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Empowering female teachers through digital competence and AI integration to improve teaching effectiveness in Islamic Schools in Southern Pakistan

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Abstract

This study addresses the problem of the low and uneven empowerment of female teachers in utilizing digital competencies and integrating AI in Islamic schools in Southern Pakistan. Limited access, pedagogical readiness, institutional support, and gender disparities potentially hinder teaching effectiveness and learning quality. The study aims to analyze the effects of digital competence, AI usage, and informal digital learning on the teaching effectiveness of female teachers, as well as the relationship between digital competence and AI use in Islamic secondary schools in Southern Pakistan. Employing a quantitative design, the study surveyed 450 female teachers from Islamic secondary schools in Southern Pakistan. Data were collected through structured questionnaires and analyzed using descriptive statistics, validity and reliability tests, and multiple linear regression to examine the effects of digital competence, AI, and informal digital learning on teaching effectiveness. The findings conclude that the empowerment effectiveness of female teachers is more strongly influenced by basic digital competence and informal digital learning than by AI adoption. Regional differences highlight the role of institutional context and social support. Digital competence has a direct impact, informal learning acts as a reinforcing factor, while AI remains insignificant due to limited pedagogical integration and insufficient policy support. This study contributes by emphasizing the importance of foundational digital competence and informal learning as key pillars of female teacher empowerment, while critically questioning assumptions about the automatic effectiveness of AI in Islamic education contexts.

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INTRODUCTION

The accelerated integration of digital technology and artificial intelligence (AI) in education presents significant challenges for female teachers in Islamic secondary schools in Southern Pakistan, particularly in rural areas that continue to experience limited digital infrastructure and restricted access to formal professional training (Aruleba & Jere, 2022; Mustafa et al., 2024). Many female teachers are still developing foundational digital competencies, while the quality of learning is increasingly determined by teachers' ability to employ adaptive learning systems, automated assessment, and AI-based tools in ethical and contextually appropriate ways (Divanji et al., 2023; Katona & Gyongyosi, 2025). This mismatch between technology-driven pedagogical demands and teachers' actual readiness constitutes a structural issue with direct implications for the quality of Islamic education in the region (Zakharova et al., 2024; Tan et al., 2025).

A growing body of international research shows that digital competence is a key determinant of technology-enhanced teaching effectiveness. Evidence from 1,654 vocational teachers in Switzerland found that digital technology use is strongly linked to perceived usefulness and more adaptive teaching profiles (Cattaneo et al., 2025; Dringo-Horvath et al., 2025). Similar findings are reported by Guillén-Gámez et al. (2023), who showed that digital factors explain 48.20% of variance in ICT integration, and by Rosyidah et al. (2025), who found that technology integration contributes 62.4% to teachers' digital pedagogical competence. However, in rural and resource-constrained settings, limited structured professional development leads teachers to build technological capacity through informal digital learning pathways (Guan et al., 2024). Meanwhile, artificial intelligence is increasingly recognized as a driver of instructional quality through personalized learning, automated assessment, and data-driven pedagogical decisions. Studies indicate that teachers' readiness to adopt AI is highly influenced by digital competence, though implementation remains limited (Galindo-Domínguez et al., 2024; Metwally & Bin-Hady, 2025).

From a gender and institutional perspective, female teachers in Islamic schools face additional challenges, including unequal access to training opportunities, limited institutional support, and sociocultural norms that shape their engagement with technology. Although Sánchez-Prieto et al. (2020) report no significant gender differences in ICT knowledge, other studies suggest that female teachers' technological capacity in rural Islamic educational settings often develops through informal and compensatory strategies rather than formal institutional pathways (Alieto et al., 2024). In Southern Pakistan, particularly in the South Punjab region, empirical evidence on these dynamics remains scarce, despite persistent constraints related to digital infrastructure and professional development (Rehman et al., 2025).

Based on the identified research gaps, this study aims to analyze the empowerment of female teachers through the influence of digital competence, artificial intelligence (AI) utilization, and informal digital learning on the teaching effectiveness of female teachers in Islamic secondary schools in Southern Pakistan, as well as to examine the relationship between digital competence and AI use. This study is expected to make both theoretical and practical contributions by enriching gender-based educational technology research through the development of an integrated empirical model, while also providing an evidence-based foundation for educational policymaking, the design of digital and AI training programs, and the formulation of female teacher empowerment strategies that are responsive to the characteristics of rural Islamic education.

Based on the conceptual framework and previous empirical findings, this study concludes that digital competence, the use of artificial intelligence (AI), and informal digital

learning are factors that have a positive and significant effect on the teaching effectiveness of female teachers. In addition, digital competence is closely related to the level of AI use among female teachers in Islamic secondary schools. These findings provide a more comprehensive empirical understanding of the key factors that determine the effectiveness of teaching and the empowerment of female teachers in the context of Islamic education in Southern Pakistan.

METHOD

Research Design

This study employs a quantitative research design, which, according to White (2023), is an appropriate approach when the aim of a study is to analyze measurable cause-effect relationships among variables. The quantitative approach enables researchers to evaluate the impact of digital competence, the use of artificial intelligence (AI), and informal digital learning on the teaching effectiveness of female teachers in Islamic secondary schools in Southern Pakistan. Bazen et al. (2021) emphasize that quantitative analysis provides a strong foundation for hypothesis testing through the systematic processing of numerical data, allowing relationships among variables to be assessed objectively. Therefore, this design ensures that any identified effects arise from measurable data patterns rather than subjective interpretation, making the research findings more reliable for the context of rural Islamic education.

Population and Sampling Procedure

The population of this study comprises female teachers teaching in Islamic secondary schools located in rural areas of Southern Punjab, Pakistan, with an estimated total of approximately 620 teachers based on school administrative data. To obtain a sample that truly represents female teachers who actively use digital technology, artificial intelligence (AI) applications, and engage in informal digital learning, this study employs purposive sampling. According to Ahmed (2024), this method is appropriate when researchers require participants with specific characteristics aligned with the research objectives. Similarly, Morea (2022) emphasizes that purposive sampling enables the selection of respondents who have direct experience with the phenomenon under investigation. Therefore, only female teachers with basic exposure to digital platforms, the use of AI-based applications, and involvement in informal digital learning such as self-directed training or online collaboration were included. This approach ensures that the sample reflects a group that genuinely experiences the use of educational technology in their teaching practices.

Based on Asare's (2025) perspective, the Krejcie and Morgan sample size determination table indicates that from a population of 620 teachers, a minimum of approximately 240 respondents is required for statistical analysis to achieve an adequate level of confidence. Referring to this principle, the present study collected 450 valid responses to enhance data reliability and reduce potential sampling error. This number, which exceeds the minimum requirement, is consistent with experts' recommendations that larger sample sizes tend to produce more stable and accurate findings. Therefore, the sample size further strengthens the validity of the research results as a continuation of the previously described sampling procedure.

Research Instrument

The research data were collected through a structured questionnaire distributed via Google Forms, thereby facilitating access for teachers in rural areas with diverse teaching schedules. The instrument consisted of five main sections: demographic data, a digital

competence scale, an AI usage in teaching scale, an informal digital learning scale, and a teacher effectiveness scale. According to Heo et al. (2022), the use of a five-point Likert scale is effective in capturing respondents' perceptions in a more measurable and consistent manner. In addition, Mårtensson et al. (2016) emphasize that structured instruments with clear indicators enable systematic assessment of the frequency of technology use and the teaching effectiveness reported by teachers. Thus, this approach ensures the quality and consistency of measurements across all research variables.

Validity and Reliability Procedures

To ensure methodological rigor, several important procedures were undertaken. Content validity was examined through a questionnaire review process conducted by three experts in the fields of educational technology and Islamic education to assess the clarity, relevance, and alignment of items with the measured constructs. Subsequently, construct validity was analyzed using exploratory factor analysis (EFA) with the assistance of SPSS to confirm the factor structure and eliminate items with low factor loadings. Reliability testing was also conducted by calculating Cronbach's alpha coefficients for each scale, namely digital competence (0.87), AI usage (0.89), informal digital learning (0.85), and teacher effectiveness (0.91). All of these values exceeded the 0.70 threshold, indicating a strong level of internal consistency.

Data Analysis Techniques

The data were analyzed using SPSS through a series of systematic statistical procedures. First, descriptive statistics were employed to describe the demographic characteristics of the respondents. Next, reliability and validity tests were conducted by calculating Cronbach's alpha and performing factor analysis to ensure the consistency and accuracy of the instrument. Multicollinearity was assessed by examining variance inflation factor (VIF) and tolerance values to ensure that excessive correlations among independent variables did not compromise the model, as explained by Li (2021). Normality and heteroskedasticity tests were also applied to evaluate the suitability of the regression model, in line with the guidelines of Cardoso et al. (2023). After the assumptions were met, multiple regression analysis was used to examine the effects of digital competence, AI usage, and informal digital learning on teacher effectiveness. t-tests were further analyzed to determine the significance of each predictor's contribution, as recommended by Ratnasari et al. (2023). This series of analyses provides a strong quantitative foundation regarding the contribution of digital tools, AI technologies, and informal digital learning practices to teacher effectiveness in rural Islamic schools.

Conceptual Framework

This study was examining the relationship among three core independent variables, that is digital competencies, AI usage, and informal digital learning, as predictors of woman teacher's effectiveness of Islamic secondary school women woman teachers in Southern Pakistan, and at the same time the combined impact. It also represents the realization that for modern educational effectiveness increasingly the integration of digital technologies more broadly the rapid integration of digital technologies (especially in the absence of formal digital education), particularly in under resourced areas such as Kot Addu District. At last it is this model which aligns with educational technology research which outlines woman teacher preparedness as well as use of digital resources ethically to facilitate classroom innovation and performance.

RESULTS AND DISCUSSION

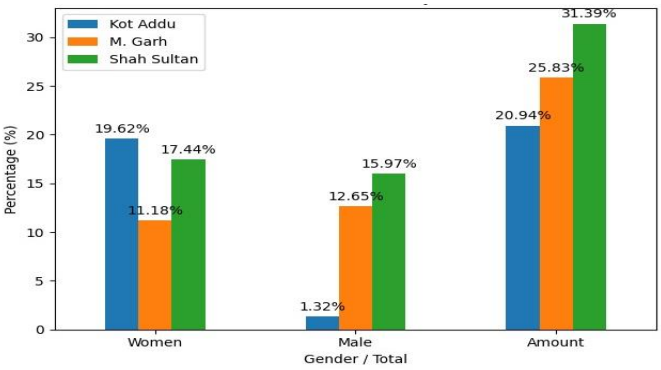
Results

Regional disparities in female teachers' use of digital and AI technologies

This study compares the use of digital tools and AI technologies among female teachers in Kot Addu, Muzaffargarh, and Shah Sultan. The results show notable regional differences linked to access, digital readiness, and institutional support, illustrating how social environments and infrastructure shape technology adoption in Islamic secondary schools.

Figure 2

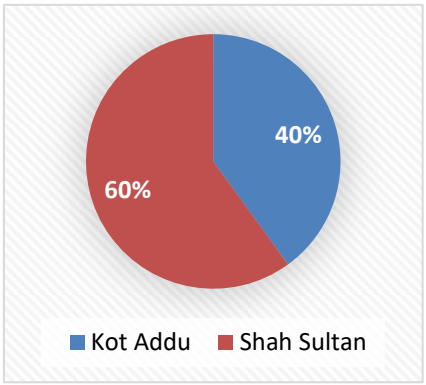
Use of digital tools, and AI usage of Secondary Women Woman Teachers



These findings indicate variations in the contribution of female teachers to the implementation of teaching tasks across different sub-districts. In Kot Addu Sub-district, female teachers carried out 19.62% of the total workload and, in aggregate, completed 20.94% of all tasks across schools. In Khan Garh Sub-district, the contribution of female teachers to teaching tasks reached 25.83%, with 11.18% representing task implementation and 12.65% reflecting task completion. Meanwhile, in Mailsi Sub-district, female teachers implemented 14.09% of the total workload and completed 8.76%, resulting in a cumulative contribution of 20.84%. In Nawan Kot Sub-district, female teachers handled 17.44% of teaching tasks; however, the completion rate was relatively lower, at 15.9%. This narrative suggests notable differences in the levels of participation and task completion effectiveness of female teachers across regions.

Figure 3

Highest and Lowest Total by location



Together, they accounted for 31.39% of the total performance. Female teachers in Nawan Kot Tehsil demonstrated performance levels that were 20.97% higher than those of their counterparts. This result also exceeded the 12.09% outcome recorded by female educators in Mailsi Tehsil. The stronger performance of female teachers in Nawan Kot can be

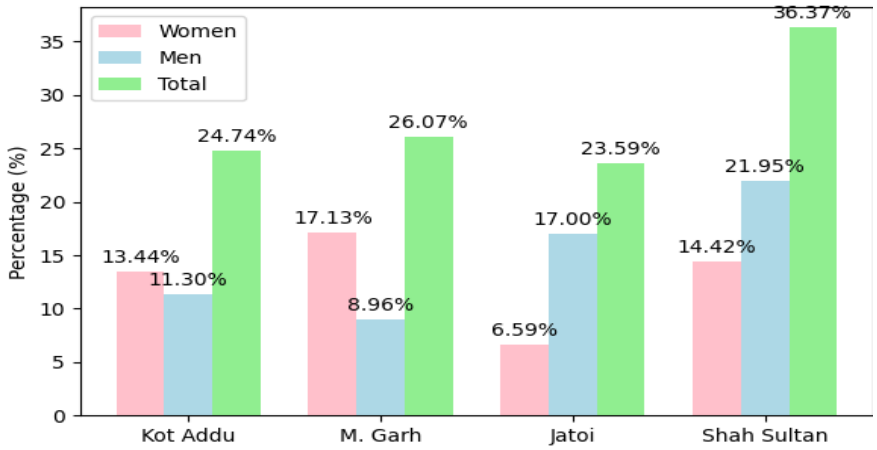
attributed to their more effective use of digital resources, as they were able to master technological tools more quickly than female teachers in Kot Addu Tehsil.

Gendered differences in digital competency use and learning across tehsils

The gender-based distribution of digital competency utilization across tehsils reveals significant variations in the application of technology for educational purposes. These differences not only reflect the division of teaching roles between female and male teachers but also indicate disparities in access, self-confidence, and institutional support for the use of educational technology in each region. These findings provide an important foundation for understanding gender dynamics in the integration of digital competencies in schools.

Figure 4

Uses of Digital competencies, in Technology for Educational Purposes

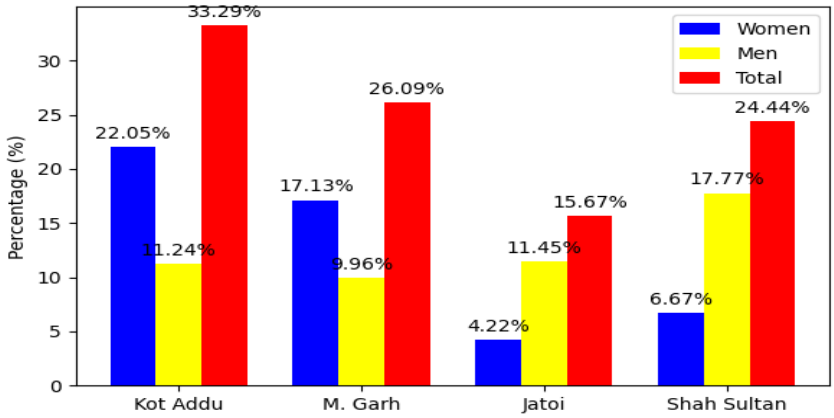


In Kot Addu Tehsil, female teachers conducted 13.44% of the lessons, while their counterparts accounted for 11.30%, resulting in a combined contribution of 24.74%. In Khan Garh Tehsil, female teachers managed approximately one-fifth of the teaching workload, whereas the remaining group contributed about one-tenth, producing a total of 26.07%. In Tehsil Mailsi, the distribution of teaching responsibilities was uneven, with 6.59% handled by one group of female teachers and 17.00% by the other, yielding a cumulative contribution of 23.59%. Meanwhile, in Tehsil Nawan Kot, female teachers delivered 14.42% of the lessons, while their counterparts were responsible for a substantially higher share of instruction at 21.95%. Overall, these figures illustrate notable variations in teaching workload distribution among female teachers across tehsils, suggesting differences in instructional roles, capacity, and contextual support across regions.

Collectively, they accounted for 36.37% of the total workload. The data indicate that female teachers in Tehsil Mailsi handled 23.95% more work than female teachers in other areas, although they received only 6.59% more assignments in the same tehsil. Meanwhile, female teachers in Nawan Kot outperformed their counterparts in Khan Garh in terms of their level of confidence in using technology for educational tasks. This finding suggests that differences in workload distribution and technological confidence vary across regions, potentially influenced by access to digital resources, training opportunities, and institutional support.

Figure 5

Use of Digital Informal Learning of Technology for Educational Purposes



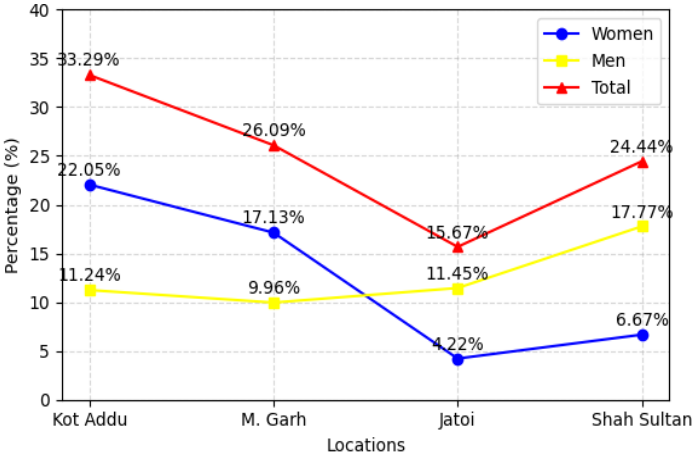
Based on the findings, notable gender-based patterns emerge across the selected tehsils. In Kot Addu Tehsil, female teachers constituted 22.05% of the total teaching workforce, while male teachers accounted for 11.24%, resulting in a combined teaching performance of 33.29%. A similar trend was observed in Khan Garh Tehsil, where female teachers contributed 17.13% compared to 9.96% male participation, yielding an overall teaching performance of 26.09%. In contrast, Mailsi Tehsil recorded substantially lower overall participation, with female teachers accounting for only 4.22%. Nawan Kot Tehsil demonstrated the highest level of female participation at 17.77%, surpassing Khan Garh Tehsil in terms of female representation. Additionally, Kot Addu Tehsil stood out in terms of educational outcomes, as female students showed stronger performance in the evaluation of digital tools and reported higher levels of trust in female teachers compared to those in other tehsils. Overall, these findings highlight the significant contribution of female teachers to teaching performance and digital engagement across regions.

The impact of digital tools, AI, and informal learning on the empowerment of female teachers

Furthermore, the combined influence of digital tool usage, artificial intelligence (AI), and informal learning on the effectiveness of secondary-level female teachers in utilizing technology for educational purposes is examined. The analysis is conducted based on gender differences and tehsil-level variations, enabling a more comprehensive understanding of differences in contribution, patterns of technology adoption, and the contextual support influencing female teachers' educational technology performance.

Figure 6

Digital Tools, AI, and Informal Learning in Women Teachers' Technological Effectiveness



The findings indicate that Kot Addu Tehsil recorded the highest overall contribution, with a significant dominance of female teachers in the effective use of educational technology. In contrast, Jatoi Tehsil demonstrated a relatively low level of contribution, particularly among female teachers, suggesting limitations in technological access or institutional support. Overall, variations across tehsils confirm that women teachers' technological effectiveness is influenced by a combination of digital factors, AI utilization, informal learning, and institutional as well as regional contexts.

Table 1

Teachers' Digital Competencies, AI Usage, and Informal Digital Learning

Statement	Strongly Agree (SS)	Agree (S)	Disagree (TS)	Strongly Disagree (STA)
I am confident in using basic digital tools such as MS Word, Excel, and PowerPoint.	SS	S	TS	STS
I can effectively integrate multimedia (audio, video, images) into my teaching.	19	80	3	4
I use online resources (YouTube, digital libraries, educational websites) to prepare lessons.	16	72	18	0
I understand how AI can personalize learning for different student needs.	9	58	37	2
I feel confident in evaluating the accuracy and bias of AI-generated content.	SS	S	TS	STS
I use AI tools (like ChatGPT, automatic grading tools, or adaptive learning platforms) in my teaching.	7	61	34	4
I have received training or guidance on how to use AI tools in education.	22	79	5	0
AI tools help me manage classroom activities more effectively.	14	85	7	0
I regularly learn new teaching techniques through online platforms (e.g., YouTube, blogs, webinars).	S4	S	TS	STS
I discuss educational technology with peers or online communities to improve my practice.	13	72	20	1
I can independently design and deliver lessons using digital platforms.	14	58	31	3
I can adapt digital content based on student needs and classroom context.	12	61	28	5

The verification team evaluated the study outcomes using data collected from 450 participants. A total of nine observation items representing digital competencies (X1), AI usage (X2), and women teachers' effectiveness (Y) were subjected to validity testing. These items were designed to assess the level of digital confidence, AI literacy, and technology integration among teachers in Islamic secondary schools. The results demonstrate strong statistical validity, as the sample size exceeded the r-table threshold at the 0.05 significance level. All items achieved Pearson correlation values above the minimum accepted score of 0.1891, confirming their validity. The validated statements reflect teachers' abilities to resolve minor technical issues, confidently use digital platforms, integrate digital resources to enhance student learning, and adapt to new teaching technologies. Overall, the validation process confirms the reliability of the measurement instruments used in this study.

The research instruments demonstrate strong validity and reliability, as indicated by Cronbach's alpha values that meet or exceed the commonly accepted threshold of 0.70. The digital competencies scale achieved a high reliability score of 0.873, while the informal digital learning self-efficacy scale recorded a reliability coefficient of 0.883. In addition, the trust in AI usage in education scale showed excellent reliability, with Cronbach's alpha values of 0.959

and 0.917 across related measures. Overall, all variables exhibited strong internal consistency, confirming the dependability of the measurement instruments.

Normality was assessed using skewness and kurtosis statistics. The skewness values for trust in AI and digital competencies were 0.438 and 0.455, respectively, while informal digital learning self-efficacy showed values of 0.132 and 0.350. These results, which are close to zero, indicate that the data follow a normal distribution.

Heteroscedasticity was examined using the Glejser test, with Abs_RES as the dependent variable. The results revealed significance values of 0.151 for AI usage (X2), 0.826 for digital competencies (X1), and 0.077 for women teachers' effectiveness (X3), all exceeding the 0.05 threshold. This confirms the absence of heteroscedasticity in the regression model. Furthermore, collinearity diagnostics indicated that multicollinearity did not adversely affect the analysis, supporting the robustness of the regression results.

Table 2
Descriptive Statistics

Variable	N	Range	Min	Max	Mean	Std. Deviation	Variance
Digital Competency Tools (X1)	440	5	3	9	6.22	1.470	2.159
AI Usage (X2)	440	8	3	10	6.08	1.455	2.120
Informal Digital Learning (Y)	440	8	3	11	6.57	1.877	3.519
Women Teachers' Effectiveness (X3)	440	7	3	10	6.33	1.677	3.420
Valid N (listwise)	440						

Based on Table 6, a total of 440 women teachers participated in this study by providing valid responses. The digital competency (computer self-efficacy) scale ranged from a score of 3, indicating a low level of use, to 9, representing an advanced level of use. The analysis shows that women teachers' responses covered the entire scale range, with a mean score of 6.22 and a standard deviation of 1.470. This finding indicates considerable variation in the digital competency levels of women teachers. Furthermore, the AI usage variable ranged from 3 to 10, with a mean value of 6.08 and a standard deviation of 1.455. The relatively large standard deviation in relation to the mean suggests a wide dispersion of data, reflecting differences in the level of AI utilization among women teachers.

The informal digital learning variable showed scores ranging from 3 to 11, with a mean of 6.57 and a standard deviation of 1.877. This indicates a fairly high level of engagement accompanied by substantial variation in responses across participants. Meanwhile, women teachers' effectiveness ranged from 3 to 10, with an average score of 6.33 and a standard deviation of 1.677. Overall, these findings demonstrate diversity in digital competencies, AI usage, informal digital learning, and teaching effectiveness among women teachers, reflectin.

Table 3
Regression Coefficients of the Model

Variable	B	Std. Error	Beta	t	Sig.
(Constant)	—	—	—	—	—
Digital Competency Skills (X1)	1.539	0.547	—	2.949	0.003
AI Usage (X2)	0.657	0.335	0.468	1.868	0.065
Informal Digital Learning	—	—	—	—	—
Women Teachers' Effectiveness (Y)	0.716	0.162	0.678	4.123	0.000

The regression analysis shows that women teachers' digital competencies significantly enhance teaching effectiveness (p = 0.003), supporting H1. Informal digital learning also has a strong positive effect (p = 0.000), supporting H3. In contrast, AI usage shows a weaker, non-significant relationship with effectiveness (p = 0.065), leading to H2 being rejected. These

findings highlight that while digital skills and informal learning are critical for improving women teachers' performance in Islamic secondary schools in Kot Addu, AI integration alone does not yet significantly influence effectiveness. The results suggest the need for professional development, institutional support, and pedagogical strategies to optimize AI's role in teaching, emphasizing the combined importance of digital competencies and informal learning in enhancing educational outcomes.

Discussion

The use of digital technology and AI on female teachers' performance

The findings indicate that the use of digital tools and AI by female teachers varies significantly across regions. The highest contribution was recorded in Khan Garh at 25.83%, followed by Kot Addu with 19.62% task implementation and 20.94% task completion. In contrast, Mailsi (14.09% implementation; 8.76% completion) and Nawan Kot (17.44% implementation; 15.9% completion) showed lower achievement levels. Conceptually, the effectiveness of technology use is directly influenced by individual digital competence, while access to technology and institutional support function as mediating factors. Regional context acts as a moderator, explaining why female teachers in certain areas are able to contribute more significantly despite operating within a relatively uniform education system.

These findings align with Luo and Liu (2025), who emphasize the role of access and experience in shaping teachers' digital readiness, as well as Li and Xu (2024), who highlight the importance of institutional support. However, the novelty of this study lies in its empirical evidence that female teachers' contributions are not homogeneous across regions. For instance, the high contributions in Khan Garh (25.83%) and Kot Addu (approximately 20%) demonstrate how strong local support can enhance the role of female teachers, whereas the lower outcomes in Mailsi indicate structural barriers. The arguments of Gandara and Laesecke (2022) regarding gender sensitivity and the findings of Charania et al. (2024) on professional development are extended by showing that variations in female teachers' performance are also strongly shaped by spatial context and the distribution of technological resources.

Within the context of Islamic secondary schools in the study areas, differences in the percentage of female teachers' contributions reflect the influence of social norms, gender-based role distribution, and the availability of digital infrastructure. The relatively higher performance in Nawan Kot compared to Mailsi shows that although task implementation reached 17.44%, the level of task completion (15.9%) remains influenced by institutional support. These findings support Khalid et al. (2018), who argue that educator performance quality is closely linked to the work environment and supporting resources. In line with Kholid et al. (2023), better digital literacy enables faster adaptation to technology, suggesting that variations in female teachers' contribution percentages can be understood as the result of interactions between individual capacity and local socio-technological contexts.

Distribution of digital competencies and the role of female teachers in school learning

Based on the findings, this study reveals the existence of gender-based differences in the use of digital competence for educational purposes across different tehsils. Conceptually, the results indicate that teachers' digital competence is not evenly distributed between female and male teachers, both in terms of teaching workload and the level of technological engagement. In Kot Addu and Khan Garh, female teachers demonstrate higher contributions, whereas in Mailsi and Nawan Kot, teaching roles tend to be dominated by male teachers. This pattern suggests that the effectiveness of educational technology use is not determined by gender alone, but is also shaped by digital readiness, access to resources, and institutional

support that structure teachers' roles and participation in each region (BenYishay et al., 2020; Tomczyk, 2024).

The analysis further shows the presence of an indirect relationship between gender and the effectiveness of technology use, mediated by access to technology, self-confidence, and opportunities for professional development. Female teachers' participation in informal digital learning functions as a key mediator that strengthens competence and teaching effectiveness, particularly in Kot Addu and Nawan Kot. In contrast, the low level of female teachers' engagement in Mailsi indicates a moderating effect of regional context, where limited infrastructure and weak institutional support reduce the influence of individual competence on teaching performance (Mayantao & Tantiado, 2024). Thus, gender differences in technology use emerge from a complex interaction between individual and structural factors (Alieto et al., 2024).

Drawing on previous literature, these findings both reinforce and extend earlier studies that emphasize the importance of gender alignment in teaching roles and pedagogical relationships (Roorda & Jak, 2024), as well as the structural constraints faced by female teachers in certain educational settings (Abdel-Salam et al., 2021). However, this study offers novelty by demonstrating that such gaps are not homogeneous, but are highly dependent on the social and institutional context of each tehsil. In the context of Islamic secondary schools in the study areas, social norms, gender-based role distribution, and access to technology training shape distinct patterns of digital adoption among female teachers. In line with Hennessy et al. (2022), these findings highlight the need for gender-sensitive policy interventions, while Ragnedda et al. (2022) and Babirye et al. (2022) help explain how persistent digital inequalities may further reinforce educational disparities if not addressed systematically.

The influence of digital competence, AI, and informal learning on female teachers

The findings indicate that the effectiveness of female teachers in using educational technology is more strongly determined by basic digital competence and informal digital learning than by the adoption of AI. The higher contribution in Kot Addu (22.05%) compared to Jatoi (4.22%) reflects the role of a supportive learning ecosystem. Conceptually, digital competence has a direct effect on teaching effectiveness (M = 6.22), while informal digital learning functions as a reinforcing mechanism (M = 6.57) that accelerates technological adaptation. This underscores the importance of self-directed learning and continuous experience in empowering female teachers.

These findings extend previous studies by showing that AI use has not yet had a significant impact on female teachers' effectiveness ($p = 0.065$), even though its level of use is moderate (M = 6.08). This supports the argument of Instefjord and Munthe (2017) that digital competence develops through pedagogical reflection and contextual practice rather than through the mere adoption of new technologies. In line with Cattaneo et al. (2022), the results highlight the interaction between individual capacity and institutional support. Analyses by Ning et al. (2024) and Salih et al. (2025) further explain the limited impact of AI, which remains largely experimental. The novelty of this study lies in its strong emphasis on the role of informal digital learning in empowering female teachers.

Within the social and institutional context of the study area, gender-based contribution gaps such as the dominance of male teachers in Shah Sultan (17.77%) compared to female teachers (6.67%) indicate that technological effectiveness is not determined solely by access to devices, but also by role distribution, professional confidence, and institutional support. These findings reveal a moderating effect of regional context on the relationship between

technology and teacher effectiveness. As analyzed by Koehorst et al. (2021) and Inayati et al. (2025), gender-sensitive policies and training are crucial for strengthening female teachers' digital readiness. Thus, strengthening basic digital competence and informal digital learning remains the most realistic and contextual strategy, while AI integration requires more targeted and sustainable institutional approaches.

Both theoretically and practically, this study enriches the field of digital education and gender studies by asserting that the relationship between technology and female teachers' effectiveness is not linear. The findings demonstrate that basic digital competence and informal digital learning serve as key mechanisms bridging technology adoption and pedagogical performance, while regional and institutional contexts act as moderating factors. These results challenge technological determinism that assumes AI automatically enhances learning effectiveness, emphasizing instead the importance of experience, pedagogical reflection, and structural support. Practically, the study recommends policies that prioritize strengthening basic digital competence, facilitating informal digital learning, and providing contextual, gender-sensitive continuous training. AI integration should be implemented gradually through mentoring, clear regulations, and curriculum development to ensure a tangible impact on learning quality.

This study has several limitations that should be considered. First, the quantitative research design limits a deeper exploration of female teachers' subjective experiences in adopting technology. Second, the focus on Islamic secondary schools in specific regions restricts the generalizability of the findings to other educational contexts. Third, AI use was measured at an early stage of adoption, so long-term impacts could not be evaluated. Therefore, future research is recommended to employ mixed or qualitative approaches to explore pedagogical dynamics in greater depth. Further studies should also investigate longitudinal AI integration, conduct cross-cultural comparisons, and examine the roles of school leadership and public policy in strengthening the digital empowerment of female teachers.

CONCLUSION

This study concludes that the effectiveness of female teachers in utilizing educational technology in Islamic secondary schools is determined more by basic digital competencies and informal digital learning than by the adoption of AI. Differences in contribution between regions, such as the dominance of female teachers in Kot Addu and the low contribution in Jatoi and Shah Sultan, show the strong influence of institutional context, access to technology, and social support. Digital competence plays a direct role in teaching effectiveness, while informal digital learning serves as an enhancer that accelerates pedagogical adaptation. Conversely, AI has not had a significant impact because it has not been pedagogically integrated and supported by adequate policies. Thus, the effectiveness of female teachers' technology is the result of a complex interaction between individual capacity, the learning ecosystem, and local institutional structures.

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AUTHOR CONTRIBUTION STATEMENT

Muhammad Kashif Majeed: Conceptualization; Formal Analysis; Investigation; Methodology; Writing Original Draft; Writing Review & Editing. **Tunku Badariah Ahmad**: Conceptualization; Methodology; Project Administration; Resources. **Aizat Bin Shamsuddin**: Conceptualization; Visualization and Writing Review & Editing.

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