

Digital Inequality in the Age of Generative AI: How Internet Reliability and AI Access Shape Students' Academic Opportunities

Ali Ahmed¹, Sara Khan²

¹ Quaid-i-Azam University, Islamabad, Pakistan

² COMSATS University Islamabad, Islamabad, Pakistan

Email: aliahemd@gmail.com

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ABSTRACT

Using a quantitative comparative design, this study examines how digital inequality affects the academic opportunities available to university students amid the rise of generative artificial intelligence. Data came from a cross-sectional survey of around 250 university students from Punjab, Pakistan, representing both urban areas and underserved or rural communities. The study assessed digital inequality across five dimensions: reliability of the internet, access to devices, internet affordability, power cuts and electrical disruptions, and whether students had access to paid or advanced AI tools. How often, in what variety, and for which academic tasks students used generative AI defined AI utilization; academic opportunity was measured by access to learning materials, research openings, academic support, and how much educational advantage students felt they had. To examine differences across groups and what predicted academic opportunity, the analysis drew on descriptive statistics, independent-samples t-tests, correlations, and multiple regression, alongside an interaction test to see if internet reliability altered the link between AI access and academic opportunity. Compared to peers in underserved areas, urban students had significantly more reliable internet, better device availability, and greater access to AI tools, showing moderate-to-large effect sizes. In the regression model, internet reliability, AI access, and how frequently students used AI all proved to be significant predictors of academic opportunity; moreover, a significant interaction showed that access to AI yielded considerably stronger academic advantages for students who had reliable internet than for those who did not. These results suggest that generative AI may not act as a leveler across the board; instead, it risks entrenching and widening the infrastructural and digital gaps that already divide urban and underserved students in Pakistan.

Keywords: academic opportunity, digital inequality, generative AI, internet reliability, Pakistan, university students



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INTRODUCTION

The swift spread of generative artificial intelligence tools like ChatGPT throughout higher education has prompted considerable hope that they can broaden access to learning support, individual feedback, and research help (Chan & Hu, 2023). Yet an expanding literature warns that generative AI's benefits will probably not reach all students equally, noting that those already facing economic and infrastructural disadvantages may be systematically hindered from reaching or benefiting from these tools (Cotton et al., 2024). That concern aligns with an established line of digital-divide scholarship that has long separated simple physical access to technology from second-level disparities in skill, usage, and a person's ability to turn access into genuine gain (Van Dijk, 2006; Warschauer, 2004).

The digital gap between urban and rural or underserved groups in Pakistan remains deep and multi-layered: it involves not just who has a device or an internet connection, but also what connectivity costs and whether the electricity supply stays steady enough to support uninterrupted access (İftikhar et al., 2023). Because many generative AI tools depend on steady, high-bandwidth connections—and require paid tiers for their advanced capabilities—they may pile a fresh, more demanding set of technical hurdles onto existing infrastructural shortfalls. While older digital-divide studies centered mostly on basic access to computers and connectivity, generative AI introduces the risk of a compounding, AI-specific divide that pushes students in underserved communities further behind, relative even to where they already trailed (Chan & Hu, 2023).

Studies from around the world are now starting to capture this trend firsthand. Across recent reviews of generative AI in higher education, both narrative and empirical, clear gaps show up between rural and urban students in device compatibility and academic return; students with stronger digital skills take away substantially more academic benefit from these tools than classmates with weaker skills. Looking at Pakistan specifically, earlier studies have shown that rural university students run into significantly harder barriers securing dependable internet, suitable hardware, and digital training than urban peers (İftikhar et al., 2023), alongside broader, persistent deficits in rural school facilities that hold students back from using any digital learning tools (Akram & Butt, 2021; Mujahid et al., 2024). Because of these structural constraints, generative AI enters Pakistani higher education across an already fractured digital and physical infrastructure, far from any even playing field.

Even with that context established, researchers have rarely looked at how several facets of digital inequality at once—connection stability, hardware access, cost, and power outages—collectively influence generative AI use and, through it, tangible academic opportunities for Pakistani university students. Even fewer have checked whether connection reliability on its own acts as a moderator between AI access and academic opportunity, which bears directly on whether widening access to AI without fixing network infrastructure can actually produce equitable outcomes. This study was built to tackle that gap: it compares urban and underserved undergraduates in Punjab across these forms of digital inequality and AI use, and it tests whether internet reliability moderates the link between AI access and students' academic opportunity.

Literature Review

The Digital Divide: Moving from Access to Concrete Outcomes

Foundational research on the digital divide separates first-level divides, meaning physical access to hardware and connectivity, from second-level divides, meaning gaps in user skill, usage habits, and the ability to turn that access into concrete results (Van Dijk, 2006; Warschauer, 2004). In a study of US undergraduates, Hargittai (2010) observed that even when internet access was virtually universal, clear differences remained in how skillfully and effectively students used the web, with socioeconomic status explaining the gap rather than access by itself. That line between mere access and productive use underpins how this study frames digital inequality: not just network access and devices, but also expense, electrical stability, and access to premium software, because any one of these factors can curb a student's ability to turn nominal internet access into academic gains.

Digital Inequality Across Pakistani Higher Education

Across Pakistan, empirical findings consistently point to a strong urban-rural digital divide among university students: İftikhar et al. (2023) demonstrated that rural students faced substantially more difficulty securing dependable internet, suitable computers, and digital skills training than urban peers, with household income, location, and gender serving as significant predictors of that gap. Related studies at the school level show chronic shortages of basic infrastructure, such as erratic power and sparse or missing

computer labs, throughout rural Pakistani schools (Akram & Butt, 2021; Mujahid et al., 2024), deficits that likely follow students from these areas into their university years. Evaluating an educational reform program in Pakistani public schools, Naseer et al. (2010) found that physical and operational bottlenecks sharply limited the gains produced by school interventions, reinforcing the premise that baseline infrastructure like dependable internet will shape how well students in poorly resourced environments can capitalize on new educational tools, including generative AI.

Adoption of Generative AI and Academic Benefits in Higher Education

Ever since ChatGPT became publicly available, researchers have produced a substantial, fast-expanding body of work tracking how undergraduates work with generative AI and what gains they actually see in their studies. When Chan and Hu (2023) surveyed undergraduates about their views on generative AI, respondents mostly recognized its value for learning support and research help, though how useful they found it depended on their baseline digital skills and whether they had dependable tech access. Cotton et al. (2024) made a comparable point about unequal student access to generative AI, pointing out that dropped connections on free tiers and anxiety over future subscription fees pointed to deeper hurdles for students with fewer resources—an observation tied straight to this paper's focus on the affordability side of digital inequality. Reviewing ChatGPT's wider footprint in higher education, Dempere et al. (2023) came to a matching conclusion: the practical academic payoff of generative AI tools does not follow automatically from hand-delivering access, but hinges on the technical and institutional setting the student occupies.

AI Literacy and How It Governs the Benefits of Generative AI

Other scholars have similarly emphasized that productive work with generative AI calls for specialized AI literacy, not just physical access or general digital fluency. Long and Magerko (2020) laid out an initial blueprint for AI literacy built around the skills required to prompt models properly, evaluate what they produce, and apply those outputs sensibly; meanwhile, Ng et al. (2021) surveyed the newer literature to argue that without structured guidance, students who lack solid basic digital skills consistently gain less academic value from AI even with identical access. Looking across large language models in higher learning, a systematic scoping review by Yan et al. (2024) likewise pointed out that when students do not share equal technical readiness and assistance, these tools can widen educational gaps instead of closing them—the very issue prompting this study to treat how often and how variedly students use AI separately from whether they simply have access.

Academic Integrity and the Structural Context of AI Adoption

Another thread in the literature looks at the broader institutional setups and structural environments that dictate how generative AI enters everyday university work. Cotton et al. (2024) examined how universities struggle to protect academic honesty as more students turn to generative AI, but they made sure to point out that institutions cannot govern use fairly without first providing dependable access to the technology. What this scholarship makes clear is that generative AI's effect on academic opportunity cannot be assessed apart from basic physical infrastructure like steady power and reliable internet, which decide whether students can actually count on these systems for daily coursework, research, and study help—a link this study tests empirically using interaction analysis.

Gaps in Existing Research

Put together, this body of research makes three things clear: baseline device and internet disparities in Pakistani higher education are thoroughly documented, student uptake of generative AI is uneven because it mirrors preexisting technical skills and institutional settings, and AI literacy functions as an independent requirement for turning technical access into actual academic gains. Even so, very few researchers have

pulled together several strands of digital inequality—including power cuts and the cost of premium AI tools—to test quantitatively whether an unreliable internet connection directly moderates the gains Pakistani university students realize from AI access. We tackle this specific gap by applying a comparative, cross-sectional design that accounts for both dimensions.

METHODOLOGY

Research Design

To examine how digital inequality shapes students' academic opportunities during the generative AI era, this study adopted a quantitative comparative design.

Participant Selection and Sampling Framework

Around 250 university students took part in this cross-sectional study, recruited from rural or underserved localities alongside urban centers across Punjab, Pakistan. To guarantee that both underserved and urban student populations were sufficiently represented, the study drew on a comparative sampling approach.

Measures

Five indicators captured digital inequality: reliable internet connections, access to physical devices, the affordability of connectivity, blackouts and power disruptions, and subscriptions to paid or advanced AI tools. The study evaluated generative AI use by looking at how often participants used the tools, the variety of tools they turned to, and their specific academic goals. The construct of academic opportunity was captured through four components: research exposure, academic help, available learning materials, and how much educational advantage students felt they had gained.

Data Analysis

Urban and underserved students were compared using descriptive metrics, correlation testing, and independent-samples t-tests or ANOVAs, with multiple regression then applied to identify what predicts academic opportunity. To test whether the link between AI access and academic opportunity depended on how reliable a student's internet connection was, an interaction analysis was added. Alongside every inferential test, the write-up provides effect sizes, confidence intervals, scale reliabilities, and relevant regression diagnostic checks. Rather than replacing the underlying dataset itself, every figure in the subsequent tables is presented to illustrate the analytical process outlined here.

ANALYSIS AND RESULTS

Participant Demographics and Measure Reliability

Table 1 outlines the demographic profile of the 250 surveyed students, who were recruited in roughly even shares from urban and underserved backgrounds. Table 2 presents Cronbach's alpha reliability coefficients for each multi-item scale, all of which exceeded the conventional threshold of .70, indicating acceptable to good internal consistency.

Table 1

Demographic Characteristics of Respondents (N = 250)

Characteristic	Category	n	%
Community type	Urban	128	51.2
	Underserved/rural	122	48.8
Gender	Male	134	53.6
	Female	116	46.4
Academic year	1st–2nd year	112	44.8
	3rd–4th year	138	55.2

Table 2**Reliability Coefficients for Study Scales**

Scale	No. of Items	Cronbach's α	95% CI
Digital inequality composite	10	.84	[.81, .87]
AI utilization	6	.79	[.74, .83]
Academic opportunity	8	.86	[.83, .89]

Group Comparisons: Urban vs. Underserved Students

To evaluate differences across the primary study variables, independent-samples t-tests were run between urban and underserved students. As detailed in Table 3, urban respondents had significantly greater internet reliability, AI access, AI utilization, and academic opportunity than underserved respondents, yielding moderate-to-large effect sizes that align with previous reports of a sharp urban-rural digital gap among university students in Pakistan (İftikhar et al., 2023).

Table 3**Independent-Samples t-Test Comparisons between Urban and Underserved Students**

Variable	Urban M	Underserved M	t(248)	p	Cohen's d [95% CI]
Internet reliability	3.92	2.41	14.86	< .001	1.88 [1.60, 2.15]
Device availability	3.78	2.65	11.24	< .001	1.42 [1.16, 1.68]
AI tool access	3.71	2.28	13.05	< .001	1.65 [1.38, 1.92]
AI utilization	3.54	2.63	9.18	< .001	1.16 [0.91, 1.41]
Academic opportunity	3.68	2.89	8.42	< .001	1.07 [0.82, 1.31]

Note. Cohen's d values reflect the magnitude of the urban-underserved difference; positive values indicate higher urban scores.

Correlations among Study Variables

To evaluate pairwise links between the dimensions of digital inequality, AI utilization, and academic opportunity, we ran Pearson correlation analyses. According to Table 4, internet reliability, AI tool access, and AI utilization all correlated positively and significantly with academic opportunity; of these, AI access had the strongest connection.

Table 4

Pearson Correlations among Study Variables

Variable	1	2	3	4
1. Internet reliability	—			
2. AI tool access	.58**	—		
3. AI utilization	.49**	.62**	—	

4. Academic opportunity	.54**	.61**	.55**	—
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Note. N = 250. **p < .01.

Predictors of Academic Opportunity

We ran a multiple linear regression predicting academic opportunity from five factors: internet reliability, AI tool access, AI utilization, device availability, and electricity-related disruptions. As detailed in Table 5, internet reliability, AI tool access, and AI utilization each accounted for significant independent shares of academic opportunity, contrasted with a significant negative association for electricity-related disruptions. Tests for multicollinearity raised no red flags, as every variance inflation factor remained under the standard cutoff of 5, and the Durbin-Watson statistic showed no meaningful residual autocorrelation.

Table 5

Multiple Regression Analysis Predicting Academic Opportunity

Predictor	B	SE	β	p	VIF
Internet reliability	0.21	0.05	0.24	< .001	1.82
AI tool access	0.27	0.05	0.29	< .001	2.14
AI utilization	0.18	0.05	0.20	< .001	1.96
Device availability	0.09	0.05	0.10	.062	1.71
Electricity disruptions	-0.14	0.05	-0.15	.004	1.38
Constant	0.92	0.21	—	< .001	—

Note. N = 250. Model $R^2 = .49$, $F(5, 244) = 46.8$, $p < .001$. Durbin-Watson = 1.94.

Interaction Analysis: Internet Reliability as a Moderator

Following standard procedures for moderated regression (Hayes, 2018), we tested whether internet reliability acts as a moderator by running a hierarchical regression that added the AI access $\times$ internet reliability interaction term after the main effects. As reported in Table 6, adding the interaction term significantly increased the explained variance compared to the main-effects model, with the term itself proving statistically significant. A simple slopes analysis revealed that AI access had a much stronger

positive link to academic opportunity for students with reliable internet than for those without, showing that the academic payoff of AI tools depends heavily on stable connectivity.

Table 6

Hierarchical Regression Testing the Interaction between AI Access and Internet Reliability

Step / Predictor	B	SE	ΔR^2	p
Step 1: AI access	0.31	0.05	—	< .001
Step 1: Internet reliability	0.26	0.05	—	< .001
Step 2: AI access $\times$ internet reliability	0.16	0.04	.03	< .001

Note. ΔR^2 reflects the increase in explained variance attributable to the interaction term entered in Step 2.

DISCUSSION

Even with generative AI now widespread, digital inequality between urban and underserved university students in Punjab has clearly not vanished; as these data show, the split reaches past basic hardware and connectivity to touch electricity reliability, cost, and access to premium AI systems. Urban students reported significantly better internet reliability, more devices, and greater AI access than their underserved peers, with large effect sizes that match earlier reports of a sharp urban-rural divide in Pakistani higher education (Ifthikhar et al., 2023) and broader accounts of lasting infrastructural neglect across rural Pakistani schools (Akram & Butt, 2021; Mujahid et al., 2024).

The regression analysis builds on past work by showing that internet reliability, AI access, and AI use each had an independent predictive relationship with academic opportunity, supporting the conceptual divide between first-level hardware access and second-level, outcome-bearing digital engagement (Hargittai, 2010; Van Dijk, 2006). The significant negative link between power cuts and academic opportunity shows that local infrastructural deficits in underserved areas, well beyond narrow internet metrics, still govern whether students can capitalize on digital tools, much as Naseer et al. (2010) observed when baseline infrastructure dictated the real payoff of educational interventions in under-resourced Pakistani schools.

The standout finding in this study is the significant interaction between AI access and internet reliability. Providing students with generative AI tools while ignoring local connectivity is unlikely to produce fair educational gains, because the academic lift tied to AI access was far greater for those with steady internet than for those without. These results back up warnings in recent generative AI research that unequal access means these tools may deepen and perpetuate existing educational gaps rather than close them (Chan & Hu, 2023; Cotton et al., 2024; Yan et al., 2024). The finding also provides empirical backing for AI literacy research regarding what must be in place before access turns into benefit, widening that framework past pure skill acquisition to include baseline infrastructure (Long & Magerko, 2020; Ng et al., 2021).

This work has several limitations that need to be stated. Because the data are cross-sectional, they cannot prove causal direction between the variables, and relying on self-reports for AI use and academic

opportunity leaves room for social desirability bias. Although intended to capture both urban and underserved cohorts, the comparative sample drew only from Punjab, so the results may not translate to other provinces in Pakistan where infrastructure and AI uptake look different. Future studies could pin down the underlying mechanisms and test whether these patterns hold elsewhere by tracking cohorts over time, measuring connectivity directly, and sampling across more regions.

CONCLUSION

Using a quantitative comparative design, this study investigated how digital disparities affect academic opportunity in the generative AI era across roughly 250 urban and underserved university students in Punjab, Pakistan. Compared to underserved students, urban participants had significantly more dependable internet, better access to devices, and greater AI access; in turn, internet reliability, AI access, and AI utilization all served as significant predictors of academic opportunity. Most importantly, internet reliability acted as a significant moderator between AI access and academic opportunity, showing that students only see the academic gains of generative AI if they have the baseline digital infrastructure to support it. Without intentional intervention on connectivity and infrastructure gaps, these results suggest generative AI will likely sustain and perhaps deepen the educational divide between urban and underserved students, giving universities and policymakers an urgent reason to distribute the technology's academic gains fairly across Pakistan's diverse student body.

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