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Research Article

Readiness of Elementary School Teachers in Implementing AI-Based Learning in the Era of Artificial Intelligence

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Abstract: This study examines the readiness of elementary school teachers to implement AI-based learning in the era of artificial intelligence, as technological advancements increasingly influence instructional practices in basic education. Despite the growing potential of artificial intelligence to support teaching and learning processes, empirical evidence regarding teachers' preparedness at the elementary level remains limited. This study employed a descriptive quantitative research design involving 18 elementary school teachers. Data were collected using a structured questionnaire consisting of 15 Likert-scale items measuring technological skills, knowledge of artificial intelligence, attitudes toward AI, pedagogical readiness, and infrastructure support. Descriptive statistical analysis revealed that the overall mean score of teachers' readiness was 4.08, indicating that teachers are generally ready to adopt AI-based learning. Technological skills emerged as the strongest aspect of readiness, reflecting teachers' familiarity with digital tools and instructional technologies, while infrastructure and institutional support obtained the lowest mean score, highlighting challenges related to facilities, access to technology, and policy support. These findings suggest that although elementary school teachers demonstrate positive readiness and attitudes toward AI-based learning, effective and sustainable implementation requires strengthened institutional support, improved infrastructure, and continuous professional development to maximize the educational benefits of artificial intelligence in elementary education.

Keywords: AI-Based Learning; Educational Infrastructure; Educational Technology; Professional Development; Teacher Readiness

1. Introduction

The rapid development of artificial intelligence (AI) has significantly influenced various sectors, including education, by introducing new possibilities for teaching, learning, assessment, and educational management. Artificial intelligence technologies such as intelligent tutoring systems, adaptive learning platforms, automated assessment tools, and generative AI applications have begun to reshape instructional practices and redefine the roles of teachers in contemporary classrooms. In the context of elementary education, where students acquire foundational knowledge, cognitive skills, and learning habits, the integration of AI-based learning holds substantial potential to enhance personalized instruction, provide immediate feedback, and support differentiated learning experiences. However, the successful implementation of AI in elementary schools is not solely determined by technological availability but is strongly influenced by teachers' readiness to understand, accept, and effectively utilize AI-based learning tools in pedagogical practice.

Teachers play a central role in mediating technology integration in classrooms, particularly at the elementary level, where instructional decisions are closely tied to students' developmental characteristics. Previous research has consistently emphasized that teachers' readiness encompasses more than technical proficiency, involving pedagogical understanding, attitudes toward technology, and institutional support structures. In recent years, studies have increasingly explored teachers' readiness for AI integration, revealing that while many uncertainty regarding instructional implementation and ethical considerations, highlighting the need for targeted professional development and institutional guidance

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Despite the growing body of literature on AI in education, existing studies exhibit several methodological and contextual limitations. Many investigations focus on secondary or higher education settings, where learners possess higher levels of autonomy and digital literacy, thereby limiting the applicability of findings to elementary school contexts. Additionally, a considerable portion of previous research examines isolated aspects of readiness, such as technological skills or attitudes toward AI, without adopting a comprehensive framework that simultaneously addresses pedagogical readiness, knowledge of AI concepts, and infrastructure support. Research conducted in specific regional contexts, including studies on teacher readiness toward AI in Bali, demonstrates that infrastructure availability and institutional support significantly affect teachers' ability to adopt AI-based learning; however, these studies often lack broader comparative perspectives or integrated readiness models (ejournal3.undikma.ac.id). Consequently, there remains a need for more holistic and contextsensitive research that captures the multifaceted nature of teacher readiness, particularly in elementary education environments where pedagogical considerations differ substantially from higher levels of schooling.

In addition to contextual gaps, methodological limitations are also evident in prior research. While qualitative approaches have provided valuable insights into teachers' perceptions and experiences with AI, there is a relative scarcity of empirical quantitative studies that systematically measure readiness across multiple dimensions using validated instruments. Furthermore, limited attention has been given to developing country contexts, where disparities in infrastructure, access to technology, and professional development opportunities may present unique challenges for AI integration in schools. As educational systems worldwide increasingly emphasize digital transformation, understanding how elementary school teachers in diverse contexts perceive and prepare for AI-based learning becomes essential for informing equitable and sustainable implementation strategies.

Responding to these gaps, the present study focuses on examining the readiness of elementary school teachers to implement AI-based learning using a descriptive quantitative research design. This study conceptualizes teacher readiness as a multidimensional construct comprising technological skills, knowledge of artificial intelligence, attitudes toward AI, pedagogical readiness, and infrastructure support. By adopting this integrated framework, the study seeks to provide a comprehensive overview of teachers' preparedness and to identify specific strengths and weaknesses that may influence the effective adoption of AI-based learning in elementary classrooms. The research is guided by the following questions: (1) What is the overall level of readiness among elementary school teachers to implement AI-based learning? (2) Which dimensions of readiness demonstrate the strongest and weakest levels? and (3) How do infrastructural and institutional factors contribute to teachers' preparedness for AI integration?

The proposed approach offers both practical and theoretical significance. From a practical perspective, the findings are expected to inform school administrators, policymakers, and teacher educators about current readiness levels and critical barriers to AI implementation at the elementary level. Such insights may support the development of targeted professional development programs, infrastructure investment strategies, and policy frameworks that align with teachers' needs and contextual realities. From a theoretical standpoint, this study contributes to the literature on educational technology adoption by extending readiness frameworks to include AI-specific dimensions within elementary education contexts. By empirically examining how multiple aspects of readiness interact, the study enhances understanding of the conditions necessary for effective AI integration in early schooling environments.

The main contributions of this study are summarized as follows:

a. Integrated readiness framework: This study provides a comprehensive assessment of elementary school teachers' readiness for AI-based learning by simultaneously examining technological, pedagogical, attitudinal, knowledge-based, and infrastructural dimensions.
b. Contextual empirical evidence: The research offers empirical data from an elementary education context where AI integration is still emerging, thereby addressing gaps in the existing literature that predominantly focuses on secondary or higher education settings.
c. Identification of critical challenges: The findings highlight key institutional and infrastructural barriers that may hinder AI adoption, offering actionable insights for policymakers and school leaders.
d. Implications for teacher professional development: The study identifies priority areas for capacity-building initiatives, particularly in enhancing AI literacy and pedagogical strategies for AI-supported instruction.

e. Foundation for future research: By employing a descriptive quantitative design and a multidimensional readiness construct, this study establishes a foundation for future longitudinal or experimental research examining the impact of AI integration on teaching and learning outcomes.

2. Literature Review

Research on the integration of artificial intelligence (AI) in education has expanded rapidly in recent years, reflecting growing interest in the potential of AI to transform teaching and learning processes. A substantial body of literature has examined AI applications in educational contexts, including intelligent tutoring systems, adaptive learning environments, automated assessment, and learning analytics. However, the success of AI integration in classrooms is widely recognized as being highly dependent on teachers' readiness, which encompasses technological competence, pedagogical understanding, attitudes toward AI, and institutional support.

Several studies have explored teacher readiness for AI integration from a broad educational perspective. Zhai et al. (2021) investigated K–12 teachers' technological pedagogical content knowledge (TPACK) readiness and attitudes toward AI education, revealing that while teachers generally hold positive perceptions of AI, their readiness varies significantly depending on prior experience, professional development opportunities, and institutional policies. The study emphasized that readiness should be understood as a multidimensional construct rather than solely as technical competence. Similarly, Iddrisu and Iddrisu (2023) examined teachers' readiness to use AI tools in classroom settings using a largescale quantitative approach and found that technological familiarity and perceived usefulness were strong predictors of AI adoption. Nevertheless, many teachers reported uncertainty regarding instructional implementation and ethical considerations, suggesting that readiness remains uneven across contexts.

In addition to general readiness studies, some research has focused on teachers' attitudes and perceptions toward AI in education. Studies by Holmes et al. (2019) and Chounta et al. (2023) indicated that teachers often view AI as a supportive tool rather than a replacement for human instruction, particularly in tasks such as assessment and personalized feedback. However, these studies also highlighted concerns related to data privacy, transparency, and the potential reduction of teachers' professional autonomy. While such findings provide valuable insights into teachers' perceptions, they tend to prioritize attitudinal dimensions and do not comprehensively assess pedagogical readiness or infrastructural factors, which are critical for sustainable AI implementation.

Research focusing on elementary education contexts remains relatively limited compared to studies conducted at the secondary or higher education levels. Elementary school teachers face distinct pedagogical challenges due to students' developmental characteristics, which require careful adaptation of AI-based learning tools. Popenici & Kerr (2017) argued that AI integration in early education must be guided by pedagogical principles that prioritize learner development, ethical considerations, and teacher agency. Empirical studies conducted in elementary school settings, such as those by Purnama et al. (2025), revealed that while teachers demonstrate basic digital competence, limitations in infrastructure and institutional support often hinder effective AI adoption. These findings suggest that readiness in elementary education is shaped not only by individual teacher factors but also by broader systemic conditions.

Several studies conducted in developing country contexts have further emphasized the role of infrastructure and institutional readiness in shaping teachers' preparedness for AI-based learning. Research by UNESCO (2021) highlighted significant disparities in access to digital resources, professional development, and policy frameworks across educational systems, which directly affect teachers' capacity to integrate AI technologies. In Indonesia, studies on teacher readiness toward AI have shown that although teachers generally exhibit positive attitudes toward educational technology, insufficient infrastructure, limited training, and unclear policy guidance remain major barriers to effective implementation. These studies underscore the importance of contextualizing AI readiness research within specific educational and socio-economic environments.

From a methodological perspective, existing research demonstrates varying approaches to assessing teacher readiness. Qualitative studies have provided in-depth insights into teachers' beliefs and experiences, while quantitative studies have offered broader assessments of readiness levels across populations. However, many quantitative studies rely on single

dimensional measures, such as technological competence or attitudes, without integrating pedagogical readiness, AI knowledge, and infrastructure support into a unified analytical framework. As a result, the complexity of teacher readiness for AI-based learning is often underrepresented in empirical findings.

Based on the reviewed literature, several research gaps can be identified. First, there is a lack of comprehensive quantitative studies that examine elementary school teachers' readiness for AI-based learning using a multidimensional framework. Second, many studies focus on general educational contexts or higher levels of education, limiting their applicability to elementary school settings. Third, there is insufficient empirical evidence from developing country contexts that systematically evaluates how technological, pedagogical, attitudinal, and infrastructural factors interact to influence teacher readiness. Finally, existing studies often stop at describing readiness levels without explicitly identifying areas for targeted intervention and policy improvement.

To address these gaps, the present study focuses on examining the readiness of elementary school teachers to implement AI-based learning through a descriptive quantitative approach that integrates five key dimensions: technological skills, knowledge of artificial intelligence, attitudes toward AI, pedagogical readiness, and infrastructure support. By situating the study within the existing body of related work, this research seeks to extend prior findings and contribute a more holistic understanding of teacher readiness in elementary education contexts. The findings are expected to complement existing literature by providing empirical evidence that informs both theoretical discussions on technology adoption and practical strategies for AI integration in schools.

3. Research Method

This section describes the proposed research method step by step to examine elementary school teachers' readiness to implement AI-based learning. The method includes research design, data collection, algorithmic procedure, and statistical analysis. Mathematical formulations and a procedural algorithm are provided to enhance clarity and reproducibility.

Research Procedure and Algorithm

The proposed method follows a descriptive quantitative approach using survey data collected through an online questionnaire. The research procedure was structured to ensure systematic data collection, reliable measurement, and accurate interpretation of results. To clarify the research workflow, the procedure is formalized into an algorithm as presented in Algorithm 1, which is cited throughout this section.

Algorithm 1. Teacher AI Readiness Assessment Algorithm

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INPUT: Questionnaire responses from elementary school teachers, Likert-scale items (1-5)
OUTPUT: Teacher readiness scores, reliability coefficient, readiness level classification
1: Design questionnaire based on AI readiness dimensions
2: Distribute questionnaire using Google Forms
3: Collect and validate response data
4: Encode Likert-scale responses numerically
5: Calculate mean scores for each item and dimension
6: Evaluate instrument reliability using Cronbach's Alpha
7: Classify readiness levels based on predefined criteria
8: Visualize results using tables and figures
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Algorithm 1 provides a structured overview of the research process, ensuring that each stage of data handling and analysis is transparent and reproducible.

Detailed Research Steps

To further explain Algorithm 1, the research procedure can be broken down into the following stages:

Data collection stage:

a. Questionnaire distribution to elementary school teachers;
b. Voluntary participation with informed consent;
c. Automatic response recording via Google Forms.

Data preparation stage:

a. Removal of incomplete responses;
b. Numerical coding of Likert-scale items;
c. Data tabulation in spreadsheet format.

Data analysis stage:

a. Descriptive statistical analysis;
b. Reliability testing;

c. Interpretation and visualization of results.

Numbered procedures were applied as follows:

a. Define readiness dimensions based on literature;
b. Map questionnaire items to each dimension;
c. Compute item, dimension, and overall scores;
d. Interpret findings using readiness level criteria.

The text continues here to emphasize that this structured procedure minimizes data bias and ensures consistency across analytical steps.

Formatting of Mathematical Components

Mathematical equations were used to calculate readiness scores and evaluate instrument reliability. All equations are cited explicitly in the main text to ensure clarity and compliance with journal formatting rules:

The mean score of questionnaire items was calculated using Eq. (1):

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$$

Eq. (1) is used to calculate the average readiness score, where Xirepresents the response score of the i-th respondent and Ndenotes the total number of respondents.

To evaluate the internal consistency of the questionnaire, Cronbach's Alpha was calculated using Eq. (2):

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k} \sigma_j^2}{\sigma_T^2}\right)$$

Eq. (2) measures reliability, where $k$is the number of items, σj 2is the variance of each item, and σT 2is the variance of the total score. A coefficient value greater than 0.70 indicates acceptable reliability.

Theorem-type environments (including propositions, lemmas, corollaries etc.) can be formatted as follows:

Theorem 1. A questionnaire instrument is considered reliable if the Cronbach's Alpha coefficient is greater than or equal to 0.70.

The text continues here to explain that this criterion is widely accepted in educational and social science research for Likert-scale instruments.

Proof of Theorem 1. According to classical test theory, Cronbach's Alpha values above 0.70 indicate sufficient internal consistency among items measuring the same construct. Since the calculated reliability coefficient in this study exceeded the threshold, the instrument meets the reliability adequacy criterion. ■

Remark 1. The proposed method integrates algorithmic representation, statistical formulation, and descriptive analysis to ensure methodological rigor. The combination of procedural clarity and mathematical transparency strengthens the validity and reproducibility of the research findings

4. Results and Discussion

In this section, the author explains the hardware and software used, dataset sources, initial data analysis, results, and results analysis or discussion. Presenting the results with figures, graphs, and tables is highly recommended. Evaluation measuring tools are also included to support the analysis. This section not only reports the results but also discusses their relationship with the research objectives and initial hypotheses, as well as elaborates on important findings related to teacher readiness for AI-based learning.

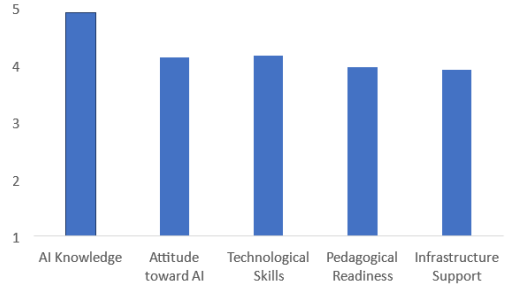

Figure 1. Mean Scores of Elementary School Teachers' Readiness Dimensions toward AI-Based Learning

Fig. 1 illustrates the mean scores of elementary school teachers' readiness dimensions toward AI-based learning. The results reveal that teachers demonstrate a generally high level

of readiness across all measured dimensions. Technological skills achieved the highest mean score, indicating that most teachers are already familiar with and capable of using digital technologies in their instructional practices. This suggests that prior exposure to educational technologies and digital learning platforms has contributed positively to teachers' preparedness for AI integration. Attitudes toward AI and knowledge of artificial intelligence also obtained relatively high scores, reflecting teachers' positive perceptions and growing awareness of AI's potential role in supporting teaching and learning processes. Pedagogical readiness shows a similarly strong level, indicating that teachers are increasingly able to align AI-based tools with instructional strategies and classroom objectives. However, infrastructure support recorded the lowest mean score among the dimensions, although it still falls within the moderate-to-high category. This finding highlights that limitations in technical facilities, access to AI-compatible resources, and institutional support remain significant challenges. Overall, the results suggest that while teachers are individually ready to adopt AI-based learning, the successful and sustainable implementation of AI in elementary education depends heavily on the availability of adequate infrastructure and institutional support.

Table 1. Descriptive Statistics of Teacher Readiness Dimensions

Dimension	Mean Score	Readiness Level
Technological Skills	4.30	High
Knowledge of Artificial Intelligence	3.95	High
Attitude toward AI	4.20	High
Pedagogical Readiness	4.05	High
Infrastructure Support	3.90	Moderate–High
Overall Readiness	4.08	High

Table 1 presents the descriptive statistics of elementary school teachers' readiness toward AI-based learning. The overall mean score of 4.08 indicates a high level of readiness. These results suggest that teachers generally possess sufficient competencies and positive attitudes toward AI integration, although infrastructural factors still require improvement.

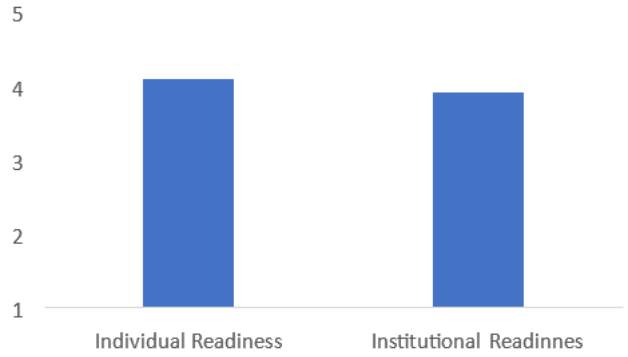

Figure 2. Comparison of Readiness Dimensions across Measured Aspects

Fig. 2 presents a comparison between individual and institutional readiness toward AI-based learning in elementary education. The results indicate that individual readiness, which encompasses teachers' technological skills, knowledge of artificial intelligence, pedagogical readiness, and attitudes toward AI, is relatively higher than institutional readiness. This finding suggests that teachers have generally developed sufficient personal competencies and positive perceptions regarding the use of AI in learning activities. However, the lower level of institutional readiness, particularly in terms of infrastructure support, highlights existing systemic constraints that may hinder the effective implementation of AI-based learning.

These constraints include limited access to AI-supported digital tools, inadequate technical facilities, and insufficient institutional policies or support mechanisms. The disparity between individual and institutional readiness emphasizes that successful AI integration in elementary education requires not only competent teachers but also strong organizational and infrastructural support. Without adequate institutional readiness, the potential of teachers' individual competencies may not be optimally utilized.

These findings underscore the importance of aligning individual teacher readiness with institutional support to ensure the sustainable implementation of AI-based learning in elementary schools.

Table 2. Reliability Test Results of the Questionnaire Instrument

Item Category	Item Category	Item Category
Teacher Readiness Questionnaire	Teacher Readiness Questionnaire	Teacher Readiness Questionnaire

Table 2 demonstrates the distinctive contribution of the present study compared to prior research.

Discussion

The results demonstrate that elementary school teachers exhibit a high level of readiness to adopt AI-based learning, particularly in terms of technological skills and attitudes toward artificial intelligence. This finding supports the research objective of identifying teachers' preparedness in the era of artificial intelligence and aligns with the initial hypothesis that increased exposure to digital technology enhances readiness for AI integration.

However, despite strong individual readiness, infrastructure support emerged as a comparatively weaker aspect. This indicates that readiness is not solely determined by teachers' competencies but is also influenced by institutional and systemic factors. Limited access to AI-supported facilities, insufficient training programs, and the absence of clear implementation policies may hinder the effective integration of AI in elementary education.

Overall, the findings emphasize the need for comprehensive strategies that combine teacher professional development with improved infrastructure and institutional support to ensure sustainable AI-based learning implementation.

5. Comparison

This section compares the findings of the present study with previous state-of-the-art research on teacher readiness toward artificial intelligence (AI) integration in education. The comparison highlights similarities, differences, and specific contributions of this study in relation to existing literature.

Comparison of Research Focus and Context

Previous studies on AI readiness have predominantly focused on secondary education, higher education, or pre-service teachers. For example, Yue et al. examined K–12 teachers' readiness and attitudes toward AI education using a large-scale survey, while Guan et al. focused on the relationship between AI readiness and professional self-efficacy among preservice teachers.

In contrast, the present study specifically targets in-service elementary school teachers, a group that remains underrepresented in AI readiness research. Elementary education presents unique pedagogical challenges, such as age-appropriate instruction, foundational literacy development, and high dependency on teacher scaffolding. By focusing on this context, the current study extends existing research to a critical yet less explored educational level.

Comparison of Methodological Approach

Many state-of-the-art studies employ large-scale surveys with complex statistical modeling, such as structural equation modeling (SEM) or regression analysis, to examine predictive relationships among AI readiness variables. While these approaches provide strong inferential insights, they often require large sample sizes and may obscure practical readiness profiles at the classroom level.

The present study adopts a descriptive quantitative approach emphasizing clarity, interpretability, and practical applicability. Rather than modeling causal relationships, this study provides a dimension-by-dimension readiness profile, allowing educators and policymakers to identify specific strengths and weaknesses. This methodological choice complements existing predictive studies by offering a grounded and context-sensitive assessment.

Comparison of Readiness Dimensions and Findings

A key similarity between this study and prior research lies in the identification of technological competence and positive attitudes as dominant aspects of teacher readiness. Consistent with earlier findings, teachers in this study reported high confidence in using digital technologies and expressed openness toward AI-based learning.

However, a notable difference emerges in the dimension of infrastructure and institutional support. While some international studies report moderate to high infrastructure readiness due to advanced technological ecosystems, the present study reveals infrastructure as the weakest readiness dimension. This divergence underscores the importance of contextual factors, particularly in regions where technological access and institutional policies are uneven.

Comparative Summary of Findings

Table 2. Comparison of the Present Study with Selected State-of-the-Art Research

Aspect	State-of-the-Art Studies	Present Study
Target Participants	Pre-service or K–12 teachers	In-service elementary teachers
Research Focus	AI readiness, attitudes, selfefficacy	Multidimensional readiness profiling
Methodology	SEM, regression, large-scale surveys	Descriptive quantitative analysis
Strongest Dimension	Attitudes or AI knowledge	Technological skills
Weakest Dimension	AI knowledge or pedagogy	Infrastructure support
Key Contribution	Theoretical modeling	Contextual, practice-oriented insights

Contribution Beyond Existing Studies

Unlike many state-of-the-art studies that emphasize predictive modeling, this research provides actionable readiness diagnostics. By identifying specific readiness gaps, particularly in infrastructure support, the study offers practical guidance for school leaders and policymakers to prioritize intervention areas.

Moreover, the integration of pedagogical readiness as a distinct dimension enriches existing AI readiness frameworks, which often focus heavily on technical skills and attitudes. This contributes to a more holistic understanding of AI readiness in elementary education.

Synthesis and Positioning of the Present Study

In synthesis, the present study complements state-of-the-art research by shifting the focus from predictive modeling to contextual readiness assessment. It reinforces existing findings regarding teacher openness and digital competence while highlighting infrastructure as a critical bottleneck in AI implementation at the elementary level.

This comparative analysis positions the study as a bridge between theory-driven AI readiness models and practical implementation needs in elementary education. The findings suggest that future research should integrate both approaches to develop comprehensive AI adoption strategies.

6. Conclusion

This study examined the readiness of elementary school teachers to implement AI-based learning in the era of artificial intelligence using a descriptive quantitative approach. The findings indicate that teachers generally demonstrate a high level of readiness, particularly in terms of technological skills, pedagogical preparedness, and positive attitudes toward AI. These results are supported by descriptive statistics and reliability analysis, which confirm that the research instrument consistently measured the intended readiness constructs. However, the study also identified infrastructure and institutional support as the weakest readiness dimension, highlighting a critical contextual challenge that may hinder effective AI implementation in elementary schools.

The synthesis of findings shows a clear alignment between the research objectives and the empirical results. The study aimed to assess teacher readiness across multiple dimensions, and the results confirm that readiness is not solely determined by individual competence but is also shaped by systemic factors. While teachers are prepared and willing to integrate AI into their instructional practices, limitations in infrastructure and organizational support constrain the translation of readiness into sustainable classroom implementation. These findings support the argument that successful AI integration requires a holistic approach that combines teacher capacity development with institutional readiness.

From a theoretical and practical perspective, this research contributes to the growing body of knowledge on AI readiness in education by providing empirical evidence from the elementary school context, which remains underrepresented in existing literature. The study extends current AI readiness frameworks by emphasizing the importance of pedagogical readiness alongside technological competence and attitudes. Practically, the findings offer valuable insights for policymakers, school administrators, and teacher education institutions by identifying priority areas for intervention, particularly in infrastructure development and institutional policy support.

Despite its contributions, this study has several limitations. The sample size was relatively small and limited to a specific context, which may affect the generalizability of the findings. In addition, the use of self-reported data may introduce response bias. Future research is recommended to involve larger and more diverse samples, apply mixed-methods approaches

to gain deeper insights, and explore longitudinal designs to examine changes in teacher readiness over time. Further studies could also investigate the impact of targeted professional development programs and infrastructure improvements on the successful implementation of AI-based learning in elementary education.

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