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"Access, Engagement, and Equity Challenges in AI-Driven Educational Tools: A Socio-Technical Analysis of Higher Education Students in Quetta, Balochistan"

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ABSTRACT

Artificial intelligence (AI) is frequently proposed as a solution to the geographic and infrastructural barriers that constrain higher education in Balochistan, Pakistan's largest and least densely served province. Yet the promise of AI-driven educational tools is conditioned on students' actual access to reliable connectivity, devices, and linguistically appropriate systems, and on whether access translates into sustained engagement rather than superficial novelty. This study examines student engagement with AI-driven educational tools in Quetta, Balochistan, and interprets the results against the socio-technical literature on access, the digital divide, and equity in AI-enabled education. A quantitative, cross-sectional survey was administered to students at the University of Balochistan and BUITEMS. Using Cochran's (1977) formula for finite populations, a minimum sample of 196 was required from a population of 400; 220 questionnaires were distributed via simple random sampling, yielding 199 valid responses. A five-point Likert-scale Engagement subscale (Items 21–30), reverse-coded for a negatively phrased item, achieved a Cronbach's alpha of 0.759. Descriptive results indicated a positive mean engagement level ($M = 3.77$, $SD = 0.63$), confirmed by a one-sample t-test against the neutral midpoint, $t(197) = 17.03$, $p < .001$. A one-way ANOVA found no statistically significant gender difference in engagement, $F(1, 196) = 0.20$, $p = .66$. Despite this generally positive picture, engagement scores contained noticeable pockets of neutrality, which, read against the literature on linguistic barriers, connectivity gaps, and gendered access constraints in Balochistan, suggest that sustained engagement is not guaranteed by access alone. The study concludes that engagement with AI-driven educational tools in Balochistan is shaped as much by infrastructural and linguistic equity as by individual motivation, and that localized, offline-capable, and multilingual AI systems are necessary to convert access into durable engagement.

1. Introduction

The vast and rugged geography of Balochistan with its anomic settlement makes it a challenging province for effective and fair distribution of education. It is highly recognized that the area is facing acute need of professional teachers, scarcity of education materials and high percentage of people out of formal educational opportunities (Bangulzai et al., 2024). Conditions such as these are the source of the continuing educational non-parity situation, particularly in rural and remote areas where there is little or no infrastructure and high socio-economic barriers. AI is often touted as an interloper: AI enabled applications like real time translation and multilingual content delivery can bridge the language divide, and this is important in Balochistan where education is often constrained by the use of local languages including Balochi, Pashto and Brahui, which are widely spoken and present a language barrier. Similarly, AI can increase support for remote teaching via virtual classrooms for learning and intelligent tutoring, to offset the province's large distances and weak physical infrastructure (Sajja et al., 2023).
However, there are also several technical risks, ethical concerns, social implications and infrastructural concerns highlighted in the same literature that presents the promise of AI, and these need to be investigated closely (Holmes et al., 2022). A lack of governance can cause unexpected outcomes in the use of AI for teaching in areas that lack adequate resources, such as Balochistan, that is poorly equipped in infrastructure, teaching facilities and institutional capacities. Therefore, in this paper the Engagement construct is separated from the whole project of the thesis investigation and the debate is shaped by literature addressing Access and literature questioning the equity issues that shape the possibilities of authenticity and sustained engagement delivered through access to AI-based tools.

- Objective: To understand the effectiveness of the AI-powered education products to enhance students' participation in the context of access and equity-related barriers as documented in literature in the study town Quetta (Balochistan).
- Research Question: What is the impact of the use of AI-based education tools on student engagement and is this impact gender sensitive?

The study site, Quetta (main educational hub in Balochistan), gives relevance to the analysis in the context of informing scalable interventions in the province. This study seeks to help design targeted educational strategies for enhancing educational outcomes in a low-resource environment in the aftermath of conflict (Bangulzai et al., 2024). The study also raises awareness about global education goals, particularly United Nations Sustainable Development Goal 4 (Quality Education) which emphasizes closing gaps in access and quality of education in underserved areas, with the potential of AI to address this (United Nations, 2015).

2. Literature Review

2.1 Access to AI-Driven Educational Tools

The foundation for conducting AI-driven learning applications is the availability of qualified network coverage and infrastructures. In developing countries, a large proportion of learners lack access to broadband over imbalanced or low coverage areas. Power outages, among other infrastructural issues, also pose to impede normal interactions with online learning platforms. The use of AI tools is greatly influenced by socioeconomic disparities; students from low-income and middle-income families may not have access to personal computers or smartphones or sufficient data plans to access more sophisticated AI platforms.
College readiness and policy are critical determinants of access for students in the field of AI. Strategic leadership, strategic

plans to integrate AI in the curriculum and teacher training programmes are linked to more successful implementation of AI in school (Zawacki-Richter et al., 2019), and the lack of a national-scale AI education policy or weaker regulations pose hurdles for nationwide use of AI tools (Zawacki-Richter et al., 2019). Teachers' proficiency in using AI tools directly impacts access; in less (digital) developed areas, a technological misunderstanding between teachers is a primary barrier to achievement or a barrier to using the tool when it is generated; in absence of proper digital training, even enthusiastic teachers could be hesitant to use the new tool.

Accessibility is also identified as affected by cultural factors (language diversity). For instance, poorly understood AI systems or those systems that are not applicable in multilingual countries, or that cannot adapt to great dialectal differences, translation algorithms and content localization are crucial to increase the relevance of the AI systems. If AI fails to be culturally competent, it can exclude large populations of students and hurl a challenge at the concept of equity. Furthermore, dominant social attitudes towards technology and gender may be noted to hinder access to AI, especially where digital skills are not taught, technological tools are limited and social stigmas exist and are unfriendly towards female students.

2.2 The Digital Divide and Infrastructure Challenges

AI's real time application requires good connectivity and electricity. The limited connectivity and frequent power failures still happen in some parts of Balochistan, thus making it impossible to interact with AI systems in many places. These rules diminish facilitating conditions affecting the technology-acceptance theory in practice because there is a strong intention to use the technology. Lack of personal devices, or having to share devices with outdated technology, also constrains access to more advanced AI education platforms, as many undergo rapid development and need newer equipment or powerful machines, which are generally lacking in schools with limited resources. Further additions to these constraints are the inadequacy of teacher readiness, as there are a considerable number of teachers in districts like Balochistan with no training in AI pedagogy, digital ethics and platform usage, which diminishes the meaning of AI interventions and makes it more possible for students to become academically reliant or use AI as a misciting tool (Farid et al., 2023).

2.3 Algorithmic Bias and Digital Colonialism

AI systems are not an unbiased force. Imbalances in their training sets tend to be due to historical, cultural and social factors, and can result in outputs that are unfair, inappropriate or otherwise not aligned with local norms or academic practices, depriving them of perceived use and consequent loss of trust. There is also evidence of bias in AI-generated examples, which may indoctrinate students into gender roles that are stereotypical unless the content is edited; and performance-expectation bias, which may disadvantage students in the humanities, where the sheer number of tutors available for centuries has directed humanities graduates into STEM jobs. There is also gender bias in AI-generated examples, which may indoctrinate students into stereotyped gender roles, unless they are edited; and performance-expectation bias which may disadvantage humanities students, due to the abundance of tutors available for centuries and the opportunities these roles offer students from this background.

Digital colonialism is an issue related to bias and concerns the power dynamics Assigned to AI infrastructures, platform regulation, control of data, and epistemology (Choudry & Mejias, 2019). The vast majority of AI products from companies expected to enhance country-level development are designed and developed by multinational tech firms who often reflect Western pedagogical norms,

languages, and value set, at the expense of considering local knowledge and languages. Students in Balochistan face the risk of cultural alienation and losing cultural context in English-based AI systems because English is not the language that is predominant in Balochistan, which is primarily Balochi, Brahui and Urdu. Data-sovereignty concerns increase the problems, as student data might be stored or processed outside of the local jurisdiction, may result in additional privacy, control, and autonomy concerns from a student's point of view. Resisting digital colonialism calls for locally relevant elements of AI platforms, open systems and locally appropriate instructional tools.

2.4 Equity, Inclusivity, and Engagement

Ethical AI use is both a challenge and an opportunity to address equity head on — tools that don't take into account students' differences in language, gender, and socio-economic status will work in favor of, but against, those at the margins. Those who reside in low-resource, rural, and non-English-speaking backgrounds might be underserved due to lack of AI feedback, or to AI assessment standards aligning with Western academic systems (UNESCO, 2022). Inclusive design, engagement outreach and access need to be built into education related solutions that focus on the ethical use of AI, however, because otherwise engagement could not be maintained on an unequal access base.

2.4a Teacher Capacity-Building and Data Privacy

Through capacity building: Providing regular training on digital skills, adapting teaching methods and continuous technical support to teachers is a prerequisite for the effective use of AI in pedagogic in under-resourced regions as a digital gap between teachers is a common source of failure in the implementation of AI. Educator adoption at the teacher level has been improved by peer-led training and community-of-practice among educators, that has led to improved student access and engagement. In addition to infrastructural and pedagogical readiness, confidentiality of student data and ethically questionable use of AI are current concerns of student fear: if student data is not openly visible and transparently governed in the framework of institutions, a student may not be willing to engage with an AI system.

2.4b Mobile and Offline-First Access Models

Existing research findings suggest that mobile platforms on AI learning opportunities offer possibilities to scale up access to students, especially in settings where there are lower levels of infrastructure. SMS-based systems to deliver educational content overcome limitation of hardware and data network infrastructure and make use of the fact that mobile phones are a ubiquitous item and not their less common counterpart – a smartphone. Offline-first AI-based learning apps are another key design element - empowering learners to interact with these systems even in the absence of an internet connection, with data syncing back when a connection is established, a crucial functionality in areas like Balochistan, with limited internet or electricity access. Such technologies exist today with consistent effects on reduced access disparities and have been used by millions of students in similar settings in the developing world; they have the potential to have a direct impact on Balochistan's two key access constraints – intermittent connectivity and electricity instability – as discussed above.

2.5 Financing, Policy, and Inclusive Design.

Apart from connectivity, there is a large impediment to the access to AI tools, in terms of sustainable financing for licensing, maintenance, and technical support required in developing education systems. Software licensing on discounted terms and partnerships with other service providers pose a common challenge to

alleviate this barrier, but whilst sustainable financing will address this barrier, there are also many instances where governance decision makers in regions at risk of resource constraints perceive a prioritization of short term educational needs over long term investment in digital infrastructure. The effective deployment of AI tools relies on co-operation between governments, non-governmental organizations, industry and education, which can be achieved at scale by building services and providing funding; partnerships can support providing a foundation for making change in small-scale pilot projects and expanding it outwards to systemic reform.

Related, but equally important, is inclusive design as a facet of access. Incorporating digital learning environments is one way that AI solutions for limited-sighted, visually and speech-impaired learners can be a mechanism for bridging the gap for underserved communities, while in settings of developing countries, this requires more investments and institutionalization. The COVID-19 pandemic raised awareness of access inequities globally, while digital learning was adopted at a faster pace and political commitment to investing in digital educational infrastructure grew, engendering momentum that will contribute to future availability of AI tools in provinces like Balochistan, though it has created huge challenges for continuity of education in many developing countries.

3. Methodology

3.1 Research Design

The research design was quantitative using a cross-sectional survey design (Creswell & Creswell, 2018) with a descriptive-correlational approach (Leedy & Ormrod, 2021) to explore the relationship between students' engagement with AI-based education tools.

3.2 Population and Sampling

The study involved 400 students from two universities in Quetta city in Balochistan, which were chosen based on their technological facilities and the integration of AI-based learning systems, the University of Balochistan and Balochistan University for (Bachelor University of Information and Education, Science) Technology. Using Cochran's (1977) formula for finite populations ($n_0 = Z^2pq/e^2$, with $Z = 1.96$, $p = 0.5$, $q = 0.5$, $e = 0.05$), the calculated sample size ($n_0 = 384.16$) was scaled to the finite population of 400, yielding a required sample of 196. Simple random sampling technique was employed to give questionnaires to 220 students proportionate to the number of students in the various institutions studied.

3.3 Research Instrument

A self-designed questionnaire with a structured design and based on dimensions of UTAUT (Performance Expectancy and Effort Expectancy), as defined by Venkatesh et al., 2003 was used. The results for the Engagement subscale (Items 21-30), which measures active participation, motivation and involvement in using AI tools, are provided with a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) [following DeVellis, 2016].

3.5 Data Collection Procedure

Three educational and research methodology experts reviewed the content for its validity, which involves minor revisions in wordings and sequencing (Polit & Beck, 2018). The Cronbach's alpha coefficients for the 30 pilot students not used in the main study ranged above the 0.70 indicating good internal consistency (Nunnally & Bernstein, 1994).

3.5 Data Collection Procedure

Four week paper and electronic (Google Forms) questionnaires were used after institutional clearance and informed consent for the collection of data. To achieve maximum response rates, reminder notices were given regularly; and incomplete/invalid responses were discarded before analyzing.

3.6 Data Analysis Techniques

SPSS, Version 26, was used to analyze the data. The Engagement construct was summarized using descriptive statistics. This was done using a one sample t-test to compare mean engagement scores with the neutral score (3) and by using a one-way ANOVA on gender differences in engagement. A p value < .05 was used as the statistical significance (Field, 2018).

3.7 Ethical Considerations

The study followed the ethical guidelines of the American Psychological Association (APA, 2020). All participants gave informed consent and were anonymous and volunteered to participate.

4. Results

4.1 Reliability of the Engagement Construct

The Engagement subscale (Items 21–30) showed acceptable internal consistency, α = 0.759, which is greater than the acceptable criterion of 0.70 (as per Nunnally and Bernstein 1994).

Table 1. Reliability of the Engagement Construct (with Acceptance and Usefulness for Reference)

Scale	Cronbach's α	Interpretation
Acceptance	0.934	Excellent
Usefulness	0.871	Very Good
Engagement	0.759	Acceptable

4.2 Descriptive Statistics

The Engagement construct produced a mean of 3.77 (SD = 0.63), indicating a generally positive impact of AI tools on engagement and motivation, although a minor percentage of respondents expressed neutral positions.

Table 2. Descriptive Statistics of the Engagement Construct (N = 199)

Construct	Mean (M)	Standard Deviation (SD)
Engagement	3.77	0.63

4.3 Inferential Analysis

A one-sample t-test comparing mean engagement against the neutral midpoint (3.0) was statistically significant, t(197) = 17.03, p < .001, indicating that AI-based learning stimulates student involvement beyond a neutral disposition. A one-way ANOVA examining gender differences in engagement was not significant, F(1, 196) = 0.20, p = .66, indicating that male and female students gain comparably from AI interaction.

Table 3. Inferential Statistics for the Engagement Construct

Test	Statistic	df	p-value	Interpretation
One-sample t-test (vs. neutral midpoint)	t = 17.03	197	< .001	Significantly above neutral
One-way ANOVA (gender)	F = 0.20	1, 196	.66	No significant gender difference

5. Discussion

5.1 Engagement Above Neutral, but with Pockets of Neutrality

Although Engagement had a statistically significant, above neutral M (M = 3.77, t (197) = 17.03, p < .001), there were clearly pockets of neutral data. The variance suggests that AI conversational interfaces create an element of newness and interaction in the classroom, but that doesn't mean students will be actively learning - the potential for continued academic participation relies on the tool being used within the curriculum. This engagement neutrality can be closely examined in the context of the local community in Quetta, considering two broad issues identified in the literature on access and equity, including the digital divide and linguistic and multilingual barriers.

5.2 Linguistic and Multilingual Barriers

The majority of the AI based learning tools available globally are mainly in English and come with a cognitive gap for students learning their academic language in Urdu, Balochi, Pashto or Brahui. This language drag can plausibly reduce the depth or amount of engagement, even when access is possible, by making the cognitive load of each interaction increases, and by accounting for the less consistent high levels of engagement than usefulness, when a user interacts with a tool in a

language other than their own or one that is not fully supported.

5.3 The Digital Divide and Inequity

The discontinuous experiences of connection with electricity and data access means that opportunities for interactive learning are difficult to develop in the urban and rural environment. Average engagement scores might seem positive, but this will likely be superficial or vary across students unless AI tools are customized to meet the challenges of multilingualism and lack of internet access for students. This is in line with the access literature reviewed above that posited that the motivation or behavioral intention reflected in an engagement score depends on institutional readiness, teacher preparedness, device availability, and connectivity.

5.4 Equity as a Precondition for Engagement

The finding that female and male students report similar engagement in AI tools does provide some positive optimism ($F = 0.20$, $p = .66$) – if there are no significant gender differences in engagement, then for those who are engaged, the reported impact on their involvement, motivation, and participation will be comparable. This finding should, however, be interpreted with some nuance in conjunction with the existing equity literature which findings have highlighted physical and digital access barriers for female learners of AI based learning tools arising from socio-cultural factors and the lack of technological resources and social stigma. Many people do use AI tools and when they do, a gender neutral engagement result does not mean engagement for people is gendered; other technical and social interventions are still required to achieve equal opportunities to arrive at the engagement point, as measured in the study.

5.5 Access, Financing, and the Sustainability of Engagement

The basis upon which the engagement is secured, documented in this study, should be examined along with its sustainability. The survey results indicate AI tool engagement but may be more sensitive than the actual descriptive statistics are assumed to be, given the lack of a well-established pathway for sustainable financing (licensing, maintenance, and technical support) of tools in resource-constrained education systems, and the fact that tools are, naturally, costly in the short-term but can be neglected in long-term plans in the face of just short-term budgetary pressures. To make the current engagement snapshot pattern pervasive, strategic collaboration between Government, Non-Government Organizations, private sector, and universities is likely required, especially as more pilot models of AI are implemented in Balochistan universities over time.

5.6 Cautious of a shallow relationship.

One of the points that the equity literature highlighted is that even if statistically significant, engagement can be superficial and not meaningful where it is more of a novelty and not pedagogically well-integrated. The extent of response and engagement documented in this study are dependent more on pedagogical integration of the technology in the curriculum, than on access alone and do not always sustain, as the novelty wears off, making the case for the infrastructural and linguistic investments that are recommended below for sustained engagement to come.

6. Conclusion

The results showed that using AI in education has a significantly increased educational engagement for the higher education students of Quetta, Balochistan, with engagement scores well above neutral, which did not vary significantly between the two genders. Meanwhile, the pockets of neutrality in terms of engagement data, decoded by literature on linguistic barriers, the digital divide, algorithmic bias and digital colonialism, say that engagement is by no means a

product of human motivation alone, but rather co-produced by the surrounding access and equity conditions. AI tools seem to be an effective way to enhance students' learning experiences, making them more interesting, motivating, and curious, but how long this boost in engagement will last is perhaps dependent on the context and cultures within which the tools are employed. Local, language-oriented and infrastructurally feasible implementation of AI will put institutions in a better position to turn limited access into lasting and fair interaction.

7. Limitations

This study focused on higher education students from Quetta only and so limitations are imposed on the generalization of the study findings to students of other provinces and those in rural or distant parts of Balochistan who have a different infrastructure and socio-cultural conditions. The Engagement measure was based on student self-report and was not used to directly measure objective measures of access (e.g., connection, accessibility of devices, language of communication), and therefore, the connections between the barriers to accessing and lack of engagement neutrality presented in the Discussion are not directly tested and interpreted. Furthermore, the study excluded the voices of teachers, school leaders, and school policies, which influence the institutional and infrastructure conducive to access and engagement.

8. Future Research

Future studies should directly assess access indicators (the reliability of connectivity, device ownership, and language of AI interaction) to see if they are statistically related to pockets of neutral activity (as noted in this study) and engagement to analyze the relationship between engagement and access. Comparative analysis across colleges, between rural and urban sectors and between provinces with different infrastructure provisions will assist in understanding the extent to which the positive engagement results shown above hold true outside of Quetta. Studies specifically focused on the access pathway of female students before they arrive at the point of engagement are also desired because the gender neutral engagement outcome could be due to either equity or survivorship effects for those that made it to this point. Finally, future research should investigate the long-term consequences, and examine specific outcomes between regions, as chronic engagement may not correspond with the patterns found here and could vary between regions.

9. Recommendations

- Institutes should invest in high-speed internet, modern computing technology, and establish AI research labs, and enhance the network's capacity to encourage greater involvement.
- It is suggested to develop local language specific AI machinery which will ease the language gaps, and continue the engagement, in the educational ecosystem of Balochistan in the local languages of Balochistan namely Balochi, Brahui, Pashto and Urdu.
- Technological and social intervention and supports need to be complementary and structured to overcome socio-cultural barriers, which need to be addressed at the root before a meaningful measurement and improvement of engagement can be achieved for female learners.
- Not just that, student participation should be encouraged with hands-on AI related seminars, competitions and innovation hubs where the AI tools can operate offline and with low band width.
- A clear national and institutional policy, based on ethical principles and inclusive practices, should be in place covering all the higher

education institutions in Balochistan for the deployment of AI in an equitable manner.

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