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Bridging the AI–STEM Divide in School Education: An Analysis of Equity, Gender, and Access Among Secondary School Teachers in Multan, Pakistan.

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ABSTRACT

The widespread adoption of Artificial Intelligence (AI) in education has exacerbated existing inequities in the fields of science, technology, engineering and mathematics (STEM) learning, especially in marginalized areas of the Global South. The advent of Artificial Intelligence (AI) in the education sector has deepened existing inequities in science, technology, engineering and mathematics (STEM) learning, particularly in under-resourced parts of the Global South. The paper explores the gender, infrastructural, and institutional challenges faced by secondary school teachers in Multan, Pakistan, as they try to incorporate AI tools into STEM education. The research is based on a cross-sectional survey involving sample of 200 teachers from urban, peri-urban and rural public secondary schools, and addresses the Digital Divide Theory, Technology Acceptance Model (TAM) and a gender-equity capability lens. Findings indicate that there are statistically significant gender differences in knowledge, self-efficacy and behavioral intention regarding AI as well as location-based differences in access to devices and connectivity. Female teachers in rural areas reported consistently lower access and self-efficacy and higher cultural barriers. The top-ranked barriers were not receiving adequate training, unreliable internet and electricity, and not having enough devices. The results highlight the importance of intentional equity-focused policy, professional learning, and infrastructure support to ensure equity rather than exacerbating the STEM divide in the use of AI.

Keywords: *Artificial Intelligence, STEM Education, Gender Equity, Digital Divide, Teacher Self-Efficacy, Multan, Pakistan, Underserved Regions, Technology Acceptance*

1. Introduction

In the STEM fields, artificial intelligence is rapidly transforming the potential of teaching and learning. Adaptive tutoring systems, generative AI tools for lesson design, automated formative assessment, and data-driven learning analytics have the potential to personalize learning, ease teacher workload, and make high-quality learning resources more accessible to learners (UNESCO, 2023; Luckin et al., 2022). However, the same structural factors that have driven the gender digital and STEM divide in the past could lead to further disproportionate impacts on education through technology adoption (UNESCO, 2025).

The situation of Pakistan is in particular dire as the country is paying attention to digital transformation and there are efforts to build capacity on digital gender issues (Ministry of Information Technology and Telecommunication & UN Women, 2026), the education system is still plagued by high levels of urban–rural disparity, gender-based enrolments and subject choice, and persistent under-resourcing of public secondary schools (Asian Development Bank, 2025; Higher Education Commission, 2023). Non-functional computer laboratories in girls' secondary schools are prevailing in the districts including Multan and the participation of female workforce in ICT and AI related occupations is one of the lowest in the world (APP, 2026; UNESCO Institute for Statistics, 2026).

Teachers are at the nexus of policy goals and classroom conditions. Whether an AI tool is a tool for equity or a tool for exclusion depends on how they access these devices, what they know about AI, how they use it, and their pedagogical self-efficacy, as well as their ability to navigate the expectations of culture. Moderate levels of generative-AI use have been reported in Pakistan, with some areas such as Multan exhibiting relatively higher levels of adoption, but still notable gender and geographic disparities (Majeed & Ahmad., 2025). Where there is under-researched overlap, however, is in the systematic, theory-driven analysis of the intersections between equity, gender, and access in the context of STEM teachers in an underserved secondary-school setting.

This study fills that gap by conducting a survey of 200 secondary school teachers of Multan District. It is based on three research questions:

RQ1. To what extent are secondary STEM teachers in urban, peri-urban and rural schools of Multan using AI tools and digital infrastructure and what are the differences between the access level of males and females?

RQ2. Are there any gender, location or experience differences in teachers' AI knowledge, pedagogical self-efficacy and future intention to use AI in STEM teaching?

RQ3. What are the key impediments to equitable integration of AI with STEM, and how do these barriers engage with gender and contextual factors?

The study provides empirical insights from a secondary-education system in the Global-South to the international literature on AI equity, and provides practical suggestions for policy and practice that seeks to close and not widen the AI–STEM divide.

2. Literature Review

2.1 AI in Education and the Promise of Equity

Advocates of AI in learning claim these dynamic systems and generative tools can help to level the playing field by making high-quality instructional support more accessible, especially in areas with limited resources and resources and where STEM expertise is scarce (Holmes et al., 2022; Luckin, 2024). Low-bandwidth or offline AI applications have been tested in a number of LMICs, and have shown positive results on student engagement and conceptual understanding (Abdullah & Ahmed, 2025). Meanwhile, critical voices remind us that AI systems, which are largely based on data from the Global-North and are not designed with consideration of local infrastructure and social relations, can reinforce or perpetuate existing exclusions (Selwyn, 2022; Williamson & Eynon, 2020; UNESCO, 2025).

Access to devices and reliable connectivity, relevant professional development, and perceived usefulness are all consistently found in empirical studies as key factors that enable teacher adoption (Tang & Zhong, 2026; Daryaseh & Mersin, 2025). Recent studies in Pakistan suggest that while some teachers are already using ChatGPT and similar AI tools to plan their lessons, the majority are not formally trained or supported in using these tools. There is regular concern for equity issues concerns that are shared by teachers about students who are unable to access personal devices or home internet, which further disenables them.

2.2 Student's Attitudes towards School Education and Learning in the Digital Age

The divide in gender representation and digital skills in STEM persists in South Asia. Women are about one-third of STEM students in the region and a significantly smaller proportion of research authorship and professional roles in AI (UNESCO, 2026). Female ICT graduates join the workforce at a much lower rate than males in Pakistan because of mobility, family expectations and marriage (APP, 2026). Girls' enrolment in science tracks is lower and less functional science laboratories and computer facilities are available in girls' schools at secondary level (Asian Development Bank, 2025).

This is not something that was left from the previous access inequities, but rather a production of curriculum design, teacher expectations, parental attitudes, and the design of technologies themselves (Starr & Simpkins, 2021; Sosale et al., 2023). If these environments are created without gender-inclusive pedagogy or support, the adoption of AI tools can be seen as a new opportunity for differential opportunity. The research on teacher AI acceptance has started to reveal gender moderation effects on the major TAM pathways, with mixed results across contexts (Venkatesh et al., 2023; Acquah, et al., 2026).

2.3 Teachers as Mediators of AI Equity

Educational technology (ET) has a profound impact on educational equity outcomes through the mediation of teachers' beliefs, self-efficacy and working conditions (Ertmer, 1999; Bandura, 1997). The research based on the Technology Acceptance Model and its extensions have all shown the positive relationship between perceived usefulness and ease of use with intention to use, and the perceived usefulness and ease of use are further influenced by prior experience, institutional support, and social norms (Davis, 1989; Tang & Zhong, 2026; Venkatesh et al., 2003). While mobile-first, context-sensitive training has proved to be promising for building teacher competence in AI in low-resource Pakistani schools (ResearchGate, 2025), there is limited evidence to date that demonstrates how the training relates to gender-differentiated self-efficacy and intention among Pakistani secondary STEM teachers.

This study, therefore, places the teacher educators of Multan in the center of three literatures AI-in-education equity, gendered STEM participation, and teacher technology acceptance to provide a more integrated understanding of the barriers and enablers of equitable AI–STEM practice.

3 Theoretical Framework

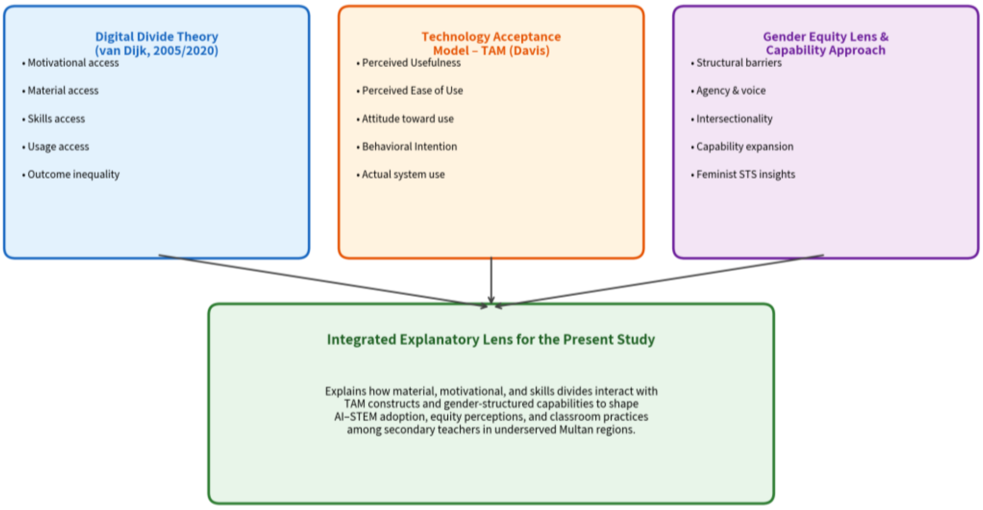
A comprehensive theoretical framework is adopted that combines elements of the Digital Divide theory (van Dijk, 2005, 2020), the Technology Acceptance Model (Davis, 1989; Venkatesh et al., 2003), and a gender-equity capability perspective, based on Sen's capability approach and feminist science and technology studies (Sen, 1999; Wajcman, 2004; UNESCO, 2025).

The Digital Divide Theory goes from a binary of "haves" and "have-nots" to successive levels of access: motivational, material, skills, and usage access, reaching to differential outcomes. While in the Multan context, access to materials (devices, electricity, internet) continues to be a first-order barrier, skills and motivational access (which is influenced by gender norms and previous educational opportunities) have also proven to be significant.

The proximal psychological mechanisms between access to adoption are provided by TAM, which includes perceived usefulness (PU), perceived ease of use (PEOU), attitude, and behavioral intention. These constructs are not gender neutral; previous experience, social influence, and anxiety are likely to be systematically different for male and female teachers and thus can moderate the path of TAM.

The gender-equity and capability lens helps focus on structural and cultural conditions that can widen or narrow teachers' actual scope of freedoms to transform resources into valued functioning, in this instance, the functioning of confident, pedagogically effective AI–STEM practice. Intersectionality is a reminder that location (urban/rural), school type and experience intersect with gender.

Integrated Theoretical Framework

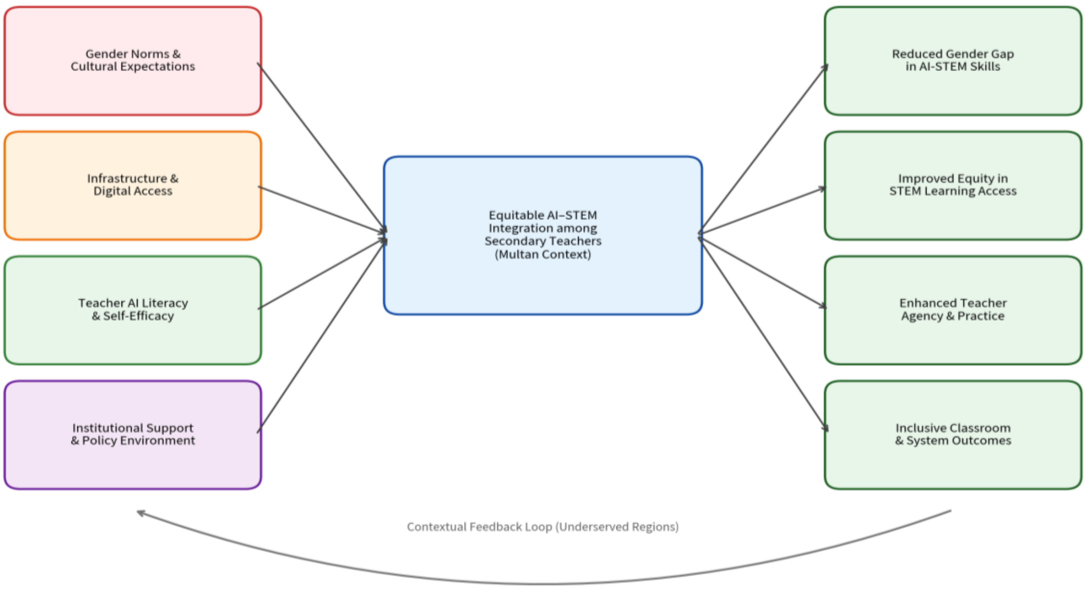


These lenses together create a sense of the material and the skills being gendered and spatially patterned; a sense of the influence of PU and PEOU on the relationship between access and intention; and a sense of the role of cultural-gender norms as a direct obstacle and as a moderator of self-efficacy and intention.

4 Conceptual Framework

The conceptual framework of the study draws from the theoretical integration presented above and proposes that the impact of four sets of contextual factors on the potential for equitable integration of AI–STEM instruction in secondary schools all individually and collectively contribute: (1) gender norms and cultural expectations, (2) infrastructure and digital access, (3) teacher AI literacy and self-efficacy, and (4) institutional support and policy environment. This integration will be expected to yield four interconnected products reduced gender gaps in AI-STEM skills, improved equity in access to STEM learning products for students, enhanced teacher agency and practice, and more inclusive classroom and system level outcomes. Changing conditions that affect future adoption are a direct result of experiences of success or failure in Multan's underserved contexts; a contextual feedback loop is acknowledged.

Conceptual Framework of the Study



5 Methodology

5.1 Research Design

To measure the prevalence at a single point in time (January–March 2026), a cross-sectional survey design was used. The design is suitable for mapping patterns of inequality and for testing hypothesized relationships between the TAM constructs and the equity-related covariates.

5.2 Setting and Participants

The study was carried out in Multan district, Punjab Province, Pakistan, where both urban and large peri-urban and rural catchment areas are present and is one of the areas identified in recent provincial data where girls' secondary schools suffer from a significant shortfall in ICT and science-laboratory provision (Asian Development Bank, 2025). The target population consisted of teachers of science, mathematics and computer science and related STEM subjects of public secondary schools.

Stratified sampling was carried out to obtain a representative sample across three location strata (urban, peri-urban and rural), as well as by gender. First, a simple random sample of schools was used in each stratum from the district education lists and then teachers were invited to participate from the schools. Of the 200 teachers who were sent out, 112 were male and 88 were female, with an effective response rate of 78% following the discarding of incomplete questionnaires. A priori sample size was calculated using the medium gender difference (Cohen's $d \approx 0.4$) and to keep $\alpha = .05$ there were approximately 80% chances of detecting medium gender differences.

5.3 Instrumentation

A structured questionnaire was designed in English and Urdu, which included the following:

Demographic and Contextual items (gender, age, teaching experience, subject, school location, school type).

- Access and infrastructure of A.I. (device ownership, functionality of computer lab, electricity reliability, internet at school and home).
- AI knowledge scale and self-efficacy scale developed from the latest AI-competence scales (Acquah et al., 2026; Daryaseh & Mersin, 2025), which contained knowledge, pedagogical use, ethical awareness, and STEM integration (5-point Likert).
- Perceived usefulness, perceived ease of use and behavioral intention (Davis, 1989; Venkatesh et al., 2003) as TAM-derived items.
- Barrier inventory based on previous studies conducted in Pakistan and with 5-point importance rating.

The pilot testing, with 25 teachers outside of the main sample, resulted in Cronbach's α coefficients from .81 to .91 for multi-item scales and high degrees of clarity.

5.4 Data Collection and Ethics

Data were gathered using paper questionnaires which were sent out through school focal persons and an equivalent online questionnaire wherever possible. The participation was voluntary, informed consent was obtained, anonymity was maintained and ethical clearance was obtained from the relevant research ethics committee of the University. The results do not contain any identifiers of individual schools or teachers.

5.5 Analytical Approach

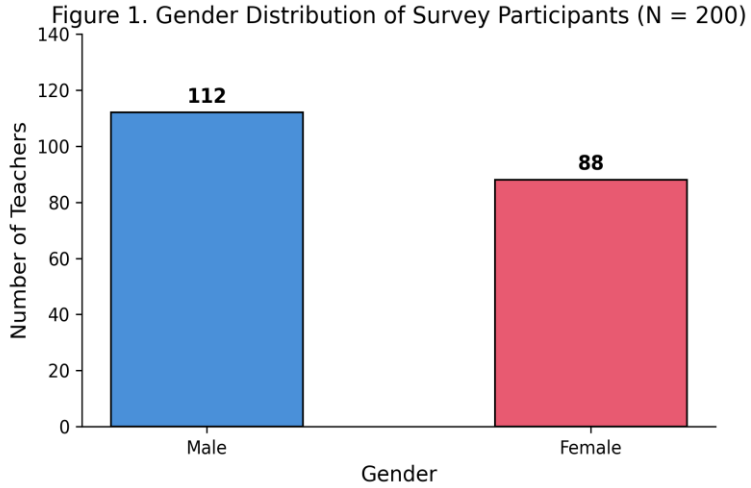
All variables were summarized using descriptive statistics (mean, standard deviations, frequencies and percentages). Gender, location and experience were compared using independent-samples t-tests and one-way ANOVAs. Chi-square tests were used to determine associations between the categorical access variables and gender/location. Multiple linear regression models were used to test the prediction of behavioral intention, using access, self-efficacy, PU, PEOU and demographic covariates. Effect sizes (Cohen's d, η^2) reported with the significance test. Data were analysed in R 4.3 and SPSS 29. A level of statistical significance was defined as $\alpha = .05$ (two-tailed).

6 Results

6.1 Sample Characteristics

Among all respondents, there were 200 people with 56% identifying as male and 44% identifying as female. There was a sample of 42% urban, 31% peri-urban and 27% rural. Teaching experience was distributed as follows: 0–5 years (22%), 6–10 years (29%), 11–15 years (27%), and 16+ years (22%). Most were science or maths teachers (68%), and the rest were computer science or integrated STEM teachers.

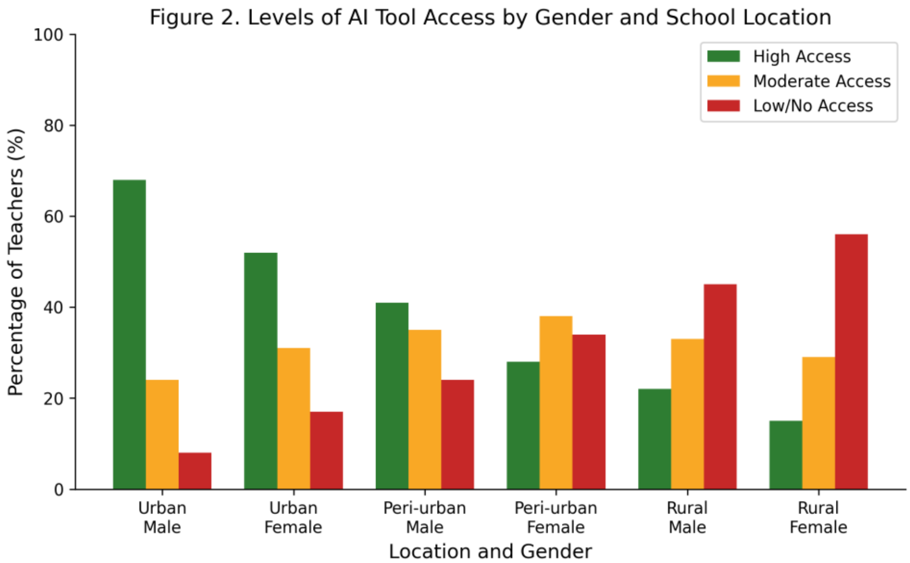
Figure 1. Gender Distribution of Survey Participants (N = 200)



6.2 Access to AI Tools and Digital Infrastructure

Overall, 31% of teachers said that they had high access to AI-enabled devices and reliable internet connections in school. Access was highly sexed, and regionally structured. Male teachers in cities had the highest level of high access (68%) and female teachers in rural areas the lowest (15%). This trend of increasing proportion of teachers with low/none access from urban to rural areas was observed, with consistently higher access levels among male teachers in both urban and rural areas.

Figure 2. Levels of AI Tool Access by Gender and School Location



The results of chi-square tests were significant for both genders, χ^2 (2) = 18.74, p < .001, and location, χ^2 (4) = 41.26, p < .001. Less than 40% of the rural teachers and 28% of the teachers in the girls' schools reported that the electricity was "usually available" and the functional computer laboratories were "usually available".

Table 1

Descriptive Statistics for Key Continuous Variables by Gender

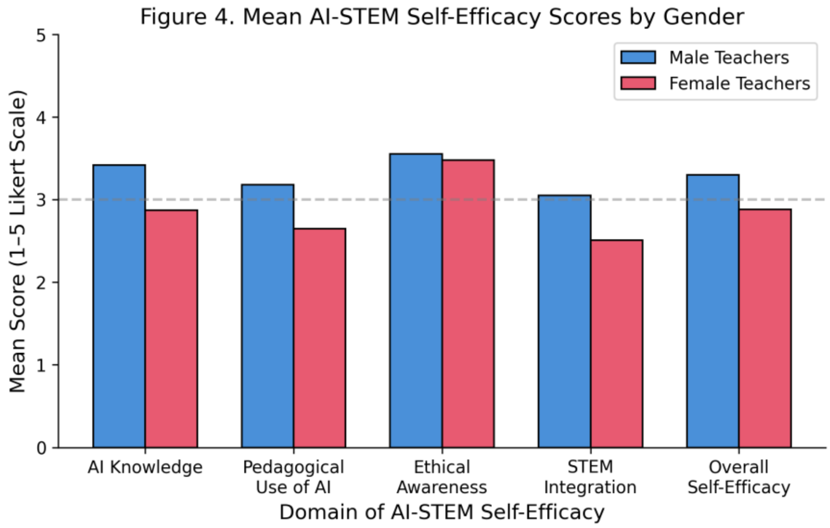
Variable	Male M (SD)	Female M (SD)	T	p / d
AI Knowledge	3.42 (0.78)	2.87 (0.81)	4.89	<.001 / 0.70
Pedagogical Self-Efficacy	3.18 (0.85)	2.65 (0.79)	4.51	<.001 / 0.65
Ethical Awareness	3.55 (0.72)	3.48 (0.69)	0.70	.485 / 0.10
STEM Integration SE	3.05 (0.88)	2.51 (0.84)	4.38	<.001 / 0.63
Overall Self-Efficacy	3.30 (0.71)	2.88 (0.68)	4.22	<.001 / 0.61
Perceived Usefulness	3.78 (0.69)	3.52 (0.74)	2.55	.012 / 0.37
Perceived Ease of Use	3.41 (0.81)	2.95 (0.86)	3.89	<.001 / 0.56
Behavioral Intention	3.55 (0.76)	3.12 (0.82)	3.81	<.001 / 0.55

Note. N = 200 (Male n = 112, Female n = 88). SE = self-efficacy. Effect size d = Cohen's d. All scales range 1–5.

6.3 Self-Efficacy and TAM Constructs

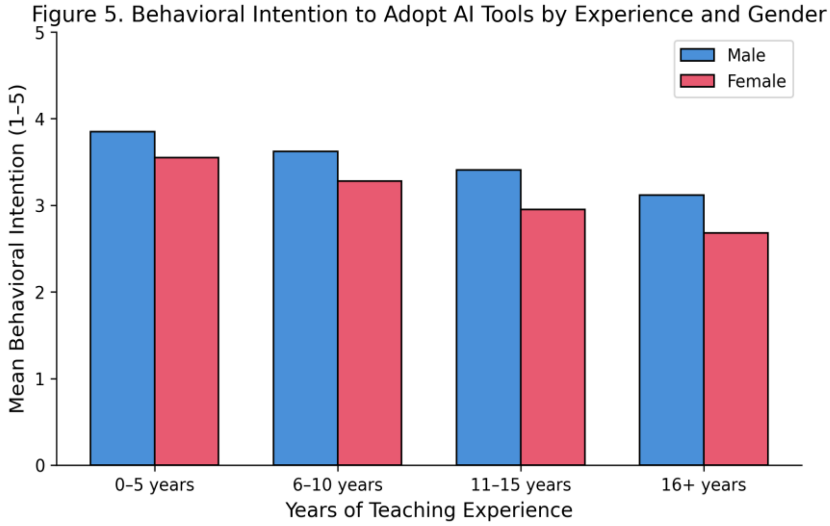
Male teachers had significantly higher scores on all four sub-scales of the AI knowledge, pedagogical self-efficacy, STEM-integration self-efficacy, perceived ease of use, and behavioral intention (all p-values < .001, medium to large effect sizes) than female teachers. There was no significant difference between males and females with regard to ethical awareness. These patterns are depicted in the figure 4.

Figure 4. Mean AI–STEM Self-Efficacy Scores by Gender



Behavioral intention also decreased as teaching experience increased, and the gender differences were evident throughout the experience bands (Figure 5). One-way ANOVA indicated a significant main effect of experience on intention, F (3, 196) = 6.84, p < .001, η^2 = .095.

Figure 5. Behavioral Intention to Adopt AI Tools by Experience and Gender



6.4 Ranked Barriers

Seven barriers to the use of ICT in teaching and learning were rated by the teachers using a 5-point scale. Poorly-trained staff (M = 4.62) and unreliable electricity/internet (M = 4.51) were the most highly rated responses, as was insufficient devices (M = 4.38). The fourth place was taken by cultural and gender norms (M = 4.15), which received higher scores from female teachers and from rural teachers. This was followed by curriculum rigidness, cost and a lack of policy support.

Figure 3. Ranked Barriers to AI Integration in STEM Teaching

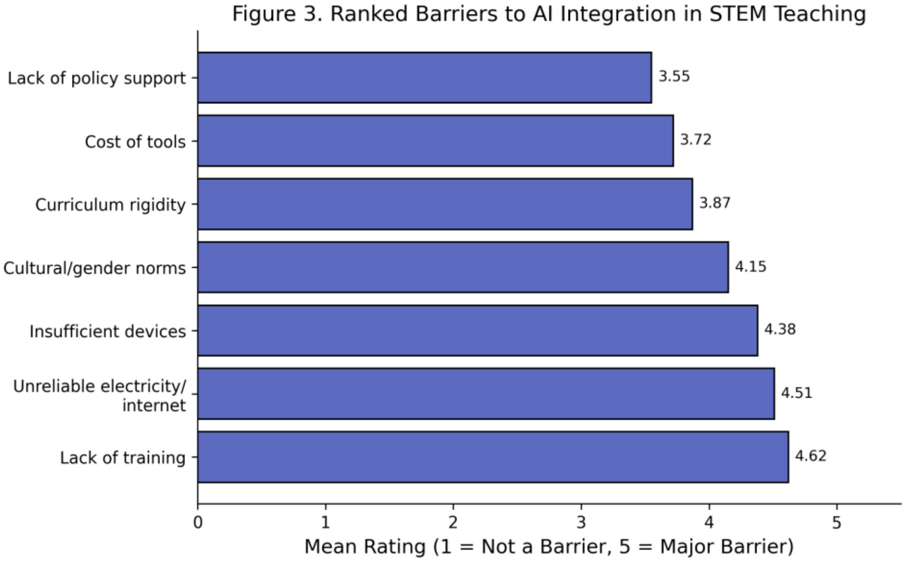


Table 2

Multiple Regression Predicting Behavioral Intention to Adopt AI

Predictor	B	SE	β	P
Constant	0.42	0.28	—	.136
Gender (Female = 1)	−0.18	0.09	−0.11	.048
Location (Rural = 1)	−0.21	0.10	−0.13	.032
AI Access Index	0.19	0.06	0.18	.002
Overall Self-Efficacy	0.31	0.07	0.29	<.001

Perceived Usefulness	0.27	0.06	0.25	<.001
Perceived Ease of Use	0.22	0.06	0.21	<.001
R^2 / Adjusted R^2	0.48 / 0.46			

Note. N = 200. Dependent variable = Behavioral Intention (1–5). Model F(6, 193) = 29.71, p < .001.

6.5 Regression Results

The multiple regression model explained 48% of the variance in behavioral intention (adjusted R^2 = .46). All these factors consistently and positively predicted the endorsement of AI, with self-efficacy (β = .29), perceived usefulness (β = .25), perceived ease of use (β = .21), AI access (β = .18), and the rural location (β = −.13) being significant.The significant factors were in the expected direction: all positively predicted the endorsement of AI: self-efficacy (β = .29), perceived usefulness (β = .25), perceived ease of use (β = .21), AI access (β = .18), and the rural location (β = −.13). Results support an extended TAM model in which access and gender mediate their effects on self-efficacy and ease-of-use perceptions.

7 Discussion

The purpose of this study was to draw a profile of the divide between AI and STEM of the secondary teachers in Multan and understand the nature and nature of the access, self-efficacy, and intention of teachers in relation to this divide. Three main results are identified.

First, however, there are issues of access to materials and skills, issues that are extensively gendered and spatially stratified. Teachers in the rural areas are in the most disadvantaged position on all the access indicators. The patterns are in line with the multi-level digital-divide framework of van Dijk and corroborate earlier findings of ICT problems in girls' schools in Multan (Asian Development Bank, 2025).

Second, there is a medium-to-large gender gap, except for the construct of ethical awareness, for constructs of self-efficacy and TAM. It is significant that there is no difference in ethical awareness, implying that female teachers are similarly aware of the normative aspects of AI, despite their less confident technical and pedagogical knowledge. Experience effects suggest that more recent teachers who may have been exposed to digital tools more recently in pre-service education, tend to have greater intention, but that this does not reduce the gender gap between cohorts.

Third, training and infrastructure were ranked first and more salient for women and rural respondents, but were not rated as highly as cultural norms were. That's a first order (external) and second order (internal/belief) distinction as per Ertmer, and also, it's seen that second order barriers still play a significant role in a gendered context.

The results presented a consistent picture in favor of the integrated theoretical model, with the levels of digital-divide constraining the formation of PU and PEOU, while self-efficacy being one of the main proximal determinants of intention and gender, respectively, being a structural constraint on access and a moderator of the psychological pathways. If left unchecked, the adoption of AI tools has the potential to exacerbate digital and STEM inequities.

7.1 Implications for policy and practice

There are several implications for action that are suggested. First, infrastructure should focus on the functional laboratories, stable power supply and bandwidth- or offline-compatible AI applications in rural and girls' schools. Second, professional development should be gender-responsive, mobile-first, wherever feasible, and technical skills and pedagogical self-efficacy. Third, a national and provincial AI-in-education strategy should include clear equitable metrics and gender disaggregated monitoring. Fourth, there is a need to update pre-service teacher education curriculum to incorporate AI literacy and equity-oriented pedagogy.

7.2 Limitations and possible further study

A cross-sectional design is not suitable for making causal inferences. Self-report measures can have social-desirability and recall biases. The Multan concentration restricts generalizability to the other provinces where linguistic, infrastructural, and cultural characteristics diverge from those of Multan. Going forward, longer-term and mixed methods should be adopted, along with student outcome data, and the effectiveness of targeted intervention for professional development should be tested.

8 Conclusion

Addressing the AI–STEM divide in remote parts of Pakistan can't be solved by simply providing tools. It requires a simultaneous consideration of access to materials, skills and self-efficacy, institutional support, and the social relations between people that will determine who can translate the technological opportunity into the pedagogical practice. The 200 secondary school teachers who were surveyed in Multan make it clear that the problem is large in size, and it is also clear that the policy and practice need to shift in which direction for AI to be used to improve equity and not further entrench inequity. It is similarly a responsibility of high-impact journals and research funders to give priority to rigorous, context-sensitive research in the Global South that can shape inclusive futures for AI in education.

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