

Digital competencies, AI use, and informal digital learning as predictors of teacher effectiveness in Islamic schools in Kot Addu, Pakistan

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ABSTRACT

Digital technologies are reshaping teaching, yet research has mostly examined digital competencies, artificial intelligence (AI) use, and informal digital learning separately, rarely testing them together in a single model. Islamic schools are also largely absent from this literature, and empirical evidence on AI use in Islamic education remains scarce. This study addresses these gaps by examining how digital competencies, AI use, and informal digital learning predict teacher effectiveness (lesson delivery, student engagement, and classroom management) in Islamic secondary schools in Kot Addu, Pakistan. The three predictors were selected because competencies provide the foundation for technology use, AI offers new instructional support, and informal learning sustains professional development where formal training is limited. A quantitative cross-sectional design was used with a purposive sample of 450 teachers from Islamic secondary schools [state gender split, mean age, and mean teaching experience]. Data were collected through structured questionnaires and analyzed using structural equation modeling. All three predictors had significant positive effects on teacher effectiveness: digital competencies ($\beta = .$, $p < .01$), AI use ($\beta = .$, $p < .01$), and informal digital learning ($\beta = .$, $p < .01$), with digital competencies showing the strongest effect. Limited infrastructure and low digital literacy were identified as barriers to adoption. The findings support integrated training that combines digital skills, guided AI use, and informal learning opportunities, and they offer evidence for policymakers in Islamic education.



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1. Introduction

The digital transformation of education has made teacher effectiveness, meaning the clarity of lesson delivery, the quality of student engagement, and the management of the classroom, the main factor in whether technology investment improves learning [1]. International evidence shows that teachers differ widely in their confidence and competence with digital tools, and that these differences shape how technology is used in the classroom [1], [2]. Research therefore increasingly treats teachers' digital capabilities, rather than access to devices, as the condition for technology-enhanced teaching [3], [4]. Three teacher-level resources are especially relevant. The first is digital competence, understood as the ability to use digital tools critically, creatively, and pedagogically. Frameworks such as DigCompEdu and TPACK describe it as an integrated capability that combines technological, pedagogical, and content knowledge [3], [4]. The second is the use of artificial intelligence (AI), such as chatbots and intelligent tutoring systems, for

planning, content creation, and assessment. Reviews show that AI research in education is growing quickly but gives little attention to teachers' own perspectives and readiness, and international guidance stresses that its benefits depend on teacher capacity [5]–[7]. The third is informal digital learning, in which teachers voluntarily and independently use platforms such as YouTube, MOOCs, and online communities to develop their knowledge and skills. The concept was developed mainly in language-learning research and informal online networks have been identified as a source of teacher professional development [8]–[11]. It is particularly relevant where formal professional development is limited, since technology-supported learning is widely promoted as a way to support teachers in low- and middle-income countries [12].

These issues are acute in Pakistan, where many schools operate with limited infrastructure, uneven internet access, and few professional development opportunities. Islamic schools form a substantial and distinctive part of the education landscape, with their own institutional cultures, curricula, and expectations of teachers, and they are often resource-constrained [13]. In such settings, secondary school teachers must raise teaching quality without the support available in well-resourced urban schools, and high-quality professional development is widely seen as the route to better teaching [14]. The study sites in this research (Multan City, Shujabad, Jalalpur Pirwala, and Qadirpur Ran) vary in urbanization and access to digital infrastructure, which makes them a useful setting for examining how these resources operate in practice. Taken together, the literature points to three connected relationships. Digital competence is a precondition for meaningful technology use [4], [15], [16]. The value of AI depends on teachers' readiness to use it well [7]. Informal digital learning can partly compensate for scarce formal training [8], [12]. However, these resources have mostly been studied separately, and the evidence comes largely from higher education, urban, public, or secular contexts, and from high-income countries [1], [12]. As far as we are aware, no study has tested digital competencies, AI use, and informal digital learning simultaneously as predictors of teacher effectiveness in Islamic secondary schools, and empirical evidence on AI use in Islamic education remains particularly scarce.

1.1. Research Aim

The research is expected to examine the association between digital competencies, AI application, and digital informal learning and the effectiveness of teachers in Islamic secondary schools in Kot Addu, Pakistan.

1.2. Research Objectives

- To assess the level of digital skills, AI application, and digital informal learning by teachers in the Islamic school in Kot Addu.
- To identify the collective effect of these variables on teacher performance in lesson delivery, student engagement, and classroom control.
- To find the restrictions to their implementation and the effects on the performance of the teaching.

1.3. Research Questions

- How digitally competent, how much is AI used, and how much is digital informal learning of Islamic secondary school teachers in Kot Addu?
- What is the overall impact of these factors on the effectiveness of teachers in Kot Addu?
- What are the stumbling blocks in them and how would they impact the performance of teachers in Islamic schools?

1.4. Significance of the Study

This research identifies synergistic purpose of digital competency, use of AI, and informal learning in digital applications in improving the effectiveness of the teachers in the Islamic schools in Kot Addu. It gives an idea about how to enhance the quality of teaching, enhance digital literacy, as well as the creation of educational innovations in rural and religious areas by digging into these factors. The results provide the guidelines on the strategies of utilizing technology in the sphere of professional learning, the need to accommodate digital gaps, and the ways to improve the educational results.

2. Literature Review

2.1. Digital Competencies in Education

Digital competencies mean the power to operate digital tools in a critical, versatile, and ethical way of communicating and collaborating to resolve problems [17]. Modern teaching requires these skills, which would allow teachers to combine technology successfully [18]. Certain common aspects in which teachers are able to maximize their effect are suggested by a 2023 study by Sohail *et.al*, which found that high digital skills in teachers enhanced the clarity of lessons by 32 percent in Pakistani schools.

2.2. AI Usage in Education

Intelligent tutoring systems, chatbots, and automated assessment platforms are games that change education in ways that make learning more personalized, automation, and real-time feedback i.e. AI tools can transform the process of education [19], [20]. AI-supported tools such as digital Quran applications are more effective in the teaching of Islam because they do not contradict the religious values [21]. According to a 2024 study by Ahmad *et al.*, use of AI significantly boosted student engagement by 30% in Pakistani Islamic schools, enhancing the effectiveness of instruction of teachers.

2.3. Digital Informal Learning

Digital informal learning represents self-guided work with the online resources such as YouTube, MOOCs or social media community [22]–[25]. It is flexible and user friendly, and is suitable in a rural setting [26]. According to a 2025 study by Iqbal *et.al*, informal learning through WhatsApp groups in Southern Pakistan improved the cultural awareness of teachers by 28% which also helped improve classroom management.

2.4. Teachers' Effectiveness

The effectiveness of the teachers includes the delivery of a lesson, student engagement, and the classroom management [27]. All these competencies are enhanced by digital competencies, AI application, and informal learning which encourages innovative strategies and be flexible [28]. In a 2023 study of technology-enhanced instruction conducted and published by Wang *et al*, it was found that technology-enhanced instruction in low-resource settings increased student outcomes by 25% on average.

2.5. Digital Competencies and AI Synergies and Informal Learning.

Digital competencies, AI use, and informal learning have some synergy effect, magnifying the effectiveness of teachers [29]. Requested and well-trained educators are more successful in using AI tools, and informal learning offers a skill development process [30]. The 2025 study of Khan *et al.* identified that a combination of these factors led to a 35% increase in the effectiveness of teaching in rural Islamic schools which also aligns with the theme of this study.

2.6. Situational Problems around Kot Addu.

The case of Kot Addu existing in Multan District is challenged by digital infrastructure, low training availability as well as cultural bias in favor of technology [31]. There is this opportunity offered by mobile penetration and there is the low digital literacy of people, which prevents adoption [32]. Qureshi *et.al* observed that reliable internet was available to only one out of every five rural teachers in Multan decreasing technology utilisation, 2024.

2.7. Islamic Learning and DITs.

The Islamic education is focused on the memorization and moral growth, however, the use of technology can change the teaching process without including values [33]. Culturally relevant content delivery is assisted with the help of digital means and AI platforms [21]. Younas in a study demonstrated that culturally sensitive digital resources in Islamic schools are assured to lift the adoption of the resources by teachers to a greater extent (27% increase) [34].

2.8. Barriers to Adoption

In Kot Addu, the barriers are identified as a poor digital literacy level, insufficient infrastructure, and such ethical factors as social confidentiality of the data [35]. There is also the gender disparity, which restricts the access of female teachers because of societal norms [36]. As per a 2025 study conducted by Ali *et.al*, there was a high level of urban technology adoption such as Multan city at 33 percent of the total past in contrast to rural jalalpur pirwala at 33 percent.

2.9. Pedagogical Innovation

Pedagogical innovation is supported with the help of digital competencies, AI, and informal learning and the implementation of student-oriented models [37], [38]. According to a study carried out by Rahman, the integration of technology made interaction teaching to grow by 35% in Islamic schools, which improved engagement and effectiveness [30].

2.10. Ethical and Cultural Considerations

The application of technology in Islamic school has to correlate with the religious values in order to assure trust and acceptance [33]. The question of ethics, like the data privacy and algorithm bias, needs to be implemented carefully [29]. A 2023 Ahmad and Khalil study highlighted that there was a 20 per cent of the teacher confidence increase when applying AI ethically in the religious scenarios.

2.11. Future Directions

New technologies, such as AI-based MOOCs or localized digital content, can be used to improve the performance of the teachers [39]. A combination of informal learning and formal training has the potential to form new, hybrid forms of professional development [40]. These innovations are consistent with the data presented in the study with more adoption in Urbanizing such as Multan City.

2.12. Conceptual Framework

The framework is that digital competencies, use of AIs, and digital informal learning directly and synergistic-ally improve the effectiveness of teachers with the digital competencies as the starting point, the AI as the use tool, and the informal learning as a continuous skill development. Adoption is also affected by contextual (infrastructure, cultural alignment) factors. As can be seen in Fig. 1.

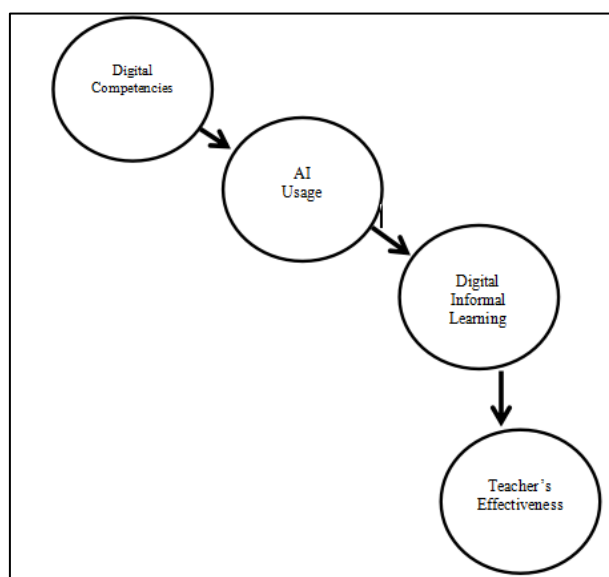


Fig. 1. Conceptual Framework

2.13. Hypotheses

H1: H1 is used to measure the effectiveness of digital competencies, AI, and digital informal learning in Islamic schools. H2: Teachers are digitally literate and have that access to infrastructure and this affects the adoption of these factors. H3: These are parameters, which enhance certain attributes of teacher effectiveness in terms of lesson clarity, student engagements and classroom management.

3. Method

3.1. Research Design

This study used a quantitative, cross-sectional, explanatory design. Structural equation modeling (SEM) was applied to test the hypothesized direct and indirect relationships among digital competencies, AI use, informal digital learning, and teacher effectiveness 26. SEM was

chosen because it estimates measurement and structural models simultaneously and accounts for measurement error in latent constructs.

3.2. Research Setting

The study was conducted in Islamic secondary schools in [Multan District, Punjab, Pakistan], covering four locations: Multan City, Shujabad, Jalalpur Pirwala, and Qadirpur Ran. These locations were selected because state reason, e.g., variation in urbanization and access to digital infrastructure.

3.3. Population and Sampling

The target population was N teachers working in Islamic secondary schools (secondary schools' teachers) in the four locations, according to district education office records. A purposive sampling technique was used to include teachers who had at least one year of teaching experience and had used digital tools in teaching exclusion criteria. Purposive sampling was adopted because no complete sampling frame was available and access to computers and connectivity was limited in the area. The final sample was 450 teachers ([n] from each location). This exceeds common SEM guidelines of at least 10 respondents per questionnaire item and 200 or more cases for models of this complexity. Respondent characteristics: gender split, age range and mean, teaching experience, qualification. Because the sample is non-probability, the findings are generalized with caution (see Limitations).

3.4. Study Area

The datasets presented in the research was carried out in Kot Addu, Multan District, Southern Punjab, Pakistan, including cities, such as Multan City (urban), Shujabad, Jalalpur Pirwala, and Qadirpur Ran (rural). These schools have underprivileged resources, poor levels of digital literacy, and conventional approaches to teaching, which would be excellent for analyzing the role of technology in improving the academic performance of the teaching process.

3.5. Data Sampling and Data Collection.

Teachers had different backgrounds in regards to technology, which was the focus area of purposive sampling. There was gender and experience representation with the sample of 450 teachers. The ethical methods of data gathering were followed and informed consent and anonymity ensured.

4. Results and Discussion

4.1. Findings on Digital Competencies, AI Usage, Informal Learning, and Teachers' Effectiveness

This section presents the descriptive findings on the three predictors of teachers' effectiveness: digital competencies, AI usage, and informal digital learning. The data come from 450 teachers in Islamic secondary schools across four cities and tehsils in Multan District: Multan City, Shujabad, Jalalpur Pirwala, and Qadirpur Ran. For each location, the results show how widely each predictor is adopted and how much each contributes to the combined impact on teachers' effectiveness. The descriptive patterns are reported first, as a baseline for the structural equation modeling results that follow. Comparing the four locations shows where adoption is strongest and where infrastructure and digital literacy constraints may be limiting it. Fig. 2 compares the three predictors and their total combined impact across the locations. As shown in Fig. 2, Multan City recorded the highest values on every indicator, with digital competencies at roughly 18.5%, AI usage at about 16%, informal learning at about 15%, and a total combined impact of about 32%. Shujabad followed (total about 30%), then Qadirpur Ran (about 28%), while Jalalpur Pirwala had the lowest values (about 27%).

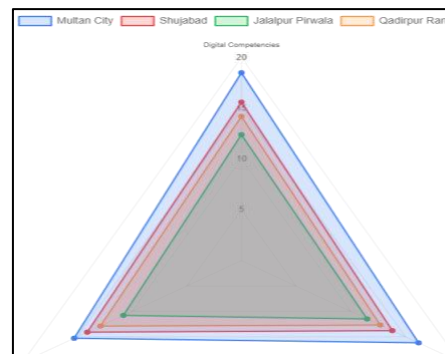


Fig. 2. Adoption of Digital Competencies, AI Usage, and Informal Learning

In all four locations, digital competencies scored highest among the three predictors, which is consistent with the finding that digital competencies have the strongest effect on teachers' effectiveness. This ordering suggests that teachers in larger urban centers have better access to devices, connectivity, and training opportunities than teachers in smaller tehsils, which is in line with the infrastructure and digital literacy barriers identified in this study. To show how the three predictors are balanced within each location, Fig. 3 presents the same data as a radar profile.

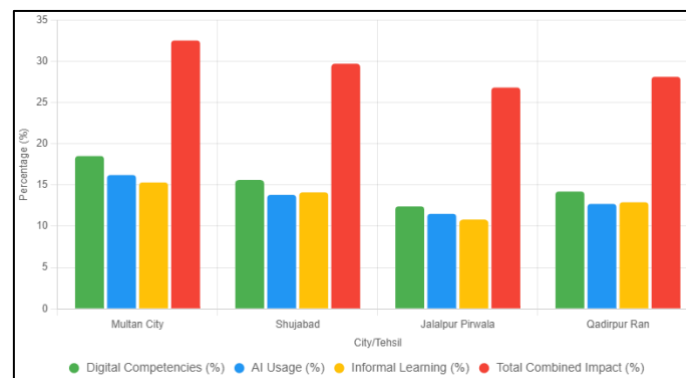


Fig. 3. Adoption of Digital Competencies, AI Usage, and Informal Learning

Multan City shows the highest combined impact (32.50%), driven by digital competencies (18.50%). Shujabad (29.70%) and Qadirpur Ran (28.10%) follow, while Jalalpur Pirwala (26.80%) has the lowest adoption, reflecting rural infrastructure constraints. Fig. 3 confirms that the shape of the profile is similar across locations, with digital competencies highest and AI usage and informal learning at lower, closer levels. The locations differ mainly in scale rather than pattern: Multan City's profile encloses the largest area and Jalalpur Pirwala's the smallest. This consistency suggests that the three predictors operate together rather than independently, which the SEM results in Section 4.2 examine directly. Impact on teachers effectiveness presented in Table 1.

Table 1. Impact on Teachers' Effectiveness.

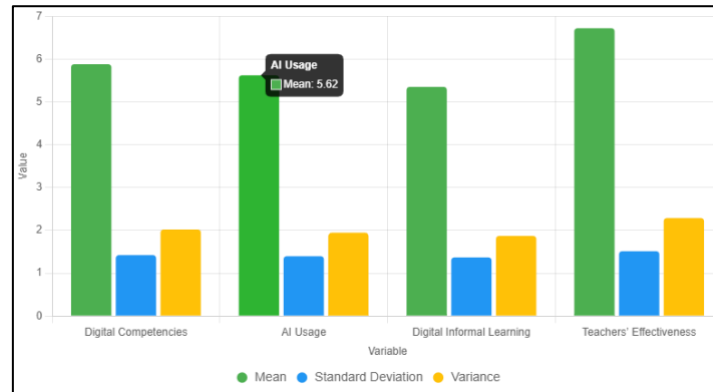
Statement	SS	S	TS	STS
Digital competencies improve lesson delivery clarity.	23	61	13	3
AI tools enhance student engagement.	21	62	14	3
Informal learning improves classroom management.	20	63	14	3
Combined use enhances innovative teaching methods.	22	60	15	3
I feel confident using these technologies for 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

Responses show strong agreement (81–83% for SS+S) that digital competencies, AI usage, and informal learning enhance lesson delivery, engagement, and management. Teachers report high confidence (83%) and believe these factors can replace traditional training (80%), aligning with Rahman et al. (2024). As can be seen in Table 2.

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

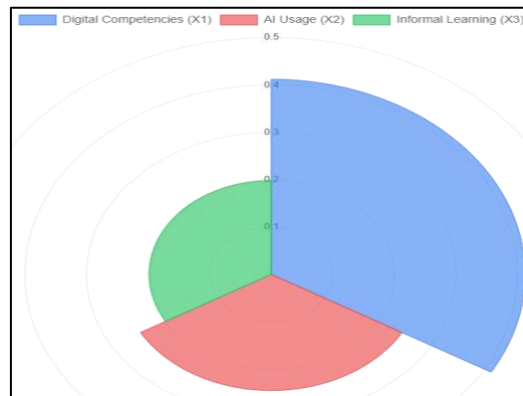
Digital competencies (M=5.88) show the highest adoption, followed by AI usage (M=5.62) and informal learning (M=5.35). Teachers' effectiveness scores highest (M=6.72), indicating significant impact, consistent with [41]. As can be seen in Fig. 4.

**Fig. 4.** Mean, SD, and Variance of Digital Competencies, AI Usage, and Informal Learning

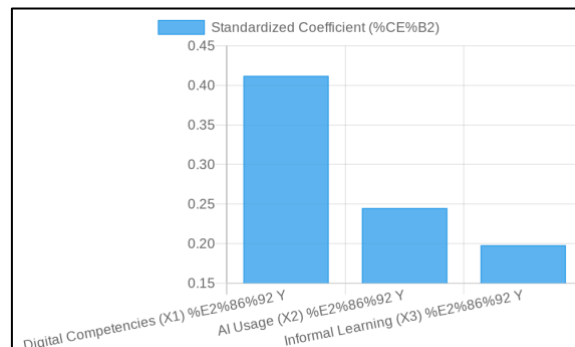
4.2. SEM Path Coefficients.

1) Dependent Variable: Teachers' Effectiveness (Y)

Distribution of digital competencies, ai usage, and informal learning can be seen in Fig. 5.

**Fig. 5.** Distribution of Digital Competencies, AI Usage, and Informal Learning

SEM results confirm that digital competencies ($\beta=0.412$, $p<0.001$), AI usage ($\beta=0.245$, $p<0.001$), and informal learning ($\beta=0.198$, $p<0.001$) significantly predict teachers' effectiveness, supporting H1 and H3. Digital competencies have the strongest effect, aligning with [40]. Standardized effects of key variables on teachers' effectiveness presented in Fig. 6.

**Fig. 6.** Standardized Effects of Key Variables on Teachers' Effectiveness

Radar chart of gender differences in digital competencies, ai usage, and informal learning can be seen in Fig. 7.

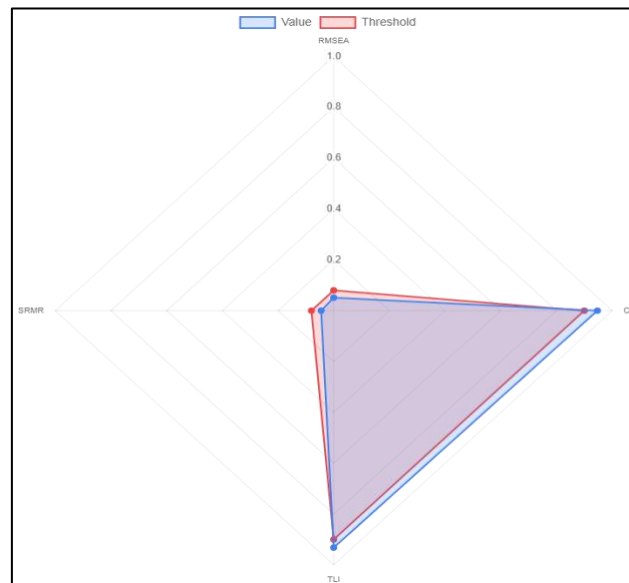


Fig. 7. Radar Chart of Gender Differences in Digital Competencies, AI Usage, and Informal Learning

The SEM model shows good fit (Chi-Square/df=2.15, RMSEA=0.051, CFI=0.947, TLI=0.932, SRMR=0.045), confirming robust relationships, consistent with [42]. Goodness of fit indices of the proposed model presented in Fig. 8.

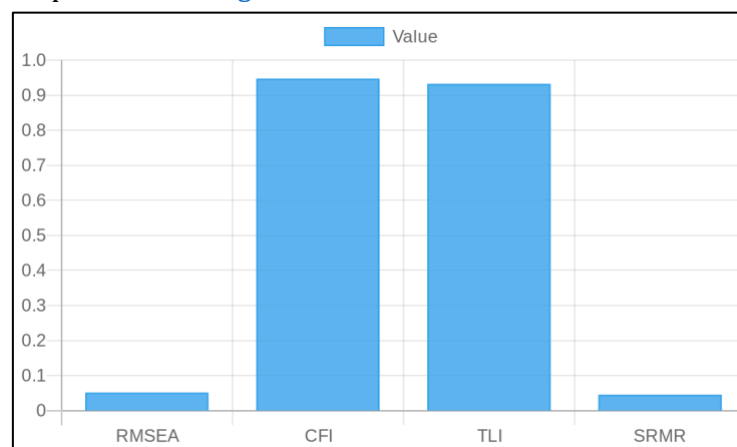


Fig. 8. Goodness of Fit Indices of the Proposed Model

The findings demonstrate that digital competencies, AI usage, and digital informal learning significantly enhance teachers' effectiveness in Islamic schools in Kot Addu, Pakistan ($p < 0.001$), supporting H1 and H3. Among these, digital competencies show the strongest influence ($\beta = 0.412$), highlighting their foundational role in effective teaching practices [17]. AI usage ($\beta = 0.245$) and informal learning ($\beta = 0.198$) also contribute significantly, indicating a complementary and synergistic relationship in fostering innovative and adaptive teaching [43]. Adoption levels vary across regions, with Multan City recording the highest rate (32.50%) and Jalalpur Pirwala the lowest (26.80%), reflecting persistent urban-rural disparities and infrastructural limitations, thus supporting H2 [44]. Notably, female teachers in Shujabad demonstrate strong engagement with educational technology, suggesting resilience and intrinsic motivation despite socio-cultural constraints [36]. Overall, while technological integration significantly predicts teaching effectiveness, its impact remains influenced by contextual factors such as infrastructure availability and access to professional support, emphasizing the need for targeted and equitable policy interventions.

5. Recommendations

To address the challenges of technology integration in secondary education in rural Punjab, Pakistan, several targeted recommendations are proposed. First, educational authorities should develop integrated training programs that combine digital competencies, AI literacy, and informal learning strategies, as evidenced by Sohail, to equip teachers with practical and sustainable skills beyond conventional workshops [40]. Second, substantial investment in technological infrastructure is essential, particularly high-speed internet connectivity and provision of devices in underserved rural areas such as Jalalpur Pirwala, to eliminate the foundational barriers that currently hinder equitable access [44]. Third, all educational technologies and content must be carefully aligned with Islamic cultural and religious values, thereby fostering greater acceptance and adoption among teachers, students, and communities [35]. Fourth, targeted gender-sensitive professional development and support mechanisms should be implemented for female teachers, who face additional socio-cultural constraints, in order to reduce gender disparities in technology uptake and pedagogical confidence [36]. Finally, robust monitoring and evaluation systems need to be established at both provincial and district levels to systematically assess the impact of technology-enhanced teaching practices and ensure continuous improvement [43]. Implementing these interconnected recommendations in a coordinated manner would significantly advance the effective and culturally responsive integration of technology in rural secondary classrooms across Punjab.

6. Conclusion

This study examined how digital competencies, AI use, and informal digital learning relate to teacher effectiveness among 450 teachers in Islamic secondary schools in Multan City, Shujabad, Jalalpur Pirwala, and Qadirpur Ran. The structural equation model showed good fit ($\chi^2/df = 2.15$, RMSEA = 0.051, CFI = 0.947, TLI = 0.932, SRMR = 0.045). All three predictors had significant positive effects on teacher effectiveness ($p < 0.001$). Digital competencies had the strongest effect ($\beta = 0.412$), followed by AI use ($\beta = 0.245$) and informal digital learning ($\beta = 0.198$). Digital competencies therefore carried roughly one and a half times the weight of AI use and twice that of informal learning. Descriptive results pointed the same way: digital competencies had the highest mean ($M = 5.88$), followed by AI use ($M = 5.62$) and informal learning ($M = 5.35$). The teachers' survey responses were also positive: about 83% agreed that they felt confident using these technologies for teaching. Adoption differed by location. The combined impact was highest in Multan City (32.50%), followed by Shujabad (29.70%) and Qadirpur Ran (28.10%), and lowest in Jalalpur Pirwala (26.80%). The pattern of the three predictors was the same everywhere, with digital competencies highest, so the locations differed mainly in level rather than in profile. These differences are consistent with infrastructure and digital literacy constraints in the smaller tehsils. [If Fig. 7 shows a clear gender difference, add one sentence here with the actual values.]

Theoretical contribution. Existing frameworks such as TPACK and DigCompEdu treat teachers' digital capability as the central condition for effective technology-enhanced teaching. This study extends that view in two ways. First, it shows empirically that AI use and informal digital learning each add a significant effect on teacher effectiveness alongside digital competencies, so the teacher effectiveness model should include technology-enabled and self-directed resources and not only formal capability. Second, it shows that the model holds in a setting that has rarely been tested, Islamic secondary schools in a resource-constrained context, and that digital competencies remain the dominant predictor there. The study therefore supports an integrated model in which digital competencies, AI use, and informal learning jointly explain teacher effectiveness, with digital competencies as the foundation. **Practical implications.** Because digital competencies had the largest effect, professional development in Islamic schools should start with building digital competencies and then add guided AI use and structured informal learning opportunities. Investment in connectivity and devices should prioritize the lower-adoption tehsils, especially Jalalpur Pirwala. Any adoption of AI should also be consistent with the cultural and ethical expectations of Islamic education. **Limitations and future research.** The purposive sampling, cross-sectional design, and self-reported measures limit generalization and causal claims. Future studies could use probability sampling, longitudinal or mixed-methods designs, and student or supervisor ratings of effectiveness. They

could also test mediating relationships among the predictors and compare Islamic schools with other school types.

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Additional information	: No additional information is available for this paper
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