of AI. Teachers with higher levels of digital competence tend to be more confident and more active in integrating AI into learning planning, learning implementation, and assessment. In addition, institutional support in the form of school policies, the availability of training, and access to technological infrastructure contribute positively to teachers' pedagogical adaptability.

To deepen these quantitative findings, qualitative data analysis was carried out through interviews. The results of the interviews show that teachers' digital competence is the main factor that affects teachers' courage and readiness in integrating AI into learning. Teachers with better digital competencies tend to have a broader understanding of the pedagogical potential of AI and are able to relate it to learning objectives.

> "*I feel more confident in using AI because I have often participated in learning technology training before. So, when there is an AI-based application, I don't just see it as a tool, but as part of a teaching strategy.*" (G05, interview, March 12, 2025)

Some teachers emphasized that the experience of attending educational technology and AI training helps them understand how to utilize AI pedagogically, not just technically. The training allows teachers to explore AI in lesson planning, assessment, and instructional differentiation.

> "*The training I participated in opened up the insight that AI can be used to adapt material to students' abilities. From there I started trying to use AI to provide a variety of questions and initial feedback.*" (G11, interview, March 18, 2025)

In addition to individual competence, the support of school institutions also emerged as an important factor in encouraging teacher pedagogical adaptation. Teachers who work in schools with policies that support innovation and the availability of technological infrastructure feel more free to experiment with AI.

> "*Schools provide the freedom to try new technologies, including AI. There is facility support and also discussions between teachers, so I have no hesitation in integrating it into learning.*" (G02, interview, March 20, 2025)

On the other hand, teachers with minimal institutional support revealed that limited facilities and lack of training made them use AI in a limited and unplanned manner. The use of AI tends to be situational and has not been integrated into the overall learning design.

> "I am actually interested in using AI, but there is no special training at school. So I use it only to help prepare the material, not to the more in-depth learning planning." (G09, interview, March 25, 2025)

The interview findings also show that the lack of institutional support has an impact on teachers' low confidence in using AI pedagogically. Teachers in this condition tend to think of AI as an additional tool, rather than as part of a learning strategy.

> "*Since there is no clear direction from the school, I am still hesitant to use AI more broadly. Fear of being wrong or not in accordance with policy.*" (G14, interview, March 28, 2025).

Forms of Pedagogical Adaptation of Teachers in Learning Practices

The results of classroom observations and interviews reveal several main forms of pedagogical adaptation of teachers in the use of AI. First, teachers use AI as a tool to support learning personalization, for example by adjusting the difficulty level of questions, providing recommendations for additional materials, or providing initial feedback on student assignments. This practice shows the teacher's efforts in responding to the differences in students' learning abilities and needs.

Second, AI is used to support formative assessments, such as analyzing online quiz results and monitoring student learning progress in real-time. Teachers utilize the data generated by AI-based systems to identify students' learning difficulties and make limited learning adjustments. Third, some teachers are beginning to show a change in pedagogical roles by adopting positions as facilitators and learning designers, where AI is used as a tool to encourage discussion, reflection, and the development of students' critical thinking skills.

However, the results of observations also show that this pedagogical adaptation has not taken place evenly. A number of teachers still use AI primarily for the automation of administrative tasks, such as simple corrections or the preparation of materials, without significant changes in pedagogical approaches. These findings show that teachers' pedagogical adaptation levels in the use of AI still span a diverse spectrum, from technical use to initial efforts at pedagogical transformation.

DISCUSSION

The findings of this study show that the pedagogical adaptation of teachers in the use of artificial intelligence (AI) is a gradual process and is greatly influenced by the learning context. The level of adaptation that is in the medium to high category indicates that most teachers are still in the initial exploration and reinforcement phase in AI integration. This condition is in line with research results that show that the adoption of AI-based technology in education generally begins with functional use before progressing towards a more profound pedagogical transformation (Kong et al., 2021; Zhu et al., 2022).

The dominance of the use of AI in the dimension of learning strategy compared to classroom management and pedagogical decision-making shows that teachers still position AI as an instructional support tool. AI is more widely used to improve the efficiency of material delivery and variety of learning activities, but it has not been fully used as a basis for designing data-based learning. These findings support the view of Trust et al. (2023) who assert that without pedagogical capacity strengthening, the use of AI risks stopping at the technical level and not resulting in substantive changes in learning practices.

The significant relationship between teachers' digital competencies and the level of pedagogical adaptation underscores the importance of mastering advanced digital skills in the context of AI-based education. Teachers with higher digital competencies tend to have better reflective abilities in selecting, adjusting, and evaluating the use of AI according to learning objectives. These findings are consistent with studies that emphasize that teachers' digital competencies are a key prerequisite for meaningful and pedagogically oriented technology integration (Falloon, 2020; Tondeur et al., 2021).

In addition to individual factors, the support of school institutions has been shown to play a significant role in strengthening teachers' pedagogical adaptation. School policies that encourage innovation, the availability of continuous training, and access to technology infrastructure provide a safe space for teachers to experiment with AI. This is in line with the findings of previous research that show that school leadership and a supportive organizational culture are determining factors for the success of educational technology integration (Dexter, 2018; Scherer et al., 2021).

Qualitative findings that show the change in the role of teachers to facilitators and learning designers reflect a shift in the pedagogical paradigm in the AI era. Teachers no longer focus on the transmission of knowledge, but rather on managing student learning experiences supported by intelligent technology. This shift supports a conceptual framework that places teachers as learning designers who are able to orchestrate interactions between students, technology, and learning content (Laurillard, 2012; Mishra & Koehler, 2006).

Nonetheless, the study also identified various challenges in teachers' pedagogical adaptation, including limitations of training focused on AI pedagogy, concerns about ethical implications, and inequality of access to technology between schools. These challenges show that AI integration is not only a technical issue, but also closely related to issues of ethics, justice, and educational governance. These findings are in line with research emphasizing the need for a comprehensive ethical and policy framework in the implementation of AI in the education sector (Holmes et al., 2022; Williamson & Eynon, 2020).

Overall, this discussion confirms that teachers' pedagogical adaptation is a key factor in ensuring that the use of AI truly contributes to improving the quality of learning in secondary schools. Therefore, the development of educational policies and teacher professional development programs needs to be directed not only at mastery of technology, but also at strengthening pedagogical capacity, ethical reflection, and the sustainability of the integration of AI in educational practices.

CONCLUSION AND RECOMMENDATION

This study shows that teachers' pedagogical adaptation in the use of artificial intelligence (AI) in secondary school learning is in the medium to high category, but is still dominated by the use of AI at the operational level. Teachers are making more use of AI to support learning strategies and formative assessments, while the use of AI for classroom management and data-driven pedagogical decision-making is still limited.

The results of the study also confirm that teachers' digital competence and the support of school institutions play a significant role in influencing the level of pedagogical adaptation. Teachers with better digital competencies and adequate policy support, training, and infrastructure tend to be more confident and reflective in integrating AI into learning.

In addition, this study indicates an initial shift in the role of teachers towards facilitators and designers of AI-based learning, although these changes have not taken place evenly. Therefore, meaningful AI integration requires strengthening teachers' pedagogical competence and AI literacy, as well as ongoing institutional support so that the use of AI can make a real contribution to improving the quality of learning in secondary schools.

ADVANCED RESEARCH

Future studies are recommended to explore teachers' pedagogical adaptation to AI using longitudinal designs to capture changes over time. Further research could also examine deeper levels of AI integration, such as data-driven decision-making and classroom management, as well as investigate the role of professional development models and school leadership in accelerating meaningful AI adoption across diverse secondary school contexts.

REFERENCES

Alam, A. (2021). Possibilities and apprehensions in the landscape of artificial intelligence in education. *Education and Information Technologies, 26*(6), 6737–6756. https://doi.org/10.1007/s10639-021-10531-x

Bayne, S., Knox, J., & Ross, J. (2020). Artificial intelligence and education: Questioning the assumptions of technological progress. *Teaching in Higher Education, 25*(2), 177–189. https://doi.org/10.1080/13562517.2020.1722733

Bozkurt, A., et al. (2021). A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis. *Asian Journal of Distance Education, 15*(1), 1–126.

Braun, V., & Clarke, V. (2021). *Thematic analysis: A practical guide*. SAGE Publications.

Celik, I., Aydin, M., & Kocabas, I. (2022). Teachers' integration of artificial intelligence into education: A systematic review. *Educational Technology*

Research and Development, 70(3), 1125–1147. https://doi.org/10.1007/s11423-022-10094-0

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access, 8*, 75264–75278. https://doi.org/10.1109/ACCESS.2020.2988510

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

Dexter, S. (2018). The role of leadership for information technology in education. *Educational Technology Research and Development, 66*(3), 1–15.

Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. *Educational Technology Research and Development, 68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.

Howard, S. K., & Mozejko, A. (2022). Teachers' pedagogical adaptation to digital innovation. *Computers & Education, 182*, 104464. https://doi.org/10.1016/j.compedu.2022.104464

Hwang, G. J., & Tu, Y. F. (2021). Roles and research trends of artificial intelligence in education: A review. *Computers and Education: Artificial Intelligence, 2*, 100001. https://doi.org/10.1016/j.caeai.2021.100001

Ifenthaler, D., & Schumacher, C. (2023). Artificial intelligence literacy for educators. *Computers and Education: Artificial Intelligence, 4*, 100103. https://doi.org/10.1016/j.caeai.2023.100103

Kong, S. C., Cheung, W. M. Y., & Zhang, G. (2021). Teachers' attitudes toward artificial intelligence in education. *Journal of Educational Technology & Society, 24*(4), 1–15.

Kong, S. C., Yang, M., & Wong, T. L. (2022). Teacher development in AI-supported learning environments. *Educational Technology & Society, 25*(1), 1–14.

Laurillard, D. (2012). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications.

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–16. https://doi.org/10.1145/3313831.3376727

Luo, T., Wang, S., & Li, Y. (2024). Teachers' professional development for AI integration: A systematic review. *Computers & Education, 195*, 104679. https://doi.org/10.1016/j.compedu.2023.104679

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2023). AI literacy: Definition, teaching, and assessment. *Computers and Education: Artificial Intelligence, 4*, 100123. https://doi.org/10.1016/j.caeai.2023.100123

Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers and Education: Artificial Intelligence, 2*, 100020. https://doi.org/10.1016/j.caeai.2021.100020

Palinkas, L. A., et al. (2015). Purposeful sampling for qualitative data collection. *Administration and Policy in Mental Health and Mental Health Services Research, 42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development. *UNESCO Working Papers*.

Regan, P. M., & Jesse, J. (2019). Ethical challenges of AI in education. *AI and Ethics, 1*(1), 1–10. https://doi.org/10.1007/s43681-019-00008-4

Scherer, R., Siddiq, F., & Tondeur, J. (2021). The technology acceptance model revisited. *Computers & Education, 162*, 104093. https://doi.org/10.1016/j.compedu.2020.104093

Selwyn, N. (2022). *Education and technology: Key issues and debates* (2nd ed.). Bloomsbury Academic.

Teräs, M., Suoranta, J., Teräs, H., & Curcher, M. (2020). Post-COVID-19 education and education technology. *Learning, Media and Technology, 45*(4), 1–15.

Trust, T., Whalen, J., & Brown, S. (2023). Reframing teacher roles in AI-supported learning. *Educational Technology Research and Development, 71*(2), 1–20.

Tondeur, J., et al. (2021). Preparing teachers for technology integration. *Educational Technology Research and Development, 69*(1), 321–343.

Williamson, B., & Eynon, R. (2020). Historical threads and future directions of AI in education. *Learning, Media and Technology, 45*(3), 223–235. https://doi.org/10.1080/17439884.2020.1798995

Zawacki-Richter, O., Marin, V. I., Bond, M., & Gouverneur, F. (2020). Systematic review of AI applications in higher education. *International Journal of Educational Technology in Higher Education, 16*(39), 1–27. https://doi.org/10.1186/s41239-019-0171-0

Zhai, X., He, P., & Liu, X. (2023). Artificial intelligence literacy education for teachers. *Computers & Education, 186*, 104539. https://doi.org/10.1016/j.compedu.2022.104539

Zhu, Z. T., Yu, M. H., & Riezebos, P. (2022). A research framework of smart education. *Smart Learning Environments, 9*(1), 1–15. https://doi.org/10.1186/s40561-022-00195-6