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Developing a Smart Teacher AI-Based Blended Training Model for Enhancing Elementary School Teachers' Professional Competence

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Abstract

This study aims to develop and examine the effectiveness of a Smart Teacher AI-based blended training model for enhancing elementary school teachers' professional competence. The study employed a Research and Development (R&D) approach based on the Borg and Gall model integrated with the Delphi technique for expert validation. The proposed model combines artificial intelligence (AI), Blended learning, and culturally responsive teaching (CRT) within an adaptive digital training platform designed to support personalized teacher professional development. The effectiveness of the model was evaluated through Preliminary Field Testing at SD Islam Al Ittihad involving 15 teachers and Main Field Testing at SD Islam Amalia Cibinong involving 20 teachers. Data were collected using pre-test and post-test instruments and analyzed using paired sample t-tests. The findings revealed that the Smart Teacher AI model significantly improved teachers' professional competence, particularly in pedagogical and technology integration aspects. The novelty of this study lies in the integration of AI, blended learning, and CRT into a unified adaptive professional development model for elementary school teachers. Practically, the model provides a flexible, scalable, and context-sensitive training framework that supports continuous teacher development in the digital era. This study contributes to the growing literature on AI-integrated teacher professional development and offers an innovative framework for educational technology implementation in elementary education.

A. Introduction

The rapid advancement of information and communication technology (ICT) has significantly transformed the educational landscape worldwide, particularly in the context of teaching and learning processes. In the era of digital transformation and Society 5.0, teachers are expected not only to master pedagogical and professional competencies but also to integrate technology effectively into classroom practices (Abedi, 2024). The growing adoption of artificial intelligence (AI) in education has accelerated this transformation by enabling adaptive learning, personalized instruction, automated assessment, and intelligent learning support systems (Hariyanto et al., 2025). Recent studies indicate that AI has substantial potential to improve instructional quality and support teacher professional development in various educational contexts (Oddone, 2022)

In addition to AI integration, Blended learning has emerged as an effective approach for enhancing flexibility, accessibility, and sustainability in teacher professional development programs. (Moriña & Perera, 2025). Blended learning combines face-to-face and online learning environments, allowing teachers to participate in continuous learning while maintaining their professional responsibilities (Jokinen & Mikkonen, 2013). Previous studies have demonstrated that Blended learning improves teacher engagement, learning effectiveness, and digital literacy development. (Han, 2025). Furthermore, culturally responsive teaching (CRT) has become increasingly important in supporting inclusive and context-sensitive instructional practices that reflect students' diverse cultural backgrounds (Hu & Zheng, 2026)

Despite these developments, many teachers' professional development programs remain fragmented and conventional in practice. Existing training models frequently focus on isolated aspects such as digital literacy, AI implementation, or Blended learning without integrating these components into a unified and adaptive professional development framework (Syahruddin & Agus, 2026). In many developing educational contexts, teachers still experience difficulties in utilizing digital technologies effectively due to limited technological competence, inadequate training design, and insufficient contextual support (Timotheou et al., 2023). Consequently, professional development programs often fail to address teachers' actual pedagogical and technological needs in sustainable ways (Revina et al., 2023)

Preliminary findings from SD Islam Al Ittihad, Bogor, Indonesia, indicate that 73% of teachers had not optimally mastered digital learning technologies, 63% had limited experience in utilizing AI for personalized learning, and 53% had insufficient familiarity with creative learning applications and culturally responsive teaching approaches. These findings suggest a substantial gap between technological advancement and teachers' professional readiness in elementary education. Similar concerns have been reported in previous studies emphasizing that teacher readiness, adaptive support systems, and contextual pedagogical approaches are critical factors influencing successful educational transformation (Timotheou et al., 2023)

The state of the art in current educational technology research shows that most previous studies primarily examine AI in education, Blended learning, or culturally responsive pedagogy separately (Grab, 2026). Limited studies have attempted to integrate artificial intelligence, Blended learning, and culturally responsive teaching simultaneously within a comprehensive teacher professional development model (Bennett, 2026). Furthermore, few studies have developed adaptive AI-supported training systems specifically designed for elementary school teachers using a systematic Research and Development (R&D) framework combined with iterative expert validation processes (Lee et al., 2024).

Therefore, this study develops a Smart Teacher AI-based blended training model designed to enhance elementary school teachers' professional competence through the integration of AI, Blended learning, and culturally responsive teaching. The novelty of this study lies in three major aspects: (1) the integration of artificial intelligence, Blended learning, and CRT into a unified adaptive teacher professional development model; (2) the development of a Smart Teacher AI digital platform that supports personalized and context-sensitive learning pathways; and (3) the application of the Borg and Gall Research and Development framework integrated with the Delphi technique for systematic model validation and refinement. (Greisberger et al., 2025)

This study contributes theoretically to the growing body of literature on AI-integrated teacher professional development and educational technology innovation. Practically, the study offers an adaptive, scalable, and flexible training framework that can support continuous teacher professional development in elementary education. Accordingly, this study addresses the following research

question: How effective is the Smart Teacher AI-based blended training model in enhancing elementary school teachers' professional competence?

B. Literature Review

B.1 Artificial Intelligence in Education

Artificial Intelligence (AI) has become one of the most transformative technologies in modern education (Zhou, 2023). AI refers to computational systems capable of simulating human intelligence processes, including learning, reasoning, problem-solving, and adaptive decision-making (Benvenuti et al., 2023). In educational contexts, AI has increasingly been utilized to support personalized learning, intelligent tutoring systems, automated assessment, predictive analytics, and adaptive instructional design (Lin et al., 2023)

Recent studies demonstrate that AI can significantly improve teaching effectiveness and learning experiences by providing real-time feedback, individualized recommendations, and data-driven instructional support (Sajja et al., 2025). AI-powered educational systems enable teachers to identify students' learning needs more accurately and to design adaptive instructional strategies based on learners' characteristics and performance data (Rincon-Flores et al., 2024) further emphasize that AI contributes to more flexible and personalized learning environments that enhance learner engagement and academic achievement (Yang & Ogata, 2023)

In teacher professional development, AI has also emerged as a strategic tool for improving teachers' pedagogical competence and digital literacy (Ng et al., 2023). AI-supported training systems provide adaptive learning pathways, automated mentoring support, and personalized professional development recommendations that align with teachers' individual needs and competencies (Li et al., 2025). (Zhai, 2025) argues that generative AI technologies have substantial potential to support innovative teaching practices and strengthen teachers' readiness for digital transformation in education. (Cheng & Wang, 2023).

Despite these advantages, several challenges remain in implementing AI within teacher training programs. Previous studies indicate that many teachers still experience difficulties in utilizing AI effectively due to limited digital competence, inadequate training support, and insufficient technological infrastructure (Cheng & Wang, 2023) Furthermore, many AI-based educational initiatives focus primarily on technological functions while overlooking contextual pedagogical and cultural dimensions that influence instructional effectiveness. (Yildiz Durak & Onan, 2025)

These findings suggest the need for adaptive AI-supported professional development models that integrate not only technological innovation but also pedagogical and contextual considerations. Therefore, AI integration within teacher professional development should be designed systematically to support sustainable, flexible, and context-sensitive learning experiences for teachers.

B.2 Blended learning for Teacher Professional Development

Blended learning is widely recognized as an effective educational approach that combines face-to-face instruction with online learning environments (Müller et al., 2023) define blended learning as the thoughtful integration of classroom interaction and digital learning experiences to enhance educational effectiveness and flexibility. This approach enables learners to access instructional materials, collaborative activities, and self-paced learning opportunities beyond traditional classroom settings (Ebbini, 2023).

In the context of teacher professional development, Blended learning offers several advantages, including flexibility in time and location, increased accessibility to training resources, and opportunities for continuous learning without disrupting teachers' professional responsibilities (Graham, 2013). (Halverson et al., 2023) found that Blended learning environments often produce better learning outcomes compared to purely traditional instructional approaches due to their ability to combine direct interaction with technology-supported learning experiences (Rajaram, 2023).

Several studies have reported positive impacts of Blended learning on teachers' professional competence and digital literacy. (Mohammadi et al., 2025) demonstrated that Blended learning improves teachers' participation and motivation in professional training programs (Mohammadi et al., 2025). Similarly, found that Blended learning supported by Learning Management Systems (LMS) enhances teachers' abilities in developing digital instructional materials and lesson planning.

However, Blended learning implementation also faces several challenges. Previous studies indicate that ineffective instructional design, low technological readiness, and limited institutional support may reduce the effectiveness of Blended learning programs (Wong & Li, 2025). In many cases, Blended learning is implemented merely as a technological supplement rather than as a comprehensive pedagogical strategy that supports adaptive and meaningful learning experiences. (Wei et al., 2023).

Therefore, successful Blended learning implementation in teacher professional development requires systematic instructional planning, appropriate technological integration, and continuous pedagogical support (Moriña & Perera, 2025). Blended learning should not only improve technological access but also strengthen teachers' professional competence through flexible, interactive, and contextually relevant learning environments (Rajaram, 2023).

B.3 Culturally Responsive Teaching (CRT)

Culturally Responsive Teaching (CRT) is an instructional approach that emphasizes the importance of integrating students' cultural backgrounds, experiences, and identities into teaching and learning processes (Khunou & Makda, 2025). (Kurian, 2024) explains that culturally responsive teaching promotes inclusive educational environments by connecting instructional practices with students' social and cultural contexts. Similarly, (Zeng et al., 2025) argues that CRT supports meaningful learning by

recognizing students' cultural identities as valuable resources within educational settings. (Zeng et al., 2025)

In elementary education, culturally responsive teaching plays an important role in improving student engagement, participation, and learning motivation. (Yang & Ogata, 2023) found that CRT implementation enhances classroom interaction and supports more inclusive learning environments. Through culturally responsive instructional strategies, teachers are encouraged to adapt learning materials, communication styles, and classroom activities to accommodate students' diverse cultural backgrounds and learning needs. (Hossain, 2024)

The integration of CRT within teacher professional development programs is increasingly important in multicultural educational contexts. Teachers require not only technological competence but also pedagogical sensitivity to ensure that digital learning environments remain inclusive and contextually relevant (Méndez et al., 2023). Previous studies suggest that teacher training programs frequently emphasize technological skills while paying insufficient attention to socio-cultural dimensions of teaching and learning. (Yuan, 2023)

Consequently, integrating CRT into AI-supported Blended learning models may provide a more holistic approach to teacher professional development. Such integration allows teachers to combine technological innovation with culturally sensitive pedagogical practices that support meaningful and adaptive learning experiences for students. (Bitar & Davidovitch, 2024).

C. Methods

This study employed a Research and Development (R&D) approach based on the Borg and Gall model to develop and evaluate a Smart Teacher AI-based blended training model for enhancing elementary school teachers' professional competence (Wang et al., 2025) The Borg and Gall framework was selected because it provides systematic stages for educational product development, including needs analysis, product design, expert validation, field testing, product revision, and effectiveness evaluation (Borg & Gall, 2003).

The study was conducted in two Islamic elementary schools in Bogor, Indonesia. Preliminary Field Testing was carried out at SD Islam Al Ittihad involving 15 teachers, while Main Field Testing was conducted at SD Islam Amalia Cibinong involving 20 teachers. These schools were selected based on preliminary findings indicating challenges related to teachers' digital literacy, utilization of artificial intelligence in learning, and implementation of culturally responsive teaching practices.

The Smart Teacher AI model was developed as an adaptive professional development platform integrating artificial intelligence (AI), Blended learning, and culturally responsive teaching (CRT). The platform included several features such as personalized learning pathways, AI-assisted instructional support, digital learning modules, progress monitoring systems, and online-offline blended training activities.

The research procedure followed several stages of the Borg and Gall R&D framework. First, a preliminary study and needs analysis were conducted to identify teachers' professional development challenges and training needs. Second, the initial Smart Teacher AI prototype was designed and developed based on literature review findings and empirical needs analysis. Third, expert validation was conducted using the Delphi technique involving experts in educational management, educational technology, and teacher professional development (NIE & WANG, 2024).

After the validation process, Preliminary Field Testing was conducted to evaluate the initial implementation of the model. Based on the preliminary findings and participant feedback, several revisions were made to improve the training design, learning materials, and adaptive support features. Subsequently, Main Field Testing was conducted to examine the effectiveness of the revised model in a broader educational setting (da Silva et al., 2023)

Data were collected using pre-test and post-test instruments designed to measure teachers' professional competence before and after participating in the training program. Additional qualitative data were obtained through observations, participant feedback, and expert validation reports to support the interpretation of findings.

The quantitative data were analysed using paired sample t-tests to determine whether significant differences existed between pre-test and post-test scores. Statistical analysis was conducted to evaluate the effectiveness of the Smart Teacher AI-based blended training model in improving teachers' professional competence. The analysis focused particularly on teachers' pedagogical competence, technology integration skills, and adaptive instructional practices developed through the training activities.

D. Results and Discussion

D.1 Preliminary Findings

The preliminary findings revealed that elementary school teachers experienced several challenges related to digital literacy, technology integration, and adaptive instructional practices. Preliminary survey data from SD Islam Al Ittihad indicated that 73% of teachers had not optimally mastered digital learning technologies, 63% had limited experience in utilizing artificial intelligence for personalized learning, and 53% had insufficient familiarity with culturally responsive teaching (CRT) and creative digital learning applications such as Canva. These findings demonstrate a substantial gap between current technological developments and teachers' professional readiness in elementary education.

The findings are consistent with previous studies emphasizing that limited digital literacy and inadequate technological readiness remain major barriers to educational transformation(Okoye et al., 2023). Similar concerns were also reported by (Timotheou et al., 2023), who argued that teachers' ability to adopt educational technology significantly influences the effectiveness of digital learning

implementation. Therefore, the development of adaptive and context-sensitive professional development models becomes increasingly important in supporting teachers' readiness for digital transformation.

D.2 Development of the Smart Teacher AI Model

Based on the preliminary findings and literature review, the Smart Teacher AI model was developed as an adaptive professional development framework integrating artificial intelligence (AI), Blended learning, and culturally responsive teaching (CRT). The model was designed to provide personalized training pathways, AI-assisted instructional support, flexible Blended learning environments, and context-sensitive pedagogical strategies.

The Smart Teacher AI platform included several key features such as AI-supported learning recommendations, digital training modules, progress monitoring systems, and adaptive instructional guidance. The integration of AI enabled personalized professional development based on teachers' learning progress and competency needs. In addition, Blended learning components allowed teachers to participate flexibly in both online and face-to-face training activities.

The model development process followed the Borg and Gall Research and Development framework combined with Delphi validation techniques. Expert validation results indicated that the model was conceptually relevant, practically feasible, and suitable for implementation in elementary school teacher professional development programs.

D.3 Preliminary Field Testing Results

The Preliminary Field Testing conducted at SD Islam Al Ittihad involving 15 teachers showed varying levels of effectiveness across training modules. The Canva-based training module demonstrated non-significant improvement in teachers' professional competence ($p = 0.189$). This finding suggests that the initial implementation of technology-based training was not fully aligned with teachers' technological readiness and learning adaptation processes.

However, the PjBL-CRT training module demonstrated significant improvement ($p = 0.003$), indicating that integrating project-based learning and culturally responsive teaching contributed positively to teachers' pedagogical competence. These findings support previous studies emphasizing that culturally responsive instructional approaches improve learning engagement, contextual understanding, and instructional effectiveness(Zeng et al., 2025)

The initial non-significant results in the Canva module are also consistent with (Nevo et al., 2026) who argued that technology integration in education often requires iterative adaptation and continuous support before producing substantial learning outcomes. Therefore, revisions and refinements were conducted after the preliminary testing stage to improve the training design and adaptive support mechanisms(Sailer et al., 2023).

D.4 Main Field Testing Results

Following the revision process, Main Field Testing was conducted at SD Islam Amalia Cibinong involving 20 teachers. The findings demonstrated significant improvement in teachers' professional competence across both training modules. The Canva-based training module showed statistically significant improvement ($p = 0.035$), while the PjBL-CRT module demonstrated highly significant improvement ($p < 0.001$).

These findings indicate that the revised Smart Teacher AI model successfully improved teachers' technological competence, pedagogical adaptability, and instructional effectiveness. The improvement observed after model refinement confirms the importance of iterative development processes in educational innovation, as emphasized in the Borg and Gall Research and Development framework.

Furthermore, the results support previous international studies suggesting that AI-supported Blended learning environments enhance teacher engagement, professional competence, and adaptive instructional practices (Cao & Phongsatha, 2025). The integration of AI and Blended learning allowed teachers to access personalized learning support while maintaining flexibility in their professional development activities.

D.5 Discussion

The findings of this study demonstrate that integrating artificial intelligence, Blended learning, and culturally responsive teaching within a unified professional development framework significantly enhances elementary school teachers' professional competence. Unlike many previous studies that focused only on technological adoption or Blended learning implementation separately, this study provides a more comprehensive and adaptive teacher professional development model.

The effectiveness of the Smart Teacher AI model can be explained through several theoretical perspectives. First, AI-supported adaptive learning enables personalized professional development pathways that align with teachers' individual learning needs and competency levels. This finding supports (Li et al., 2025), who emphasized that AI enhances educational effectiveness through personalization and intelligent instructional support.

Second, Blended learning contributes to flexibility, accessibility, and sustainability in teacher professional development. Teachers were able to participate in learning activities without disrupting their professional responsibilities (Al Mamun & Lawrie, 2023), which aligns with the findings of Garrison and Vaughan (2008) and Means et al. (2013). The combination of online and face-to-face learning environments also supported continuous interaction and collaborative learning experiences.

Third, integrating culturally responsive teaching strengthened the contextual relevance of instructional practices. The CRT component enabled teachers to develop more inclusive and meaningful learning experiences that considered students' cultural backgrounds and social contexts. This finding is

consistent with (Grab, 2026), who argued that culturally responsive pedagogy enhances student engagement and instructional effectiveness.

Compared to previous studies, this research offers a stronger adaptive framework by combining AI-supported personalization, Blended learning flexibility, and culturally responsive pedagogy within a single professional development model. The integration of these components represents the major novelty of the Smart Teacher AI model.

Nevertheless, this study has several limitations. The research involved a relatively small number of participants and was limited to two Islamic elementary schools in Bogor, Indonesia. Therefore, the findings may not fully represent broader educational contexts. Future studies are recommended to examine the long-term effectiveness of the model and to implement the framework across wider educational environments and different school levels.

Theoretically, this study contributes to the growing literature on AI-integrated teacher professional development by proposing an adaptive and context-sensitive training framework. Practically, the Smart Teacher AI model provides an innovative approach for supporting continuous teacher professional development in the digital era through flexible and personalized learning environments.

E. Conclusions

This study concludes that the Smart Teacher AI-based blended training model is effective in enhancing elementary school teachers' professional competence. The integration of artificial intelligence (AI), Blended learning, and culturally responsive teaching (CRT) within an adaptive professional development framework significantly improved teachers' pedagogical competence, technology integration skills, and instructional adaptability. The findings demonstrate that AI-supported personalized learning pathways combined with flexible Blended learning environments can strengthen teacher professional development in the digital era. The study also confirms that iterative model refinement through the Borg and Gall Research and Development framework and Delphi expert validation contributed to the effectiveness and practical feasibility of the developed model. The major contribution of this study lies in the development of a unified adaptive teacher professional development model that integrates technological, pedagogical, and contextual dimensions simultaneously. Practically, the Smart Teacher AI model provides a flexible, scalable, and context-sensitive framework that can support continuous teacher professional development in elementary education. Nevertheless, this study was limited to a relatively small sample and specific educational settings in Bogor, Indonesia. Therefore, future studies are recommended to examine the long-term effectiveness of the model and its implementation across broader educational contexts and different school levels.

Declarations

F. Acknowledgement

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G. Ethics Approval and Consent to Participate

This study was reviewed and approved by the Research Ethics Committee of Pakuan University (Komite Integritas Akademik), Bogor, Indonesia (Research Ethics Approval Certificate No. 43/KIA-UNPAK/VI/2026, dated June 9, 2026).

The study involved adult teacher participants and was categorized as a minimal-risk educational research study. It did not involve any medical, physical, psychological, or experimental interventions involving participants.

All procedures involving human participants were conducted in accordance with the ethical principles and guidelines established by the Research Ethics Committee of Pakuan University and relevant ethical standards for educational research.

Participation in the study was entirely voluntary. Informed consent was obtained from all participants prior to data collection. Participant confidentiality and privacy were maintained throughout the research process, and all findings are reported in aggregate form without identifying individual participants or schools.

H. Consent for Publication

Not applicable. No identifiable personal data, images, or individual participant details are included in this manuscript.

I. Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

J. Funding Declaration

This research received no external funding.

K. Competing Interests

The authors declare no competing interests.

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