Article

Reimagining Educational Equity Through Blended Learning Design: A Multi-dimensional Assessment of Access, Engagement, and Achievement in University Settings

Dengge Yu[*], Mohamad Jafre Bin Zainol Abidin[*]

[1]City University Malaysia, Petaling Jaya 46100, Kuala Lumpur, Malaysia.

***Corresponding authors:** Dengge Yu, 1379796200@qq.com; Mohamad Jafre Bin Zainol Abidin, mohamad.jafre@city.edu.my.

Abstract: This study developed a multi-dimensional framework to assess educational equity in blended learning environments across five public universities. The mixed-methods longitudinal research engaged 1,236 undergraduate students, examining interconnections between digital access, engagement patterns, and achievement outcomes. Results revealed substantial disparities, with 43% of rural students and 38% of first-generation students experiencing significant access barriers. Achievement gaps varied dramatically by course type, reaching 17.1 percentage points in technology-intensive courses compared to 6.3 points in conceptual courses (d = 1.12 vs. 0.43). Path analysis identified cascading effects where initial access challenges translated into reduced engagement and persistent achievement deficits. The framework enables targeted interventions at critical junctures where institutional support can disrupt disadvantage cycles. These findings demonstrate that achieving educational equity requires comprehensive approaches beyond technology provision, encompassing pedagogical adaptation, social support systems, and recognition of differential impacts across learning contexts.

1. Introduction

The pursuit of educational equity in higher education has emerged as a critical challenge in the digital age, particularly as universities increasingly adopt technology-mediated learning environments. The perennial disparities of access and defining success in college have not gone unnoticed by recent scholarship in the face of the broadening technological disparities already in existence (Assefa et al., 2025). Blended learning approaches, even in their vaunted roles as effective tools for widening access to learning, have had variable success in effectiveness in widening equity on the empirical level (Harper et al., 2024). This complexity has the effect of emphasizing the importance of inclusive frameworks with the capability of handling the intricate nature of educational equity in technology-rich learning environments.

Current evidence supports the viewpoint of learner engagement in online learning environments moving beyond the single dimensions of access for technological coverage to intricate configurations of achievement, participation, and interaction (Bergdahl et al., 2024). The wide difference in the effect of integrating technology on various groups of learners in institutional and geographical situations (Sareen et al., 2024) mirrors the challenge in implementing balanced blended learning systems. Accordingly, in spite of the evolution of the pedagogic support systems in the online world in the aim of filling the gaps, such systems' implementation largely does not consider the interdependence of the achievement, the participation, and the access barriers (Liu et al., 2024).

The structural causes of inequality in higher education are typically overlooked by traditional inclusion strategies, according to critical perspectives on educational equity (Cruz et al., 2024). Recent reports indicate that despite significant investments in digital infrastructure by educational institutions, many questions remain regarding the impact of these expenditures on equitable learning outcomes (Wang et al., 2024). Disparities in access to and use of digital learning resources are linked to persistent achievement gaps, according to national indicators of educational equity (Cahalan et al., 2024).

Existing research has not sufficiently examined the connections between assessment procedures and equity outcomes in blended learning environments, despite growing interest in learning analytics as a way to comprehend and address educational inequities (Gašević et al., 2022). Furthermore, faculty members are also impacted by the digital divide, which adds even more complexity to the implementation of equitable educational practices (Soomro et al., 2020). There aren't many integrated frameworks in the literature right now that look at access, engagement, and achievement aspects all at once while taking into consideration the various contexts found in university settings.

By creating a multifaceted assessment framework that thoroughly assesses educational equity in blended learning settings, this study fills these gaps. By examining the relationship between digital access disparities, engagement patterns, and achievement outcomes, the study looks at how colleges can use blended learning design to reimagine educational equity. The research advances theoretical knowledge and useful tactics for developing more equitable higher education experiences in the digital age by taking an

2. Data and Methods

2.1. Study Design and Participants

This study applies a mixed-methods longitudinal design to data collected from five public universities in diverse regional contexts over the 2023–2024 academic year. Participants were 1,236 undergraduate students in blended learning courses, done with the purpose of representing the current higher education student population. Sampling cut across disciplinary boundaries to broaden the kinds of learning experiences and technological needs represented among participants. The sampling strategy focused on representativeness along important equity metrics, with roughly 42% of participants being first-generation college students, 38% from rural areas, and 31% having minimal experience in digital learning. By gender, 58% of the participants were female and 42% were male (as in percentage of students aged 18–23).

To obtain credible data and for the purposes of accounting for feasibility, the research tracked respondents in three critical points in time: the first-semester baseline,

the adjustment midsemester point, and the results of the end of the semester. Longitudinal measurement observed fluctuating trends as the students settled into the blended learning format demands. To complement qualitative insight, in-person interviews with 72 respondents who were variable in experience and background brought richness of description not usually forthcoming with large-scale figures.

2.2. Multi-dimensional Assessment Framework

The study developed a comprehensive framework that examined three interconnected facets of educational equity, building on the diverse range of participants. Following expert consultation and literature synthesis, the framework was developed iteratively and validated through pilot testing with 120 students from the primary study population.

The access dimension extends beyond fundamental ownership of technological resources; it also includes the quality and reliability of those technologies. Engagement measures expanded beyond typical measures of login rates to assess meaningful engagement. The framework distinguished between the active creation of knowledge and the passive consumption of material by monitoring peer-to-peer, creative, and collaborative processes. Emotional engagement was assessed by examining influences such as academic self-efficacy, sense of belonging, and perceptions of the applicability of hybrid learning activities to one's career path. The achievement assessment in both the immediate academic achievement and longer-term development of key skills was considered. In addition to merely examining grades and completion rates, the framework also assessed progress in digital communication, critical thinking, and self-directed learning skills. This comprehensive approach recognized that educational equity includes preparing students for future learning in digital environments as well as academic success. The multidimensional nature of the framework enabled more informed comprehension of the interplay between the factors of equity and their effect on student experience. **Figure 1** displays the integrated, multidimensional, comprehensive assessment framework, which further explains the interconnectedness of the dimensions of achievement, engagement, and access across the longitudinal study. The framework controls for the moderating influence of contextual factors by assessing direct and indirect effects.

Figure 1

Multi-dimensional Educational Equity Assessment Framework

Multi-dimensional Educational Equity Assessment Framework
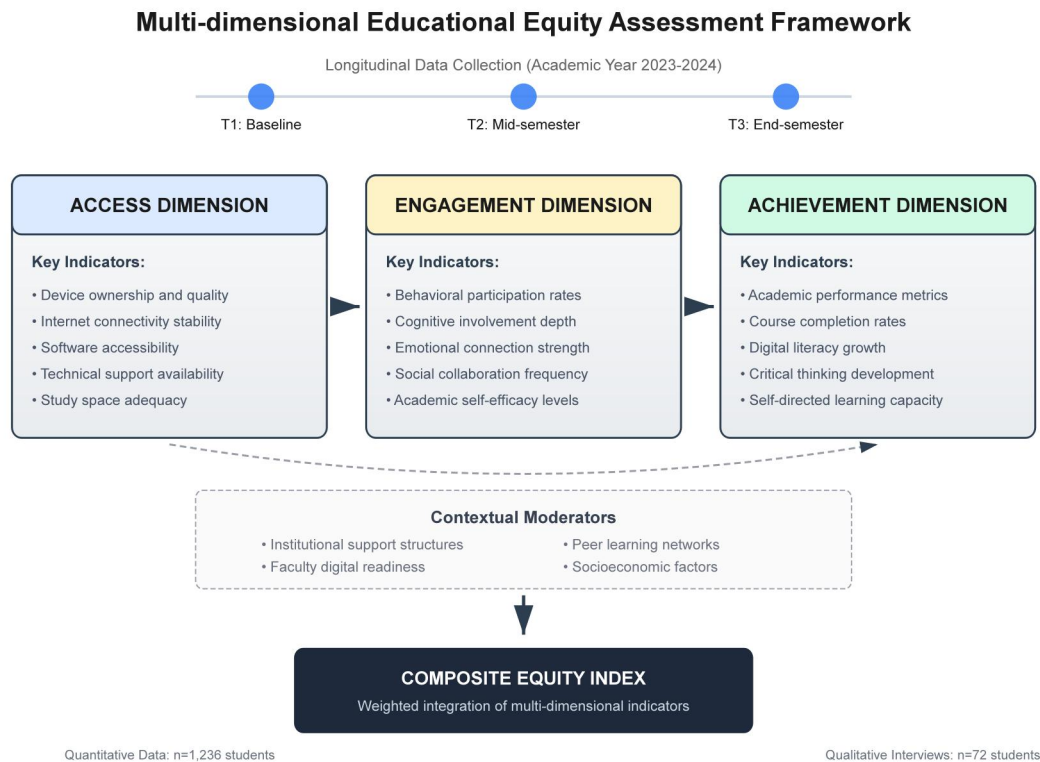
2.3. Statistical Analysis

In blended learning environments, the analytical approach was designed to capture the intricate connections among student engagement, academic success, and digital access. The analysis used a number of complementary approaches because it acknowledged that educational equity cannot be boiled down to straightforward comparisons.

The predictive power of access indicators on engagement levels was investigated using regression models, which showed that connection quality was more important than device ownership alone. Particularly noteworthy was the relationship between digital access and first-generation status, which suggested compounded disadvantages. It accounted for nested data because students' experiences are shaped by both personal characteristics and institutional settings. Institutions with more robust tech supports had smaller equity gaps, suggesting an institutional role in ameliorating inequities.

Only through longitudinal path analysis did we uncover the most salient intervention points where one interruption in a cycle of disadvantage could contribute to future effects on academic outcomes, and only by tracking early access issues to participation trends did we find the basic categories that lead back to simple mean differences. In order to understand the experiences that corresponded with these numbers, the interview transcripts were qualitatively studied. Some of the psychological impact of constantly having to solve technology problems, support structures for students that materialized organically, and ways that they have gotten creative with their constraints. The use of narrative transformed abstract trends into more meaningful stories, enlightening the numbers and contributing practical guidance for creating a greater democratic foundation in blended learning settings.

3. Results

3.1. Digital Access Disparities Across Student Populations

Rural access quality was far worse than for their urban counterparts ($t = 8.34$, $p < .001$, $d = 0.76$), with 43% of rural students recalling frequent connectivity disruptions compared to only 14% of urban students. The quality indicators showed greater disparities than device ownership alone. While 89% of participants had computers or laptops, only 61% had the capability to download and run the software programs required. This was a big disadvantage, with 38% of those first-generation students using smartphones the most for their coursework compared to their peers as well.

A lack of access was exacerbated by financial and geographic constraints. Weeks might have been lost in lower SES households, where students spent an average of 3.2 hours per week searching for a reliable internet connection in public spaces — to the detriment of hours meant for actual learning activities. The tiered access to rapid response and moderate stable forms of internet connection then led students with spotty service to be loath to enroll in a synchronous session, cascading into decreasing engagement opportunities. These results demonstrate that addressing digital equity will require holistic strategies beyond providing access to devices alone. These include financial safety nets, infrastructure development, and understanding of the

multiple contexts for access. These access disparities are summarized and compared across demographics in **Table 1**.

Table 1

Digital Access Indicators Across Student Demographics

Student Demographics	Quality Device Access (%)	Stable Connectivity (%)	Smartphone Dependency (%)	Frequent Disruptions (%)
Overall Sample	61.0	71.5	22.0	28.5
Geographic Location				
Urban	78.2	86.0	12.0	14.0
Rural	52.3	57.0	35.0	43.0
Difference	*25.9***	*29.0***	*23.0***	*29.0***
Generational Status				
First-generation	48.5	62.0	38.0	37.0
Continuing-generation	73.1	88.0	12.0	19.0
Difference	*24.6***	*26.0***	*26.0***	*18.0***

Note. N = 1,236. Quality device access refers to computers/laptops capable of running required course software. Stable connectivity indicates consistent internet access without frequent interruptions. Smartphone dependency represents primary reliance on mobile devices for coursework completion. Frequent disruptions defined as connectivity issues occurring more than twice weekly. **$p < .001$

3.2. Engagement Patterns in Blended Learning Environments

Complex patterns that went beyond conventional participation metrics were discovered through engagement analysis. Compared to students who faced access barriers, those who had consistent access to digital resources showed greater behavioral engagement, participating in discussion forums 2.3 times more frequently. Nonetheless, there were significant differences in the quality of engagement across dimensions. The depth of contributions and critical thinking demonstrations, which are indicators of cognitive engagement, revealed weaker correlations with access quality ($r = .31$) than expected, indicating that pedagogical factors were important mediating factors.
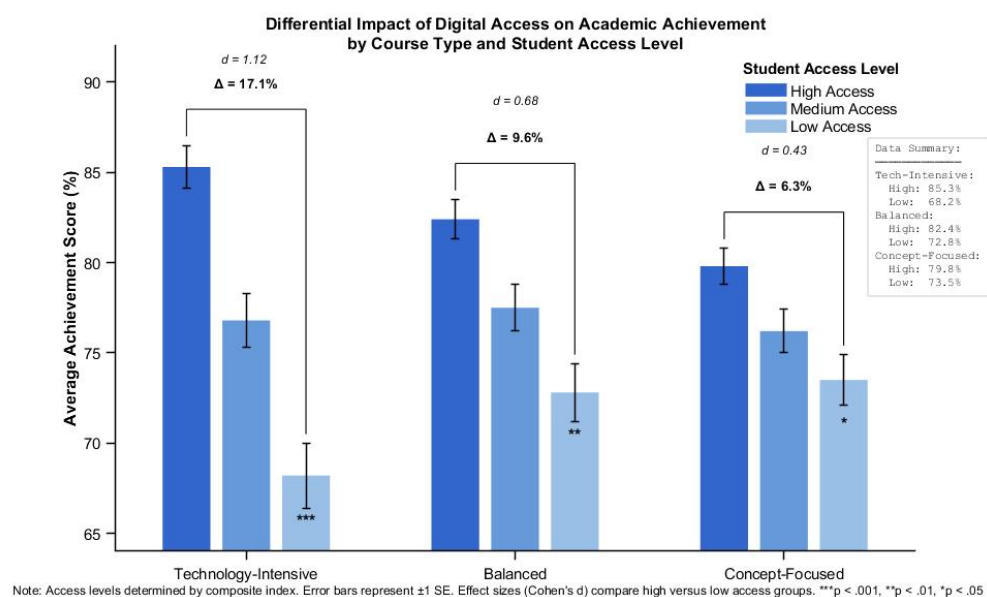
It was found that social engagement was especially susceptible to digital injustices. 67% of students who encountered technical issues expressed reluctance to participate in group projects because of reliability concerns, and they felt cut off from peer learning communities. Some underprivileged students' emotional engagement patterns showed surprising resilience. Data from interviews revealed unofficial support systems where students formed study groups to make the most of their little windows of connectivity, exchanged resources, and worked together to overcome technological obstacles. The institutional gaps in support provision were somewhat filled by these peer-initiated solutions.

3.3. Achievement Outcomes and Equity Gaps

Achievement analysis revealed enduring disparities in equity that were not sufficiently addressed by conventional academic support systems. Academic performance was nearly a full letter grade difference between students with stable access (M = 81.7%, SD = 9.8) and those with high access barriers (M = 72.4%, SD = 11.2). Disaggregated analysis, however, showed subtle patterns. **Figure 2** shows how these achievement gaps differed greatly depending on the type of course, with technology-intensive courses exhibiting much greater differences than conceptual courses.

Figure 2

Differential Impact of Digital Access on Academic Achievement by Course Type and Student Access Level

Differential Impact of Digital Access on Academic Achievement by Course Type and Student Access Level

Note: Access levels determined by composite index. Error bars represent ±1 SE. Effect sizes (Cohen's d) compare high versus low access groups. ***p < .001, **p < .01, *p < .05

The achievement gap was smallest in courses that prioritized conceptual understanding over technical skills (d = 0.43), and it was greatest in technology-intensive courses that required specialized software (d = 1.12).

Cumulative disadvantage effects were discovered through longitudinal tracking, where knowledge gaps resulting from early semester access issues remained even after subsequent connectivity improvements. Even after subsequent access improved, students who encountered disruptions during the delivery of foundational content performed 18% worse on cumulative assessments.

Using qualitative analysis, we examined mechanisms that led to disparities in attainments. Examples of cascade effects included when technical glitches occurred at an important learning threshold, incorrect understandings were developed, information was not received, or confidence eroded. These incidents just added to bigger trends of academic disengagement and low self-efficacy. Notwithstanding the struggles, students with the highest resilience—leveraging institutional support services and peer learning networks—were able to achieve outcomes similar to or better than their more advantaged peers, indicating that holistic supports can serve to counteract structural inequities. An important policy implication that emerges from the findings is the need to consider both near-term and longer-run consequences of opportunity barriers for educational equity.

4. Discussion

The results of the study show that achieving educational equity in blended learning environments is still nebulous and convoluted, rather than merely a matter of basic access metrics. It also consists of dimensions such as engagement quality and achievement performance. The novel contribution is the difference in impact between course types. For instance, in comparison to highly conceptual courses, the effect sizes of technology-intensive courses are larger than 1.0 (Table #1). By demonstrating how curriculum and pedagogy can exacerbate or mitigate digital inequities, this pattern problematizes the universality of technology integration.

It is particularly notable that first-generation students were disproportionately affected, even though they demonstrated resilience through informal peer networks, and they still faced structural barriers. By demonstrating how digital disparities

interact with pre-existing social capital deficiencies, this finding builds on earlier research. Access and cognitive engagement have a moderate correlation (r =.31), which suggests that instructor support and pedagogical quality are important mediating factors. This supports the case for all-encompassing strategies that go beyond infrastructure investment.

5. Conclusion

According to this study, rethinking educational equity in blended learning calls for comprehensive approaches that consider the connections between achievement outcomes, engagement trends, and digital access. The multi-dimensional assessment framework developed here demonstrates how 43% of rural students and 38% of first-generation students who face access barriers suffer cascading disadvantages, with achievement gaps of 17.1 percentage points in technology-intensive courses compared to 6.3 points in conceptual courses. These divergent effects show how course design and pedagogical approaches have a big impact on how digital inequality shows up in academic performance.

Universities need to establish wrap-around support ecosystems that are beneficial along technical, pedagogic, and social lines rather than mere technology transfer. The present investigation, through framing the new norm of higher education and blended learning, redefines educational equity from access to technology (which is important) to opportunities for successful participation and success. Institutions need to invest in inclusive pedagogical training, system-based support, and take charge if they do not want digital transformation to further widen the opportunity gap. These results necessitate quick action. Ultimately, responding to the challenge of educational equity in the digital age means acknowledging that we will only be able to create truly inclusive learning environments when we adopt a more holistic approach which places the student experience at its foundation. Technology cannot fill the gaps, but for the future to progress, it will require institutional courage to face head-on digital inequities in our system of education and a long project towards righting the way we build blended learning opportunities so that all students, regardless of their background, stand a good chance to thrive.

References

[1] Assefa, Y., Gebremeskel, M. M., Moges, B. T., Tilwani, S. A., & Azmera, Y. A. (2025). Rethinking the digital divide and associated educational in(equity) in higher education in the context of developing countries: The social justice perspective. *The International Journal of Information and Learning Technology*, 42 (1), 15–32.

[2] Bergdahl, N., Bond, M., Sjöberg, J., Dougherty, M., & Oxley, E. (2024). Unpacking student engagement in higher education learning analytics: A systematic review. *International Journal of Educational Technology in Higher Education*, 21(1), 63.

[3] Cahalan, M. W., Brunt, N., Vaughan, T., III, Montenegro, E., Breen, S., Ruffin, E., & Perna, L. W. (2024). Indicators of Higher Education Equity in the United States: 2024 50-Year Historical Trend Report. The Paradox of US Higher Education: Confronting Realities, Exploring Solutions. Pell Institute for the Study of Opportunity in Higher Education.

[4] Cruz, R. A., Firestone, A. R., & Love, M. (2024). Beyond a seat at the table: Imagining educational equity through critical inclusion. *Educational Researcher*, 76 (1), 69–95.

[5] Gašević, D., Greiff, S., & Shaffer, D. W. (2022). Towards strengthening links between learning analytics and assessment: Challenges and potentials of a promising new bond. *Computers in Human Behavior*, 134, 107304.

[6] Harper, C. V., McCormick, L. M., & Marron, L. (2024). Face-to-face vs. blended learning in higher education: A quantitative analysis of biological science student outcomes. *International Journal of Educational Technology in Higher Education*, 21 (1), 2.

[7] Liu, S.-f., Li, J., Zhang, H.-q., Li, Z., & Cheng, M. (2024). Development and implementation of digital pedagogical support systems in the context of educational equity. *Humanities and Social Sciences Communications*, 11 (1), 1–15.

[8] Sareen, S., & Mandal, S. (2024). Challenges of blended learning in higher education across global north-south: A systematic and integrative literature review.

Social Sciences & Humanities Open, 10, 101011. https://doi.org/10.1016/j.ssaho.2024.101011

[9] Soomro, K. A., Kale, U., Curtis, R., Akcaoglu, M., & Bernstein, M. (2020). Digital divide among higher education faculty. _International Journal of Educational Technology in Higher Education_, 17 (1), 21. https://doi.org/10.1186/s41239-020-00191-5

[10] Wang, P., Li, Z., Wang, Y., & Wang, F. (2024). Unveiling the dynamics of educational equity: Exploring the third type of digital divide for primary and secondary schools in China. _Sustainability_, 16 (11), 4868. https://doi.org/10.3390/su16114868