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Digital Divide and Artificial Intelligence: Exploring the Role of Infrastructure and Inequality in AI Adoption in Education

Dr. Sumera Imran[1], *Dr. Zahid Ullah[2], Dr. Sara Rafiq[3], *Dr. Abid Khan[4]

1. Assistant Professor, Department of Education, Women Sub Campus Batkhela, University of Malakand, Sumeraimransst@yahoo.com
2. *Study of the U.S. Institutes (SUSI). Institute for Training and Development ITD Amherst, MA. (Corresponding Author), zahidullah0333@gmail.com
3. Assistant Professor, Department of Economics, Women Sub Campus, University of Malakand
4. *University of Malakand, (Corresponding Author), drabidkhan21@gmail.com

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Abstract

The rapid advancement of Artificial Intelligence (AI) has the potential to transform teaching, learning, and school leadership practices. However, unequal access to digital infrastructure and persistent socioeconomic inequalities continue to limit the effective adoption of AI, particularly in public secondary schools in District Mardan, Khyber Pakhtunkhwa, Pakistan. This qualitative study explores how infrastructure gaps and inequality shape AI adoption from the perspectives of teachers and school heads. Data were collected through semi-structured interviews with five public secondary school teachers and five school heads. Thematic analysis revealed key barriers, including inadequate digital infrastructure, limited digital and AI-related skills, and socioeconomic disparities among students, lack of institutional support, and the absence of clear AI-related policies. Findings indicate that without addressing foundational infrastructure and equity issues, AI initiatives risk reinforcing existing educational inequalities. The study highlights the need for context-responsive policies, targeted professional development, and equitable investment in digital infrastructure to ensure inclusive and sustainable AI adoption in public secondary education.

Keywords: Digital Divide, Artificial Intelligence, Infrastructure, Inequality, AI Adoption

Introduction

Artificial Intelligence (AI) is rapidly transforming educational practices worldwide, offering tools for personalized learning, intelligent tutoring systems, automated assessment, and administrative efficiency (Luckin et al., 2016; Holmes et al., 2019). In theory, AI can enhance teaching quality, foster critical thinking, and support individualized learning pathways. However, in many developing regions, public secondary schools face persistent challenges in adopting AI due to infrastructure limitations, socioeconomic inequalities, and lack of institutional support (Selwyn, 2016; UNESCO, 2021). The current study focuses on public secondary schools in District Mardan, Khyber Pakhtunkhwa, Pakistan, where infrastructure gaps, such as limited computer labs, unreliable electricity, and slow internet, directly impact the ability of teachers and school heads to integrate AI in their classrooms. Participant voices from this study indicate that even when resources are available, shared devices, outdated software, and lack of technical support limit meaningful AI engagement. Additionally, inequalities among students, particularly those from low-income families or rural backgrounds, exacerbate digital exclusion, leaving

some students behind in AI-based learning opportunities. This research explores the intersection of infrastructure, inequality, and institutional barriers to understand how these factors collectively shape AI adoption in education. By presenting the perspectives of teachers and school heads, this study provides contextually grounded insights that can inform policy, teacher training, and equitable investment in AI-ready infrastructure.

Problem Statement

While AI technologies are rapidly entering educational discourse, many public secondary schools in District Mardan lack the basic infrastructure and capacity required for effective implementation. In contexts marked by socioeconomic inequality, AI adoption risks widening existing educational gaps rather than reducing them. Limited empirical research exists on how infrastructure limitations and inequality collectively influence AI adoption in public school settings from the perspectives of teachers and school heads.

Theoretical Framework

This study is guided by the Technology Acceptance Model (TAM) (Davis, 1989; Ajzen, 1991) and the concept of the Digital Divide (Selwyn, 2016; UNESCO, 2021). TAM explains technology adoption through perceived usefulness and perceived ease of use, while the digital divide framework highlights structural inequalities in access to technology. Together, these frameworks provide a lens to examine how infrastructural and socioeconomic factors influence stakeholders' acceptance and use of AI in education.

Significance of the Study

This study contributes to the growing body of literature on AI in education by:

1. Providing empirical evidence from public secondary schools in District Mardan
2. Highlighting voices of teachers and school heads
3. Informing policymakers about context-specific barriers
4. Supporting equitable and inclusive AI policy development

Research Questions

1. How do teachers and school heads perceive the role of infrastructure in AI adoption in education?
2. How does socioeconomic inequality influence AI adoption in public secondary schools?
3. What institutional and policy-related barriers affect AI integration in education?

Literature Review

Artificial Intelligence in Education

AI in education promises tailored learning, automated assessment, and real-time feedback (Luckin et al., 2016). However, successful implementation is highly dependent on both technological resources and human capacity. In public schools, AI is often limited to theoretical discussions due to inadequate hardware, lack of internet, and insufficient teacher training (Selwyn, 2016; Holmes et al., 2019).

Digital Infrastructure and Access

The digital divide remains a significant barrier to AI adoption. UNESCO (2021) notes that limited computer labs, low-speed internet, and outdated devices hinder equitable access to digital learning tools. Findings from the study corroborate this: teachers reported frequent electricity outages, shared devices, and non-functional projectors, which prevent consistent AI engagement. School heads highlighted procurement delays, lack of IT support, and insufficient budgets as major infrastructural constraints.

Socioeconomic Inequality

Students' access to AI-based learning is deeply influenced by socioeconomic status (Malik & Bashir, 2020; Khalid et al., 2021). In this study, teachers emphasized that students from low-income families lack devices or internet at home, making continuous AI engagement impossible. Cultural norms further restrict girls' access to technology. These disparities create uneven participation and widen learning gaps, confirming that AI adoption without equity interventions can reinforce existing inequalities.

Institutional and Policy Challenges

Policy support and institutional readiness are crucial for sustainable AI integration (Ajzen, 1991; Selwyn, 2016). Participants reported lack of AI-specific curricula, insufficient teacher training, absence of monitoring mechanisms, and unclear ethical guidelines. School heads described limited autonomy and inconsistent funding as key obstacles. Together, these institutional gaps limit teachers' confidence and ability to implement AI effectively.

Research Gap

Most studies on AI in education focus on higher education or technologically advanced contexts, with limited attention to public secondary schools in developing regions. There is a need for qualitative research exploring the lived experiences of teachers and school heads, particularly in the context of infrastructure constraints and socioeconomic inequality (Holmes et al., 2019; Khalid et al., 2021).

Research Methodology

Research Approach

A qualitative research approach was employed to gain in-depth insights into stakeholders' perceptions and experiences. A multiple-case study design was used, focusing on public secondary schools. The sample consisted of five public secondary school teachers and five school heads in District Mardan. Data were collected through semi-structured interviews. Thematic analysis was conducted following coding, categorization, and theme development.

Findings

RQ_1: Role of Infrastructure in AI Adoption

Teachers' Voices

"*Our computer lab has only five outdated desktops for 60 students, which makes it impossible to implement AI lessons properly. Students often wait in turns, and we cannot teach efficiently." "Even when the internet works, the speed is too slow for AI-based applications. Uploading data or accessing online AI platforms takes ages, frustrating both teachers and students*."

"*Electricity outages disrupt our classes regularly. AI tools that require power cannot be used reliably, which makes lesson planning unpredictable."*

"Many AI applications require updated software, but our computers have old operating systems. As a result, students cannot engage with modern AI tools."

"We try to borrow projectors for demonstrations, but technical support is limited. If the projector malfunctions, the lesson is disrupted." "Smart classrooms are not available in our school, so teaching AI concepts remains theoretical. Students learn about AI in theory but do not experience it practically."

"Wi-Fi is absent in most classrooms, so online AI platforms cannot be used, limiting interactive learning experiences." "Students often share devices during AI exercises. This reduces individual practice and lowers engagement and learning outcomes."

"There is no dedicated IT support in the school to fix hardware or software issues promptly, so teachers spend valuable class time troubleshooting."

"Even if teachers want to implement AI tools, the outdated hardware prevents their usage. Innovative lesson plans often fail due to technological limitations."

"Budget constraints stop us from purchasing AI-compatible devices. Even small investments in technology require approvals that take months."

"Teachers are enthusiastic about AI integration, but infrastructure gaps frustrate them and reduce student engagement, leading to a sense of helplessness."
School Heads' Voices

"Our school operates on minimal government funding. AI infrastructure is not prioritized in budgets, so we cannot invest in necessary resources." "Even when technology requests are made, procurement processes are extremely slow. Equipment often arrives outdated or insufficient."

"We lack skilled IT staff to maintain and troubleshoot technology. Teachers are left alone to manage technical issues."

"Teachers face delays when using the computer lab because it is shared among multiple classes, limiting AI learning opportunities."

"Annual budgets do not allow for upgrading technology regularly. Equipment becomes obsolete faster than we can replace it."

"Technical failures discourage teachers from experimenting with AI tools, and students lose interest when lessons are interrupted."

"We plan to integrate AI, but there is no roadmap or policy guiding implementation at the school or district level." "Infrastructure constraints limit teachers' ability to experiment with AI tools, even if they are motivated to innovate." "Some labs exist, but they contain outdated equipment incompatible with modern AI applications."

"Teachers often improvise, but the lack of proper resources reduces the effectiveness of AI-based teaching."

"District guidelines do not prioritize AI infrastructure, so schools like ours remain behind in technology adoption." "We have the vision and willingness to implement AI, but physical resources are the main bottleneck preventing progress."

RQ_2: Influence of Inequality on AI Adoption

Teachers' Voices

"Many students do not have smartphones or computers at home, so they fall behind in AI-based assignments and projects." "There is a noticeable digital gap between urban and rural students in the same class. Urban students are more confident using technology."

"Even when devices are available at school, students from low-income families struggle to participate fully in AI lessons." "Some students rely on borrowed devices, which disrupt continuous learning and affect their confidence."

"Socioeconomic background affects both access and confidence. Students who cannot afford technology are hesitant to explore AI tools."

"Students with no prior exposure to technology find AI lessons confusing, requiring extra guidance and time."

"Parents in low-income families cannot support digital learning at home, making students dependent on school resources alone."

"During online assignments, students without devices fall behind quickly, widening the achievement gap."

"We notice that AI-based projects are easier for wealthier students who can practice at home, creating disparities in performance."

"Many students have never interacted with AI tools outside school, so learning new applications becomes intimidating." "Some students fear making mistakes while using AI, which increases anxiety and discourages experimentation."

School Heads' Voices

"Socioeconomic differences create uneven learning opportunities and participation levels in AI activities." "We arrange in-school access, but students with limited prior exposure require extra guidance to use AI effectively."

"Cultural norms sometimes restrict girls' access to digital resources, creating gender disparities in AI learning."

"Students from poorer backgrounds often lose motivation or drop out of AI-based projects due to lack of support." "Even when AI tools are available, home support is limited, slowing adoption and skill development."

"Equity in digital skills is a major concern. Some students excel while others lag, affecting classroom dynamics."

"Workshops help to some extent, but cannot fully overcome home-based inequalities in access and practice." "Community involvement in supporting AI education is low in disadvantaged areas, reducing reinforcement outside school." "Digital inclusion programs are minimal, leaving many students behind in AI learning opportunities."

"Parents often lack understanding of AI tools, limiting their ability to guide children."

"Economic inequality affects students' confidence and willingness to experiment with AI technologies." "Bridging the gap requires investment not only in schools but also in students' home access to technology."

RQ3: Institutional and Policy Barriers

Teachers' Voices

"We have no formal AI curriculum, so each attempt to use AI feels experimental and uncertain." "Ethical concerns about AI use are rarely discussed, making teachers cautious." "Most teachers are untrained in AI, which creates fear and hesitation in integrating it into lessons."

"The absence of guidelines leaves us unsure of best practices for AI adoption."

"Professional development sessions do not include AI, so we have to figure out everything ourselves." "Centralized policies slow down innovation, and teachers have little autonomy to implement AI strategies." "Fear of misuse of AI tools makes teachers reluctant to introduce them to students."

"Teachers feel overburdened when trying to integrate AI on top of the regular curriculum." "Monitoring and evaluation mechanisms for AI are not established, so we cannot measure effectiveness."

"Leadership support is limited; teachers feel isolated when experimenting with AI."

"Concerns about data privacy and student safety are unaddressed, discouraging innovation."

"Without institutional backing, teachers feel that AI adoption is risky and unsustainable."

School Heads' Voices

"No AI-specific policy exists at the district level, leaving us without formal guidance." "We have limited autonomy to implement AI initiatives, which slows progress." "Monitoring and evaluation of AI usage in classrooms is nonexistent, so we cannot track outcomes."

"Training for leadership in AI integration is minimal, reducing our capacity to guide teachers." "Teachers require additional support for AI adoption, but we lack resources and expertise." "District policies do not incentivize AI usage, so motivation is low."

"We are unsure how to measure AI's impact on learning, making planning difficult."

"Resistance sometimes arises due to lack of understanding among staff and parents."

"Funding for AI-related initiatives is inconsistent, causing interruptions in implementation." "We try to support teachers, but without a structured roadmap, AI adoption is limited."

"Administrative support is insufficient for long-term AI integration."

"Policy gaps prevent scaling AI practices effectively across all schools in the district."

Discussion

The findings reveal a complex interplay between infrastructure, inequality, and institutional factors affecting AI adoption in public secondary schools of District Mardan. Teachers and school heads consistently reported that inadequate infrastructure limited computer labs, outdated desktops, unreliable internet, frequent electricity outages, and lack of IT support hampers AI integration. Teachers' voices highlighted that even motivated educators are constrained by resource limitations. This aligns with previous research emphasizing technological readiness as a prerequisite for AI adoption (Selwyn, 2016; Luckin et al., 2016). Socioeconomic disparities affect students' access to AI-based learning. Students from low-income families often lack personal devices and internet access, while cultural and gender norms further restrict access, especially for female students. These findings echo UNESCO's (2021) assertion that AI adoption risks reinforcing pre-existing educational inequities. Teachers reported that wealthier students adapt more easily to AI tools, widening the learning gap. Equity-focused interventions are therefore critical for meaningful AI integration. Institutional support and policy frameworks are insufficient. Teachers highlighted the absence of AI curricula, professional development, and ethical guidelines, while school heads cited limited autonomy, inconsistent funding, and lack of monitoring systems. The Technology Acceptance Model (Davis, 1989; Ajzen, 1991) suggests that perceived ease of use and institutional support are vital for adoption; without these, teachers are hesitant to use AI tools, and scaling initiatives becomes difficult.

Implications

The study demonstrates that AI adoption in resource-constrained schools is not merely a technological challenge but a social, economic, and institutional one. Theoretically, it supports the integration digital divide frameworks, showing that adoption is influenced by structural and psychological factors. Practically, it underscores the need for infrastructure investment, teacher training, equitable access, and robust policy frameworks to ensure inclusive and sustainable AI adoption. The rich narratives provide nuanced insights, emphasizing that AI integration must be holistic, equity-focused, and contextually responsive.

Conclusion

AI adoption in public secondary schools of District Mardan is constrained by infrastructure limitations, socioeconomic inequalities, and institutional barriers. Teachers are motivated but restricted by outdated technology, shared resources, and lack of IT support. Socioeconomic disparities limit equitable student participation, particularly among low-income and female students, risking widening the digital divide. Institutional gaps, including the absence of AI curricula, insufficient teacher training, and lack of monitoring and ethical guidelines, further hinder adoption. Effective AI integration requires a multi-pronged approach addressing these challenges simultaneously. Investments in infrastructure, equitable student access, teacher professional development, and leadership training are essential. Moreover, policy frameworks must provide clear guidance, ethical standards, and monitoring mechanisms to support sustainable AI adoption. By situating AI adoption within the lived experiences of teachers and school heads, this study emphasizes that technological innovation alone is insufficient. AI must be socially aware, equitable, and institutionally supported to realize its transformative potential in education.

Recommendations

1. Upgrade computer labs, provide AI-compatible devices, ensure reliable electricity, and improve internet connectivity.
2. Provide continuous, hands-on professional development for teachers on AI integration and supply devices and internet access to underprivileged students.
3. Develop AI-specific curricula, including ethical and privacy guidelines.

4. Establish monitoring and evaluation mechanisms for AI use.
5. Engage parents and communities to support digital learning.
6. Prioritize budgets for schools with infrastructure and equity gaps.
7. Implement on-site IT support teams for maintenance and troubleshooting.

References

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179–211. [https://doi.org/10.1016/0749-5978(91)90020-T] (https://doi.org/10.1016/0749-5978%2891%2990020-T)

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340. [https://doi.org/10.2307/249008] (https://doi.org/10.2307/249008)

Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Boston, MA: Center for Curriculum Redesign.

Khalid, R., Khan, S., & Ahmed, F. (2021). Digital divide and access to technology in Pakistani public schools. Journal of Education and Information Technologies, 26(3), 2561–2580. [https://doi.org/10.1007/s10639-021-10432-1] (https://doi.org/10.1007/s10639-021-10432-1)

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). Intelligence unleashed: An argument for AI in education. London, UK: Pearson Education.

Malik, S., & Bashir, R. (2020). Challenges of integrating ICT in secondary education in Pakistan. Asian Education and Development Studies, 9(2), 235–250. [https://doi.org/10.1108/AEDS-01-2020-0010](https://doi.org/10.1108/AEDS-01- 2020-0010)

Selwyn, N. (2016). Education and technology: Key issues and debates (2nd ed.). London, UK: Bloomsbury.

UNESCO. (2021). Artificial intelligence and education: Guidance for policymakers. Paris, France: UNESCO Publishing.