

Digital Competencies, AI Usage, and Informal Learning Effects on Teachers' Effectiveness in Islamic Schools

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ABSTRACT

The rapid expansion of digital technologies has reshaped teaching practices, yet their combined influence on teacher effectiveness in resource-constrained Islamic schools remains insufficiently explored. This study aims to examine how digital competencies, AI usage, and digital informal learning interact to enhance teachers' effectiveness. A quantitative approach was employed using a cross-sectional survey design involving 440 teachers from Islamic secondary schools in Kot Addu, Pakistan. Data were analyzed using Structural Equation Modeling (SEM) to assess both direct and indirect relationships among variables. The findings indicate that digital competencies have the strongest influence on teachers' effectiveness, followed by AI usage and digital informal learning, all of which show significant positive effects. The results suggest that digital competence serves as a foundational capability that enables teachers to utilize AI tools effectively and engage in continuous professional learning. However, disparities in infrastructure and access remain critical barriers, particularly in rural areas. While the study provides an integrated perspective on technology-enhanced teaching, its cross-sectional design and reliance on self-reported data may limit generalizability. These findings offer practical insights for designing integrated teacher development strategies in digital education contexts.

Perkembangan teknologi digital telah mengubah praktik pembelajaran, namun pengaruh terpadu terhadap efektivitas guru di sekolah Islam dengan keterbatasan sumber daya masih belum banyak dikaji. Penelitian ini bertujuan untuk menganalisis bagaimana kompetensi digital, penggunaan AI, dan pembelajaran informal digital berkontribusi terhadap efektivitas guru. Penelitian ini menggunakan pendekatan kuantitatif dengan desain survei cross-sectional yang melibatkan 440 guru sekolah menengah Islam di Kot Addu, Pakistan. Data dianalisis menggunakan Structural Equation Modeling (SEM) untuk menguji hubungan langsung dan tidak langsung antar variabel. Hasil penelitian menunjukkan bahwa kompetensi digital memiliki pengaruh paling kuat terhadap efektivitas guru, diikuti oleh penggunaan AI dan pembelajaran informal digital yang juga berpengaruh positif signifikan. Temuan ini menegaskan bahwa kompetensi digital menjadi fondasi utama dalam pemanfaatan teknologi pembelajaran. Namun, keterbatasan infrastruktur dan akses masih menjadi hambatan, terutama di wilayah rural. Penelitian ini memberikan implikasi praktis bagi pengembangan strategi peningkatan kompetensi guru berbasis teknologi.

Keywords: digital competencies, artificial intelligence usage, digital informal learning, teacher effectiveness

Introduction

The accelerating evolution of digital technologies has not only redefined the operational landscape of education but has also reshaped the very expectations placed upon teachers as central actors in the learning process. In contemporary educational discourse, teacher effectiveness is increasingly interpreted through the lens of adaptability to digital environments, where instructional delivery, student interaction, and classroom management are mediated by technological tools. This shift reflects a broader transformation from teacher-



centered paradigms toward more dynamic, technology-supported learning ecosystems (Baharudin et al., 2019; Wang, 2023). However, this transformation is unevenly distributed, particularly in developing and rural contexts, where disparities in infrastructure, access, and digital literacy continue to create significant gaps in educational quality (Sohail, 2023). Consequently, understanding how teachers navigate and leverage digital tools within such constraints becomes a critical area of inquiry.

Within this evolving landscape, digital competence emerges not merely as a technical skill set but as a comprehensive capability that integrates cognitive, ethical, and pedagogical dimensions of technology use. It involves the capacity to critically evaluate digital resources, design meaningful learning experiences, and facilitate interactive engagement that aligns with educational objectives (Ilomäki, 2021). Importantly, digital competence also encompasses the ability to adapt technologies to context-specific needs, rather than applying them in a generic or superficial manner. Empirical findings indicate that teachers who possess higher levels of digital competence tend to demonstrate greater instructional clarity, flexibility in pedagogical strategies, and improved classroom organization (Moraes, 2025; Ye, 2025). Nevertheless, the acquisition and application of such competencies are not uniform, as they are influenced by contextual factors such as institutional support, training opportunities, and socio-economic conditions.

Parallel to the development of digital competence, Artificial Intelligence (AI) has introduced a new dimension to educational innovation by enabling more responsive and personalized learning environments. Unlike traditional digital tools, AI systems are capable of analyzing patterns in student behavior, predicting learning needs, and generating adaptive feedback in real time. This capacity allows teachers to move beyond standardized instruction toward more individualized pedagogical approaches (Holmes et al., 2021; Jiang, 2025). Moreover, AI can function as a supportive mechanism that enhances, rather than replaces, the teacher's role by providing insights that inform decision-making processes (Lin, 2025; Rahman, 2024). However, the integration of AI into teaching practices is not without challenges. It requires not only technical readiness but also critical awareness of ethical considerations, such as data privacy, algorithmic bias, and the cultural appropriateness of technological applications (Sreela & Karthik Deepa, 2025; Velander, 2026).

In addition to formal and structured professional development, digital informal learning has emerged as a complementary pathway through which teachers continuously refine their competencies. This form of learning is characterized by its voluntary, self-directed nature, often occurring through engagement with online platforms, peer networks, and open-access educational resources. Unlike institutional training programs, digital informal learning allows teachers to respond flexibly to immediate pedagogical challenges and evolving technological trends (AbdulRab, 2023; Nguyen, 2022). It also fosters a sense of professional autonomy and collaborative knowledge construction, as educators exchange experiences and practical solutions within digital communities (Iqbal et al., 2025; Rahman, 2024). Despite its potential, the effectiveness of informal learning is contingent upon individual motivation, digital access, and the broader technological ecosystem that supports or constrains such engagement.

A growing body of literature suggests that digital competence, AI usage, and digital informal learning should not be examined as isolated variables, but rather as interdependent components of a broader technological-pedagogical system. Digital competence provides the foundational knowledge and skills required to engage with AI tools effectively, while digital informal learning facilitates continuous skill enhancement and adaptation to emerging

technologies (Rubio-Gragera et al., 2025; Scarci et al., 2024). The interaction among these elements creates a synergistic dynamic, wherein their combined influence on teaching effectiveness is more substantial than their individual contributions (Alif Fairus Bin Nor Mohamad et al., 2025; Holmes et al., 2021). However, despite this conceptual interconnection, empirical research that simultaneously examines these variables within a unified analytical framework remains limited. Most existing studies tend to focus on single dimensions or pairwise relationships, thereby overlooking the complexity of their combined effects.

This limitation becomes even more pronounced when considering specific educational contexts, such as Islamic secondary schools in rural regions. These institutions operate within unique socio-cultural and structural conditions that shape both the opportunities and constraints associated with technology integration. Challenges such as limited digital infrastructure, inadequate access to training, and reliance on traditional pedagogical approaches often hinder the effective adoption of digital innovations (Dr. Muhammad Jamil et al., 2024; Scarci et al., 2024). At the same time, cultural and religious values play a significant role in influencing attitudes toward technology, necessitating approaches that are not only technologically sound but also culturally and ethically aligned (Amira Santos et al., 2024; Majeed & Ahmad, 2025; Mar, 2024). These contextual complexities highlight the need for research that is sensitive to both technological and socio-cultural dimensions.

In response to these gaps, this study seeks to examine the combined and individual effects of digital competencies, AI usage, and digital informal learning on teachers' effectiveness in Islamic secondary schools in Kot Addu, Pakistan. By employing a structural equation modeling approach, the study captures both direct and indirect relationships among these variables, providing a more nuanced understanding of their interactions (Sugiyono, 2023). The significance of this research lies in its integrative perspective, which moves beyond fragmented analyses to offer a comprehensive model of technology-enhanced teaching effectiveness. Furthermore, by situating the study within a culturally specific and under-researched context, it contributes to the development of more inclusive and contextually relevant educational strategies, ultimately supporting the advancement of sustainable and equitable digital education.

Methods

This study was designed using a quantitative approach with a cross-sectional survey to explore how digital competencies, AI usage, and digital informal learning interact in shaping teachers' effectiveness within Islamic secondary schools. The choice of a quantitative design was driven by the need to examine patterns of relationships among multiple constructs in a systematic and measurable manner, allowing the findings to be interpreted with statistical confidence (Creswell & Creswell, 2018). To capture the complexity of these interrelated variables, Structural Equation Modeling (SEM) was employed as the main analytical framework, as it enables the simultaneous examination of direct and indirect relationships within a unified model (Hair et al., 2019). The conceptual structure of the study, illustrating the hypothesized relationships among the variables, is presented in Figure 1, which serves as a visual representation of the analytical framework guiding the research.

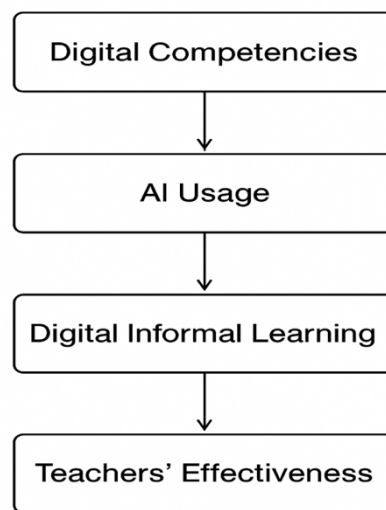


Figure 1. Conceptual Framework of the Study

The study was conducted in Islamic secondary schools in Kot Addu, located in the Multan District of Southern Punjab, Pakistan, an area characterized by a combination of urban and rural educational settings. This context was deliberately selected to capture variations in digital access, technological exposure, and instructional practices. A purposive sampling technique was employed to ensure that participants had relevant experience with digital tools in teaching environments (Sugiyono, 2023). From an initial target of 450 teachers, a total of 440 valid responses were obtained and included in the analysis, meeting recommended sample size requirements for SEM to produce stable and reliable estimates (Kline, 2016). Data were collected using a structured questionnaire adapted from previously validated instruments and aligned with established frameworks of digital competence and educational technology integration (Redecker, 2020). The instrument consisted of multiple items measuring four key constructs: digital competencies (e.g., ability to use and integrate digital tools in teaching), AI usage (e.g., frequency and pedagogical application of AI-based tools), digital informal learning (e.g., engagement with online platforms for self-directed professional development), and teachers' effectiveness (e.g., instructional clarity, student engagement, and classroom management). All items were measured using a five-point Likert scale ranging from strongly disagree to strongly agree. To ensure the quality of the instrument, expert validation was conducted to assess content relevance, followed by pilot testing to refine item clarity and improve reliability.

Data collection was carried out through both online and offline modes to accommodate differences in technological access among participants. Online responses were obtained via Google Forms, while paper-based questionnaires were distributed in schools with limited internet connectivity. Ethical standards were strictly maintained throughout the process, including informed consent, voluntary participation, and the assurance of anonymity and confidentiality (Creswell & Creswell, 2018). The collected data were analyzed using SPSS version 27 for preliminary statistical analysis and AMOS version 26 for advanced modeling. The analysis began with descriptive statistics to summarize data characteristics, followed by Confirmatory Factor Analysis (CFA) to evaluate the measurement model in terms of validity and reliability. Convergent validity was assessed using Composite Reliability (CR) and Average

Variance Extracted (AVE), with threshold values of 0.70 and 0.50 respectively indicating acceptable levels (Hair et al., 2022). Structural Equation Modeling (SEM) was then applied to test the hypothesized relationships among variables. Model fit was evaluated using multiple indices, including Chi-square/df, RMSEA, CFI, and TLI, based on established criteria (Hair et al., 2022; Kline, 2016). Additionally, preliminary tests for normality, linearity, and multicollinearity were conducted to ensure the robustness and validity of the analytical results.

Result

The findings of this study provide a comprehensive understanding of how digital competencies, AI usage, and digital informal learning contribute to teachers' effectiveness within Islamic secondary schools. The results are presented in a systematic sequence, beginning with the level of adoption across regions, followed by teachers' perceptions, descriptive statistics, and finally the structural relationships among variables based on SEM analysis. The level of adoption of digital competencies, AI usage, and digital informal learning varies across the four study areas, as illustrated in Figure 2 and its corresponding graphical visualization. Multan City demonstrates the highest combined adoption level (32.50%), largely driven by strong digital competencies (18.50%), indicating a more advanced integration of technology in teaching practices within urban environments. In contrast, Jalalpur Pirwala records the lowest adoption rate (26.80%), reflecting limitations in digital infrastructure and access. Meanwhile, Shujabad (29.70%) and Qadirpur Ran (28.10%) show moderate adoption levels, suggesting a transitional stage between limited and more developed technological integration. This pattern highlights a clear urban – rural divide, where access to resources and technological exposure significantly influence the extent to which teachers engage with digital tools.

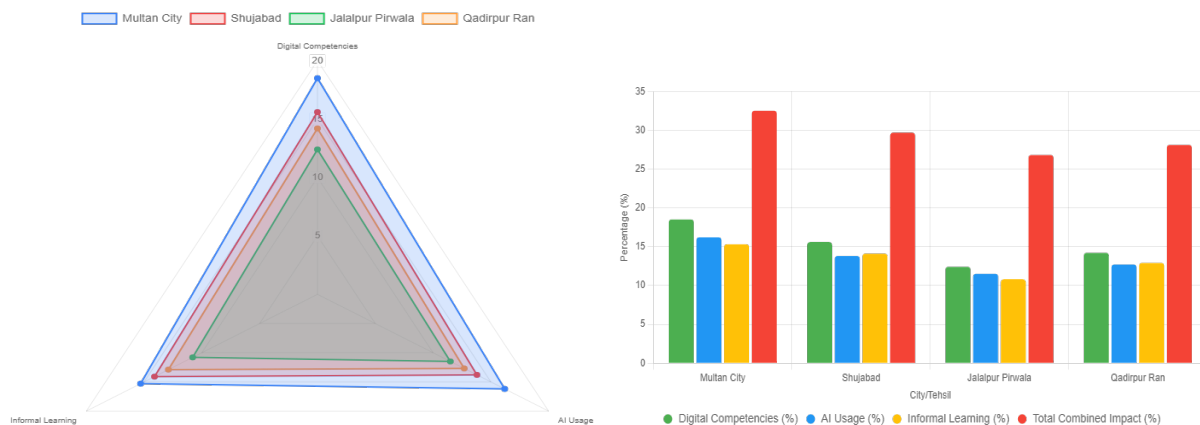


Figure 2. Adoption of Digital Competencies, AI Usage, and Informal Learning

Teachers' perceptions further reinforce these findings. As presented in Table 1, a substantial majority of respondents (ranging from 81% to 83% for strongly agree and agree) indicated that digital competencies improve lesson clarity, AI tools enhance student engagement, and digital informal learning supports classroom management. Additionally, teachers reported high levels of confidence (83%) in using these technologies and acknowledged their role in improving instructional planning and addressing classroom challenges. Notably, approximately 80% of respondents agreed that these technological approaches could complement or even replace traditional training methods. These results

suggest that teachers not only recognize the value of digital integration but also actively rely on it to enhance their teaching practices.

Table 1. Impact on Teachers' Effectiveness

Statement	SS	S	TS	STS
Digital competencies improve lesson delivery clarity.	23	61	13	3
AI tools enhance student engagement.	21	62	14	3
Informal learning improves classroom management.	20	63	14	3
Combined use enhances innovative teaching methods.	22	60	15	3
I feel confident using these technologies for teaching.	19	64	14	3
These factors improve my ability to address classroom challenges.	18	65	13	4
They enhance instructional planning and delivery.	17	66	12	5
They can replace traditional training for effectiveness.	19	61	15	5

The descriptive statistics presented in Table 3 provide further empirical support for these perceptions. Digital competencies recorded the highest mean score ($M = 5.88$), followed by AI usage ($M = 5.62$) and digital informal learning ($M = 5.35$). This indicates that teachers are relatively more confident in their foundational digital skills compared to more advanced or self-directed learning practices. Teachers' effectiveness achieved the highest mean score overall ($M = 6.72$), suggesting that respondents perceive their instructional performance as positively influenced by these technological factors. The relatively consistent standard deviations across variables indicate that these perceptions are widely shared among participants.

Table 2. Descriptive Statistics

Variable	N	Range	Min	Max	Mean	Std. Deviation	Variance
Digital Competencies (X1)	440	6	3	9	5.88	1.421	2.019
AI Usage (X2)	440	6	3	9	5.62	1.395	1.946
Digital Informal Learning (X3)	440	5	3	8	5.35	1.367	1.869
Teachers' Effectiveness (Y)	440	7	3	10	6.72	1.512	2.286

To examine the relationships among variables more rigorously, Structural Equation Modeling (SEM) was conducted. The structural model, as presented in Figure 3, illustrates the direct effects of digital competencies, AI usage, and digital informal learning on teachers' effectiveness. The model reveals a consistent pattern of positive relationships among all variables, indicating that each factor contributes to enhancing teaching effectiveness.

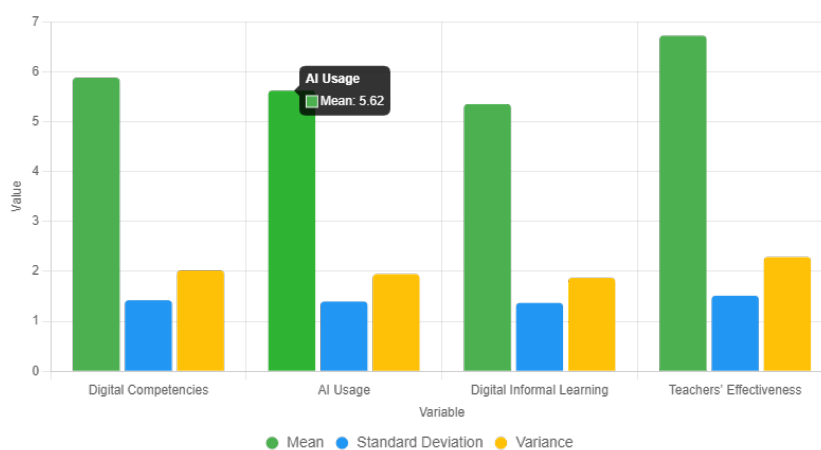


Figure 3. Structural Equation Model

The detailed results of the path analysis are presented in Figure 4 and supported by graphical visualization. Digital competencies exhibit the strongest influence on teachers' effectiveness ($\beta = 0.412$, $p < 0.001$), confirming their central role as a foundational element in technology-integrated teaching. AI usage also shows a significant positive effect ($\beta = 0.245$, $p < 0.001$), suggesting that the use of intelligent tools enhances interactive and adaptive teaching practices. Meanwhile, digital informal learning contributes positively ($\beta = 0.198$, $p < 0.001$), although its effect is relatively smaller, indicating that it plays a supportive role in strengthening teachers' professional development.

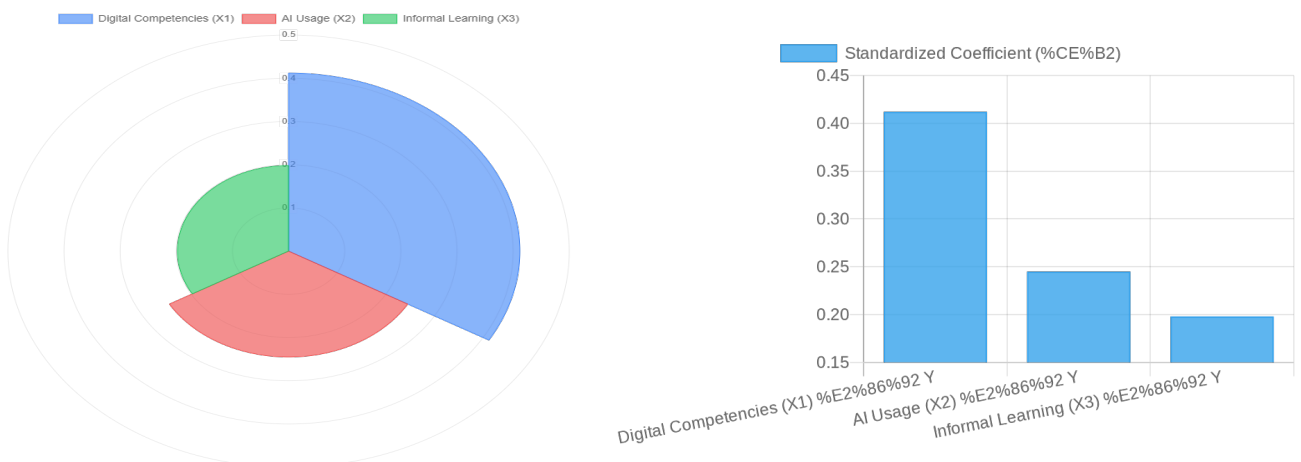


Figure 4. SEM Path Coefficients

The proportional contribution of each variable is further illustrated in the graphical representation, where digital competencies occupy the largest segment, followed by AI usage and digital informal learning. This visualization reinforces the hierarchical importance of these variables and highlights the dominant role of digital competence in shaping teachers' effectiveness. To ensure the robustness of the model, goodness-of-fit indices were evaluated, and the results are presented in Table 5 along with supporting graphical output. The model demonstrates a satisfactory fit to the data, with Chi-square/df = 2.15, RMSEA = 0.051, CFI = 0.947, TLI = 0.932, and SRMR = 0.045, all of which meet the recommended thresholds for acceptable model fit. These results indicate that the proposed model adequately represents the observed relationships among variables and provides a reliable basis for interpretation.

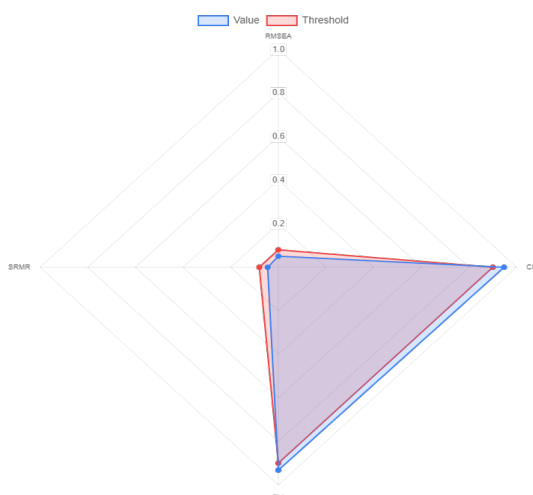


Figure 5. Model Fit Indices

The graphical representation of the model fit indices further confirms that all indicators fall within acceptable ranges, demonstrating consistency and stability in the model. This strengthens confidence in the validity of the findings and suggests that the relationships identified are both statistically and theoretically meaningful. Overall, the results demonstrate a coherent and consistent pattern in which digital competencies, AI usage, and digital informal learning collectively enhance teachers' effectiveness. Digital competence emerges as the most influential factor, serving as a foundation that enables teachers to effectively utilize AI tools and engage in continuous learning. Meanwhile, AI usage and informal learning function as complementary elements that reinforce teachers' ability to adapt, innovate, and respond to classroom challenges. These findings highlight the importance of an integrated approach to technology-enhanced education, particularly in contexts characterized by resource limitations and evolving instructional demands.

Discussion

The findings of this study demonstrate that digital competencies play a central and decisive role in shaping teachers' effectiveness, particularly within educational environments that are undergoing technological transition. In line with previous studies, digital competence is not limited to the ability to operate technological tools, but extends to the capacity to integrate them meaningfully into pedagogical practices (Ilomäki, 2021; Redecker, 2020). Teachers who possess stronger digital competencies tend to demonstrate greater clarity in lesson delivery, improved classroom management, and more adaptive instructional strategies. This suggests that digital competence functions as a foundational capability that enables teachers to navigate increasingly complex and technology-driven learning environments. In this sense, the findings reinforce the argument that effective teaching in the digital era is inherently linked to the ability to align pedagogical goals with technological affordances.

Beyond digital competence, the role of AI usage in enhancing teachers' effectiveness reflects an important shift in how technology is positioned within the classroom. Rather than replacing teachers, AI appears to function as a supportive mechanism that enhances instructional responsiveness and student engagement. This is consistent with the perspective that AI can facilitate personalized learning experiences and provide real-time feedback, thereby enabling more dynamic interaction between teachers and students (Holmes et al., 2021; Jiang, 2025). However, the findings also indicate that the impact of AI is not as strong as that of digital competence, suggesting that the effectiveness of AI depends largely on the teacher's ability to understand and utilize it appropriately. In other words, AI does not operate independently but is mediated by the teacher's digital readiness and pedagogical awareness.

The contribution of digital informal learning further highlights the importance of continuous and self-directed professional development in contemporary education. Informal learning, which often takes place through online platforms and professional communities, allows teachers to acquire new knowledge, exchange experiences, and adapt to emerging educational trends (Iqbal et al., 2025; Nguyen, 2022). The findings of this study suggest that while informal learning contributes positively to teaching effectiveness, its influence is more complementary than primary. This indicates that informal learning alone may not be sufficient to significantly transform teaching practices unless it is supported by a solid foundation of digital competence and access to relevant technological tools. Thus, informal learning can be understood as a reinforcing mechanism that strengthens existing capabilities rather than acting as a standalone driver of change.

An important insight emerging from this study is the synergistic relationship among digital competencies, AI usage, and digital informal learning. These elements do not operate in isolation but interact in ways that collectively enhance teachers' effectiveness. This supports the view that technology integration in education is a multidimensional process that requires the alignment of skills, tools, and continuous learning (Rubio-Gragera et al., 2025; Scarci et al., 2024). The findings indicate that digital competence enables teachers to utilize AI effectively, while informal learning provides opportunities for continuous improvement and adaptation. This interconnected dynamic suggests that efforts to improve teaching effectiveness should not focus on a single factor, but rather adopt a holistic approach that considers the interplay between multiple dimensions of technological and professional development.

At the same time, the variation in adoption levels across different regions highlights the influence of contextual factors, particularly in relation to infrastructure and access to technology. Teachers in urban areas tend to demonstrate higher levels of adoption compared to those in rural settings, where limitations in digital infrastructure and training opportunities remain significant barriers (Alif Fairus Bin Nor Mohamad et al., 2025; Dr. Muhammad Jamil et al., 2024). This disparity suggests that the effectiveness of digital competencies, AI usage, and informal learning is not solely determined by individual capabilities, but is also shaped by broader structural conditions. Therefore, addressing these contextual challenges is essential to ensure that technological advancements in education can be equitably accessed and effectively utilized across different settings.

Despite its contributions, this study has several limitations that should be acknowledged. The use of a cross-sectional design limits the ability to capture changes over time and to establish causal relationships among variables. In addition, the reliance on self-reported data may introduce bias, as respondents may overestimate their competencies or effectiveness. The study is also limited to a specific geographical context, which may affect the generalizability of the findings to other educational environments. Future research is therefore encouraged to adopt longitudinal approaches, incorporate objective measures of teaching performance, and explore diverse contexts to provide a more comprehensive understanding of the relationships identified in this study. From a practical perspective, the findings suggest that policymakers and educational institutions should prioritize integrated training programs that simultaneously develop digital competence, support AI integration, and encourage continuous informal learning, while also addressing infrastructural and contextual constraints that may hinder effective implementation.

Conclusion

This study examined how digital competencies, AI usage, and digital informal learning collectively influence teachers' effectiveness within Islamic secondary schools in a resource-constrained context. The findings indicate that these elements function as interconnected dimensions rather than independent factors, with digital competencies emerging as the most influential driver of effective teaching. Teachers who possess strong digital competencies are better able to integrate AI tools into their instructional practices and benefit from informal learning opportunities, thereby enhancing lesson delivery, student engagement, and classroom management. At the same time, the results highlight that technology alone does not determine effectiveness; rather, its impact depends on how it is meaningfully applied within pedagogical contexts. The variation between urban and rural settings further emphasizes the role of

infrastructure, access, and institutional support in shaping the extent to which these benefits can be realized.

From a practical perspective, the study underscores the importance of adopting an integrated approach to teacher development that simultaneously strengthens digital competencies, supports AI integration, and promotes continuous informal learning. Educational policymakers and institutions are encouraged to design context-sensitive training programs and improve digital infrastructure to ensure equitable access to technology-enhanced education. The study contributes to the literature by offering an integrative framework that captures the combined effects of technological and informal learning factors on teachers' effectiveness. However, its limitations—including the cross-sectional design and reliance on self-reported data—suggest the need for future research to adopt longitudinal approaches, incorporate objective performance measures, and explore diverse educational contexts. Overall, the findings provide a foundation for advancing both research and practice toward more adaptive and sustainable models of teaching in the digital era.

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