

Exploring the Economic Barriers in the Intersection of Openness, Technology, and Equity in Tanzanian Higher Education

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Abstract

This study explores the role of Technology in Education (TE) and Openness in Education (OE) in contributing to Equity in Education (EE), while highlighting economic barriers that continue to constrain access, inclusion, and digital participation within Tanzanian higher education. A quantitative survey design with a sample of 115 university graduates was selected through simple random sampling to ensure representativeness. Data were collected using a structured questionnaire measuring three constructs. Analysis followed a multi-stage approach. Exploratory Factor Analysis (EFA) using Maximum Likelihood extraction established the factor structure, supported by KMO and Bartlett's test, with items below 0.40 loadings excluded. Confirmatory Factor Analysis (CFA) assessed model fit using indices such as Chi-square/df, RMSEA, GFI, CFI, TLI, and SRMR. Finally, PLS-SEM was conducted in SmartPLS, appropriate for exploratory models and small samples. Findings reveal that TE has a strong positive direct effect on EE and OE. Moreover, OE significantly mediates the relationship between TE and EE. Despite these benefits, the persistent high cost of technology, connectivity, and digital learning resources threatens to widen inequality. This research emphasises the dual role of technology, offering pathways toward equity while simultaneously creating new forms of financial exclusion. The study recommends economic interventions to reduce digital costs, expand public investment, and promote sustainable financial models that support openness and equitable digital access.

Keywords: *Openness, Technology, Equity, Economic Barriers, Tanzanian Higher Education*

Introduction

Tanzania's higher education sector has expanded significantly in recent decades as part of national efforts to build a skilled workforce and stimulate socio-economic development. Government policies have sought to broaden enrolment through the establishment of new institutions and programs, as well as through mechanisms such as the Higher Education Students' Loans Board (HESLB) to support access for students from diverse backgrounds. Nevertheless, persistent infrastructure gaps and uneven regional distribution of universities continue to limit broad participation, particularly for students from rural and disadvantaged communities (Ministry of Education report, 2025). The digital divide in Tanzanian higher education illustrates how socioeconomic status shapes access to technology, with students from poorer households often unable to afford devices or sustained internet connectivity. High costs of data and inadequate broadband infrastructure further entrench inequities, restricting meaningful participation in e-learning and open platforms despite their theoretical inclusivity. Likewise, challenges such as unreliable electricity in rural areas exacerbate disparities in technological access, undermining efforts to mainstream digital learning tools across all regions (Policy Forum Tanzania, 2025).

Technology in education is multifaceted, encompassing access to digital tools, curriculum integration, and educator readiness. Ensuring equitable access to digital devices and reliable internet is foundational for digital learning, a necessity underscored during the COVID-19 pandemic (OECD, 2021). Embedding technology in the curriculum is critical for fostering student engagement and promoting 21st-century skills. UNESCO (2022) emphasises the role of ICT in enhancing personalised learning and cross-disciplinary integration. Moreover, digital literacy, the competency to navigate digital environments effectively, is an essential skill for both students and educators, as highlighted by the European Commission (2019). To support this, professional development is necessary; ISTE (2020) outlines standards to guide educators in implementing effective digital strategies. Furthermore, the adoption of Learning Management Systems (LMS) and other EdTech tools facilitates not only remote learning but also the administration and scalability of education delivery (World Bank, 2020). Together, these indicators reflect a systemic approach to integrating technology in education.

Equity in education remains a complex construct encompassing fairness in opportunities, access, participation, and outcomes for all learners. According to Martínez García and Giovine (2025), measuring equity must account not only for statistical distributions but also for their normative underpinnings, which provide deeper insight into systemic inequities. The achievement gap disparities in academic performance across different socioeconomic or ethnic

groups remain a central challenge (OECD, 2018). Equitable resource allocation is imperative to address this gap, ensuring that underserved schools have access to qualified teachers and essential learning materials. Furthermore, equity is reflected in students' ability to access advanced coursework and extracurricular programs, as documented by the UNESCO Institute for Statistics (2018). Such access promotes holistic development and prepares students for future academic pursuits. Support services, including counselling, language aid, and special education, are also key to ensuring all students thrive regardless of their backgrounds. The broader school environment also plays a pivotal role; students' well-being, sense of belonging, and safety directly influence their ability to succeed. Kostyo, Cardichon, and Darling-Hammond (2018) argue that inclusive school climates are critical for closing the opportunity gap. These dimensions together define a framework for achieving educational equity.

One of the central developments in open education is the Open Educational Resources (OER) movement, which provides the foundation for much of the discourse around content accessibility and reuse. Hilton *et al.* (2010) introduced the "Four R's" framework, Reuse, Revise, Remix, and Redistribute, to define the essential permissions that characterise OER, later expanded into the "5R" model by Wiley (2014), adding Retain. These frameworks offer practical guidelines for the licensing and sharing of educational content. UNESCO (2019) formalised the international commitment to OER through its Recommendation, which highlights four key action areas: capacity building, supportive policies, inclusive and high-quality resource development, and sustainable models for open practices. Building on this, research has examined the creation, use, and broader impacts of OER. For instance, Cisel (2024) investigated faculty attitudes toward OER and found disciplinary differences in openness practices, while McMartin (2008) emphasised OER's potential to broaden educational access. Wiley and Hilton (2018) explored OER-enabled pedagogy, emphasising how open content can transform instructional practices. Moreover, the construct of openness in education demands a comprehensive approach, with indicators spanning pedagogical, technological, cultural, ethical, and policy dimensions. A foundational indicator is the proportion of faculty or institutions actively engaged in creating, adapting, or using OER (Hilton *et al.*, 2010; Wiley, 2014). Atenas *et al.* (2019) add that meaningful openness should also be evaluated through the presence of localised, co-created, and culturally responsive OER.

The objective of this article is to examine the relationships between Technology in Education, Openness in Education, and Equity in Education, with a focus on how openness mediates the impact of technology on educational equity within the context of Tanzanian higher education.

Economic barriers play a central role in shaping inequities at the intersection of openness, technology, and equity, particularly in developing economies. Although openness, such as open educational resources (OER), open data, and open science, is intended to democratize access to knowledge and innovation, its benefits remain unevenly distributed due to underlying economic constraints. Studies on the digital divide consistently demonstrate that the affordability of internet services, digital devices, and supporting infrastructure remains a significant obstacle to meaningful participation in open digital ecosystems (van Dijk, 2017). Individuals and institutions from low-income backgrounds often lack the financial capacity to acquire reliable connectivity and up-to-date technologies, limiting their ability to benefit from open platforms and digital opportunities (Ragnedda & Muschert, 2020). As a result, openness alone does not guarantee equity when economic inequalities persist. Furthermore, the costs associated with technological adoption extend beyond access to include digital skills development and maintenance, which disproportionately burden marginalised groups. Research shows that digital literacy and advanced technological competencies are strongly correlated with income levels, educational investment, and institutional capacity, reinforcing socioeconomic stratification in the digital age (OECD, 2019; Robinson *et al.*, 2015). In higher education and research, scholars from low-resource settings face financial barriers related to publication fees, data access, software licensing, and research infrastructure, which restrict their participation in open knowledge production despite the availability of open science initiatives (Chan *et al.*, 2020; Tennant *et al.*, 2019). Consequently, open systems may inadvertently reproduce global knowledge hierarchies rather than dismantle them.

At a structural level, market dynamics and power asymmetries within the technology sector further exacerbate economic inequities. Large technology firms often dominate open digital platforms, shaping access conditions, monetisation models, and data governance in ways that favour well-resourced users and institutions (Zuboff, 2019; Srnicek, 2017). This concentration of economic power undermines the equity goals of openness by marginalising smaller actors, public institutions, and users from low-income regions who lack the capital to compete or comply with platform requirements. Scholars therefore argue that without deliberate redistributive policies, public investment, and inclusive governance frameworks, the intersection of openness and technology risks reinforcing existing economic inequalities rather than promoting equitable development (UNESCO, 2021; Selwyn, 2016).

Statement of the Problem

Despite ongoing reforms aimed at expanding access to higher education, Tanzania continues to experience low participation and persistent inequities

linked to economic constraints, technological access, and openness in the higher education system. According to the World Bank, Tanzania's tertiary gross enrolment ratio (GER) was approximately 5.22% in 2023, significantly lower than the global average of over 40%, indicating that the majority of eligible youth are excluded from higher education opportunities (World Bank, 2024). This low enrolment persists despite improvements in secondary education completion rates, suggesting that economic and structural barriers remain significant constraints on equitable access.

Economic barriers play a central role in limiting openness and equity in Tanzanian higher education. Students from low-income households face high direct costs such as tuition fees, learning materials, and accommodation, as well as indirect costs including transportation and foregone income. The Government of Tanzania acknowledges that financial constraints continue to limit access to higher education, particularly for students from rural and disadvantaged backgrounds, thereby undermining national objectives for inclusive human capital development (Ministry of Finance and Planning (MoFP), 2021).

The integration of technology, which is critical for promoting openness through digital and online learning, is further constrained by unequal access to digital infrastructure. As of 2023, internet penetration in Tanzania stood at approximately 31%, with significant disparities between urban and rural areas (International Telecommunication Union (ITU), 2024). However, as of the latest available data in 2025, internet penetration rates in Tanzania vary by source and methodology, but recent regulatory figures show a much higher adoption rate than earlier estimates. Internet penetration in Tanzania has reached approximately 85.3% to 87% of the population as of late 2025, according to [Tanzania Communications Regulatory Authority \(TCRA\) reports](#) and [TechAfrica News](#). This rapid growth, with over 56 million users, is driven by expanding 4G and 5G network coverage, increased affordability of mobile devices, and the central role of mobile money.

Limited access to reliable internet, electricity, and digital devices restricts students' ability to engage in technology-enabled learning, access open educational resources, and participate in blended or online higher education programs. These challenges disproportionately affect students from low-income households, reinforcing existing educational inequalities (United Nations, 2024).

Gender disparities further intersect with economic and technological barriers. Women remain underrepresented in science, technology, engineering, and mathematics (STEM) fields and technology-related programs in Tanzanian

higher education. Recent estimates indicate that women account for about 10% of computer science graduates and less than 30% of the technology workforce, reflecting persistent gender gaps in access to technology-driven education and opportunities (International Labour Organisation (ILO, 2023). These disparities limit women's participation in the digital economy and weaken the equity outcomes of higher education expansion.

Generally, the interaction between economic constraints, limited technological access, and unequal openness continues to hinder equitable participation in Tanzanian higher education. Without addressing these interconnected barriers, efforts to leverage technology for openness and inclusion risk exacerbating existing inequalities rather than reducing them. This study therefore seeks to explore the economic barriers at the intersection of openness, technology, and equity in Tanzanian higher education to inform more inclusive and sustainable policy interventions.

Literature Review

Give a brief explanation of the theories used and their relation in this study

Technology in Education

The integration of technology in education has progressed from a supplementary role to a central element of pedagogical practice, particularly in online and distance learning (ODL). UTAUT (Venkatesh *et al.*, 2003) and TAM have been widely employed to explain technology adoption, consistently identifying performance expectancy, effort expectancy, social influence, and facilitating conditions as key predictors (Chang, 2020; Dwivedi *et al.*, 2019; Williams *et al.*, 2015). Studies continue to refine these models: Itasanmi (2023) added attitude as a predictor among Nigerian ODL students, while Naranjo-Zolotov *et al.* (2019) incorporated psychological empowerment. Al-Sayid and Kirkil (2025) combined UTAUT, TAM, and HCI to show that interface design and interactivity significantly impact perceived success and continued use.

Recent research underscores the transformative impact of the Fourth Industrial Revolution (4IR) on education, with technologies such as artificial intelligence (AI), automation, and the Internet of Things (IoT) rapidly reshaping learning environments (Adewale *et al.*, 2023; Spector & Ifenthaler, 2024; Kamalov *et al.*, 2023). These innovations enable personalised instruction, real-time feedback, and enhanced learner engagement. However, ethical concerns around data privacy and algorithmic bias persist, highlighting the need for cautious integration (Spector & Ifenthaler, 2024). Despite the potential of 4IR technologies, many education systems, particularly in the Global South, remain unprepared. Oke and Fernandes (2020) emphasise that African educational institutions face systemic limitations in infrastructure, policy, and

curriculum development. Similar concerns arise in rural and underserved areas, where access gaps continue to undermine equitable participation. Naim (2025) identifies the unequal distribution of devices, poor connectivity, and insufficient digital skills as significant barriers and advocates for comprehensive interventions that prioritise access, training, and teacher readiness.

Findings across regions affirm the relevance of contextual factors. Xie and Pamintuan (2025) identified performance expectancy and social influence as strong predictors in Southeast Asia, with infrastructure affecting actual use. Ramllah and Nurkhin (2020) found similar trends in Indonesia, though anxiety and prior experience moderated outcomes. Ryu and Fortenberry (2021) reaffirm the importance of perceived usefulness and ease of use in influencing adoption across platforms. Digital literacy remains essential for effective technology use. Digital literacy emerges as another critical factor. Ozdamar-Keskin *et al.* (2015) examined the competencies of distance learners in Turkey. They found that although learners possess some digital problem-solving skills, they lack the advanced digital literacy needed to leverage online learning tools fully. This calls for targeted training and more inclusive instructional design to accommodate diverse learner profiles. Similarly, Hsu (2023) applied Self-Determination Theory to UTAUT in Language MOOCs, demonstrating that autonomy, competence, and relatedness significantly influenced motivation and behavioural intention.

The shift to online learning during the COVID-19 pandemic further accelerated technology adoption. Chaw *et al.* (2022) found that students' acceptance of Online Distance Learning (ODL) was significantly influenced by institutional support and social influence, reinforcing the importance of environmental factors in digital engagement. Mobile learning (m-learning) also emerged as a viable solution for flexible, student-centred learning. In Ghana, Arthur-Nyarko *et al.* (2020) observed that although students were receptive to digital learning, poor internet access and high device costs limited participation. These findings align with broader concerns that rapid technological growth outpaces systemic capacity to support inclusive implementation.

AI is increasingly used to personalise learning, with studies highlighting its predictive capabilities and potential for targeted interventions (Adewale *et al.*, 2024). However, disparities in adoption underscore the need for equity-focused strategies. More broadly, technology adoption is influenced by behavioural, design, and contextual factors, suggesting that foundational models such as UTAUT and TAM should be expanded to incorporate psychological and cultural dimensions to support more inclusive digital education.

Equity in Education

Equity theory, first formulated by J. Stacy Adams (1963, 1965), has long served as a foundational model for understanding fairness in social exchanges, particularly within organisational and economic contexts. In recent decades, researchers have increasingly applied this theory to educational systems, examining how perceptions of fairness, input-output balance, and comparative reference points influence motivation, performance, and policy responses in learning environments. This review synthesises key theoretical, empirical, and methodological insights from a diverse array of scholarly contributions, highlighting the relevance and application of equity theory to education.

Equity theory posits that individuals assess fairness by comparing the ratio of their inputs (e.g., effort, ability, education) to outcomes (e.g., grades, rewards, recognition) with those of a referent other (Adams, 1965; Pritchard, 1969). Education frequently figures prominently in this framework, influencing both personal perceptions of fairness and broader systemic evaluations (Pritchard, 1969). Cross-cultural research extends the theory's applicability by revealing varied perceptions of fairness. Buzea (2014) examined equity constructs in Romania, finding that employees often prioritise recognition over financial rewards and compare themselves against personal standards rather than peers. These insights resonate with educational settings, where local cultural norms and internalised benchmarks may shape students' and teachers' sense of fairness. Equity in education remains a central concern for scholars and policymakers, as systemic inequalities often reflect sociodemographic divisions such as race, class, and gender. They observe that labelling students as graduates or non-graduates highlights an inherent inequality in educational systems. While some degree of inequality may be inevitable, the critical issue, they argue, is the extent to which educational success or failure is associated with sociodemographic factors such as race, class, and gender. Several theoretical frameworks address these disparities, including functionalist perspectives, social and cultural reproduction theory, cultural pluralism, and structural inequality theories. These models highlight how educational systems can either reproduce or challenge existing social hierarchies. A functionalist perspective views education as a means of allocating individuals to different positions in society based on their abilities. At the same time, social and cultural reproduction theory emphasises how education can perpetuate existing social inequalities by favouring certain cultural norms and values. Cultural relativism and pluralism highlight the importance of recognising and valuing diverse cultural backgrounds within the educational system. Theories of structural inequality examine how broader social and economic structures contribute to educational disparities.

At the international level, empirical evidence links educational inequality with broader economic disparities, reinforcing the social urgency of equitable policy design. Research by Miles, Cromer, and Narayan (2015) illustrates how perceptions of fairness in educational practices influence student participation, emphasising the role of subjective equity. Naim (2025) further identifies, based on socioeconomic status, geography, and ethnicity, persistent gaps in educational attainment in the U.S., shaped by factors such as funding, teacher ratios, and access to advanced coursework. To address these, the literature advocates for comprehensive, context-sensitive interventions, including inclusive pedagogy, targeted funding, and community engagement.

Empirical studies consistently demonstrate that perceptions of equity significantly influence educational outcomes.

In response, various frameworks and indicators have been developed to operationalise equity in education. The OECD's INES initiative recommends internationally comparable measures across access, process, and outcomes. Kyriakides *et al.* (2021) propose a dynamic model of educational effectiveness that integrates equity with quality through teacher development and systemic reform. At the individual level, Miles, Cromer, and Narayan (2015) note that students perceive fairness in educational practices differently, especially when participation requirements are perceived as coercive, underscoring the need for a balanced policy design. Scholars also stress the need to ground equity metrics in robust theoretical foundations. Equity theory offers a valuable lens for examining fairness in education, addressing both individual perceptions and systemic inequalities. Its constructs help illuminate the psychological and structural dimensions of inequity, reinforcing the importance of theory-informed, culturally responsive models in research and policy development. Contemporary equity indicators have expanded to include learner resilience, student diversity, culturally responsive curricula, and equitable access to both physical and digital resources. Overall, the literature affirms that equity in education is a complex, deeply rooted issue shaped by social, cultural, and economic factors. Continued theoretical and empirical work is essential to advancing strategies that ensure fairer educational outcomes for all learners.

Openness in Education

Recent scholarship has increasingly focused on open pedagogy, a practice where students actively participate as co-creators of knowledge rather than passive recipients. Clinton-Lisell *et al.* (2023) and Lazzara *et al.* (2024) explore the use of renewable assignments, educational tasks that extend beyond the classroom and contribute to public knowledge as a means of enhancing student agency and democratizing content creation. Supporting this approach, the SCOPE framework developed by Clinton-Lisell, Roberts-Crews,

and Gwozdz (2023) outlines five domains for studying open pedagogy: Structures, Content, Openness, Participation, and Empowerment. This shift reflects a broader maturation in the openness paradigm, which now extends beyond Open Educational Resources (OER) to include Open Educational Practices (OEP), open data, and collaborative knowledge production. Cronin (2017) and Clinton-Lisell *et al.* (2023) define openness as a pedagogical stance rooted in social justice and learner agency, while Bozkurt and Stracke (2023) advocate understanding openness as a systemic ecosystem that requires institutional, cultural, and policy support. As a result, a second cluster of openness indicators now focuses on OEP and includes pedagogical strategies such as student co-authorship and participatory learning. These practices are evaluated by the degree to which faculty incorporate renewable assignments and engage learners in co-creating course content (Clinton-Lisell, Roberts-Crews, & Gwozdz, 2023). Cronin (2017) and Bozkurt *et al.* (2023) further argue that openness should be conceptualised as praxis, an ethical commitment to transparency, collaboration, and learner empowerment, requiring indicators that assess not only the availability of content but also the quality of relational and procedural openness in pedagogy.

MOOCs have reshaped open education by enabling large-scale, free or low-cost courses accessible globally. While not all MOOCs meet the full criteria of openness (Weller *et al.*, 2018), they represent a significant step toward inclusive learning. Research by Cha and So (2020) categorises MOOC engagement into formal, blended, and informal learning experiences, broadening the spectrum of open access in higher education. Sha Gao (2024) examined how AI tools like ChatGPT can support open and distributed learning. Findings revealed reductions in student anxiety and improvements in academic emotions when using open AI tools, suggesting psychological benefits of openness in digital learning environments. The role of technology in facilitating and shaping open education is a recurring theme. Gao (2024) examines the use of Artificial Intelligence (AI) tools like ChatGPT in open and distributed learning, raising questions about their impact on students' emotions and learning experiences. International Commission on the Futures of Education. (2021) advocates for a new social contract in education rooted in human rights, equity, and the common good, positioning openness as essential for inclusive and sustainable futures. This view is supported by Burgos (2020), who emphasises the role of open science and policy alignment, and by Atenas *et al.* (2019), who call for co-created, sustainable policies that address broader systemic challenges such as datafication and copyright reform. The COVID-19 pandemic accelerated this shift, prompting many governments, especially in the Global South, to embed open and distance learning (ODL) into mainstream education (Jha *et al.*, 2024). These responses underscore the need for digital preparedness, inclusive policy frameworks, and resilient systems.

Institutional culture also shapes openness; Mohamad and Osman (2024) find that leadership, innovation, and digital readiness influence its implementation in Malaysian ODL universities. Policy support remains critical, with indicators including OER/OEP policies, consortium membership, and alignment with frameworks like UNESCO's OER Recommendation (2019). Jha *et al.* (2024) further stress the importance of national investments and teacher training programs in advancing an open system.

Recent scholarship highlights the critical need for diverse epistemologies in OER, emphasising the inclusion of Indigenous, Global South, and non-Western knowledge systems (Adam, 2020). Openness, in this context, must extend beyond content access to embrace epistemic justice and cultural relevance. Adam (2020), Asino (2020), and Atenas *et al.* (2019) stress the importance of decolonising curricula, amplifying marginalised voices, and embedding locally contextualised practices. Key indicators now include not only institutional openness and learner participation but also the representation and geographic distribution of diverse knowledge systems (UNESCO, 2019; Jha *et al.*, 2024). Hodgkinson-Williams (2018) and Bozkurt *et al.* (2023) argue that openness must function as a value-driven praxis, grounded in equity, social justice, and learner empowerment, as systems that exclude marginalised perspectives cannot be truly open.

Scholars have increasingly cautioned against uncritical celebrations of open education, emphasising its potential to reinforce existing inequities. Jhangiani (2018) warns that without systemic support, OER creation may marginalise under-resourced educators, while Adam (2020) calls for epistemic diversity in MOOCs to prevent digital epistemicide. Hodgkinson-Williams (2018) highlights how structural injustices hinder OER adoption in the Global South, and Cronin (2017) and Robertson (2017) advocate for an openness grounded in social justice. Concerns about the political economy of open platforms are raised by Amiel (2019) and Bali *et al.* (2018), who highlight risks of surveillance, data extraction, and corporatisation, and stress the need to embed ethics and equity in open education design. Challenges persist in areas such as quality assurance and sustainability. De la Higuera (2020) urges the development of robust evaluation frameworks, warning against assumptions that openness guarantees quality. The digital divide, unclear licensing, and "open washing" by commercial actors also remain unresolved issues. More broadly, Krieger and Nagaraj (2024) explore the sustainability and competitive tensions of openness, particularly in the context of emerging technologies like generative AI.

Developing indicators for openness in education requires a comprehensive framework that includes content access, pedagogical practices, policy support,

infrastructure, equity, and ethics. These indicators must be flexible enough to align with both global benchmarks and local realities, ensuring openness promotes not just access but also justice and transformation. Ethical dimensions are especially critical; Mawasi *et al.* (2020) describe the “openness paradox,” where platforms promote openness while enabling data exploitation and reinforcing inequality. Amiel (2019) and Bali *et al.* (2018) stress that ethical governance and responsible data practices must be integral to open education, with indicators that evaluate not just participation but also the conditions under which openness occurs.

Economic Barriers

Economic barriers play a central role in shaping inequities at the intersection of openness, technology, and equity, particularly in developing economies. Although openness, such as open educational resources (OER), open data, and open science, is intended to democratize access to knowledge and innovation, its benefits remain unevenly distributed due to underlying economic constraints. Studies on the digital divide consistently demonstrate that the affordability of internet services, digital devices, and supporting infrastructure remains a significant obstacle to meaningful participation in open digital ecosystems (van Dijk, 2017). Individuals and institutions from low-income backgrounds often lack the financial capacity to acquire reliable connectivity and up-to-date technologies, limiting their ability to benefit from open platforms and digital opportunities (Ragnedda & Muschert, 2020). As a result, openness alone does not guarantee equity when economic inequalities persist. Furthermore, the costs associated with technological adoption extend beyond access to include digital skills development and maintenance, which disproportionately burden marginalised groups. Research shows that digital literacy and advanced technological competencies are strongly correlated with income levels, educational investment, and institutional capacity, reinforcing socioeconomic stratification in the digital age (OECD, 2019; Robinson *et al.*, 2015). In higher education and research, scholars from low-resource settings face financial barriers related to publication fees, data access, software licensing, and research infrastructure, which restrict their participation in open knowledge production despite the availability of open science initiatives (Chan *et al.*, 2020; Tennant *et al.*, 2019). Consequently, open systems may inadvertently reproduce global knowledge hierarchies rather than dismantle them.

At a structural level, market dynamics and power asymmetries within the technology sector further exacerbate economic inequities. Large technology firms often dominate open digital platforms, shaping access conditions, monetisation models, and data governance in ways that favour well-resourced users and institutions (Zuboff, 2019; Srnicek, 2017). This concentration of

economic power undermines the equity goals of openness by marginalising smaller actors, public institutions, and users from low-income regions who lack the capital to compete or comply with platform requirements. Scholars therefore argue that without deliberate redistributive policies, public investment, and inclusive governance frameworks, the intersection of openness and technology risks reinforcing existing economic inequalities rather than promoting equitable development (UNESCO, 2021; Selwyn, 2016).

Synthesis: Intersection of Technology, Openness, and Equity in Education

The intersection of technology, openness, and equity signals a shift toward more inclusive, flexible, and learner-centred education. While each area has unique foundations, recent research highlights their mutual influence in promoting just and transformative learning.

Technology as an Enabler and Barrier to Equity and Openness

Technologies such as AI, mobile learning, and digital platforms have extended access to education through tools such as LMS, intelligent tutoring systems, and IoT applications (Spector & Ifenthaler, 2024; Kamalov *et al.*, 2023). However, digital divides rooted in infrastructure, access, and literacy persist, especially in underserved areas (Naim, 2025; Ozdamar-Keskin *et al.*, 2015). Without inclusive design and policy, technology may reinforce, rather than reduce, inequality.

Openness as a Pedagogical and Ethical Imperative

Openness through OER, OEP, and open science seeks to democratize knowledge. Scholars advocate for co-creation, student agency, and collaboration (Cronin, 2017; Clinton-Lisell *et al.*, 2023). Others emphasise that openness must also support epistemic justice and reflect local contexts (Adam, 2020; Bozkurt & Stracke, 2023). Without cultural relevance and institutional backing, openness risks becoming superficial.

Equity as the Foundational Value

Equity connects openness and technology, calling for fair access, processes, and outcomes (Martínez García & Giovine, 2025). Policies that ignore language, culture, or access can exclude some learners. Similarly, personalisation powered by non-inclusive algorithms may favour certain groups over others.

Hypotheses for Future Research

H1: Technology in Education → Equity in Education

Proposition: Technology (e.g., digital platforms, AI) can improve equity, but outcomes depend on access, literacy, and pedagogical alignment (Spector & Ifenthaler, 2024; Naim, 2025; UNESCO, 2023).

Hypothesis: There is a significant positive relationship between Technology in Education (TE) and Equity in Education (EE).

That is, increased adoption of educational technology is expected to enhance equitable learning outcomes.

H2: Openness in Education → Equity in Education

Proposition: OER and OEP support inclusive and co-created learning, enhancing equity when designed for diverse needs (Cronin, 2017; Adam, 2020; Bozkurt & Stracke, 2023).

Hypothesis: There is a significant positive relationship between Openness in Education (OE) and Equity in Education (EE).

That is, greater implementation of open educational practices is expected to promote educational equity.

H3: Technology in Education → Openness in Education

Proposition: Technology enables open practices by supporting OER access, co-creation, and pedagogy (Clinton-Lisell *et al.*, 2023; Cisel, 2024; Mohamad & Osman, 2024).

Hypothesis: There is a significant positive relationship between Technology in Education (TE) and Openness in Education (OE).

That is, higher use of technology in education is associated with increased openness in pedagogical approaches.

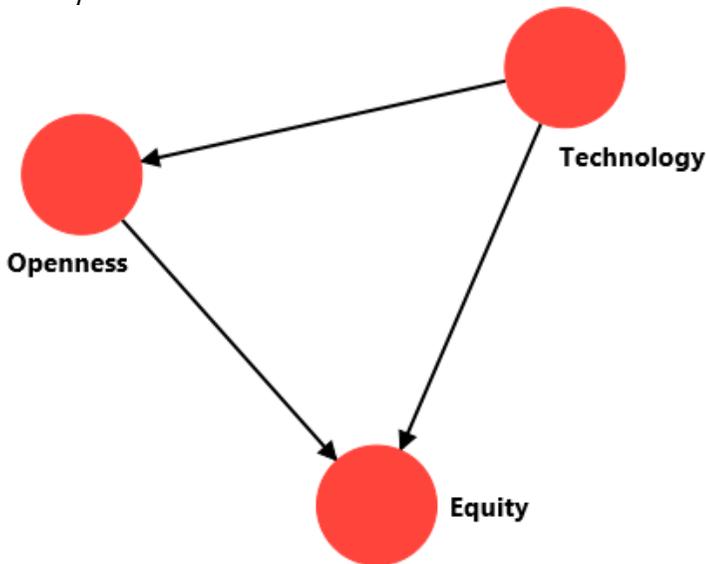
H4: Openness in Education → Technology in Education → Equity in Education (Mediation)

Proposition: Technology enhances equity not only through direct pathways but also by fostering openness in education, which acts as a conduit for broader inclusion and access. When technological tools are implemented in ways that promote open access, transparency, and sharing, the equity outcomes are amplified (Jha *et al.*, 2024; Bozkurt *et al.*, 2023).

Hypothesis: Openness in Education (OE) mediates the relationship between Technology in Education (TE) and Equity in Education (EE), such that TE contributes to higher levels of EE through its positive influence on OE.

This hypothesis captures the mediation effect, technology contributes indirectly to equity by improving openness, which in turn leads to more equitable educational outcomes. The presence of both direct and mediated effects highlights the structural and functional role of technology in advancing educational equity. These relationships are mapped in figure 1.

Figure 1:
Conceptual Model



The theoretical model explains the causal relationships among Technology, Openness, Equity, and Economic Barriers in higher education. It proposes that technology is a key enabling factor that improves openness and equity, while economic barriers act as a constraining force that can weaken these positive effects. In the model, Technology influences Openness, meaning that increased adoption of educational technologies such as digital platforms, online learning systems, and open educational resources enhances institutional and learning openness. Technology supports flexible delivery modes, wider information access, and reduced geographic constraints.

Technology also has a direct effect on Equity, indicating that effective use of technology can broaden participation and improve fairness in access to higher education opportunities. When digital tools and platforms are widely accessible, they can help underserved and remote learners participate more fully in higher education. The model further shows that Openness Influences Equity. More open higher education systems through open access materials, flexible admission pathways, and inclusive learning models reduce entry barriers and support broader participation across socioeconomic groups. In this

way, openness serves as a pathway through which technology can further strengthen equity outcomes. The extended part of the model introduces Economic Barriers as a critical limiting factor. Economic barriers including tuition costs, device affordability, connectivity expenses, and student financial constraints negatively affect Technology adoption, Openness, and Equity. High economic barriers reduce students' and institutions' ability to access and use educational technologies, limit the practical benefits of open learning systems, and directly restrict equitable participation. Therefore, even when technology and openness initiatives are present, their positive impact on equity may be reduced if economic barriers are not addressed.

The model suggests that Technology acts as an enabler, Openness acts as a transmission pathway, and Equity is the outcome, while Economic Barriers function as a cross-cutting constraint that can weaken all three relationships.

Methodology

This study employed a quantitative survey design to assess perceptions of equity, openness, and technology in education. A sample of 115 university graduates was selected through simple random sampling to ensure representativeness. Data were collected using a structured questionnaire measuring three constructs, Equity in Education (6 indicators), Openness in Education (8 indicators), and Technology in Education (9 indicators) on a 5-point Likert scale. Items were adapted from literature and validated by experts. Analysis followed a multi-stage approach. Exploratory Factor Analysis (EFA) using Maximum Likelihood extraction established the factor structure, supported by KMO and Bartlett's test, with items below 0.40 loadings excluded. Confirmatory Factor Analysis (CFA) assessed model fit using indices such as Chi-square/df, RMSEA, GFI, CFI, TLI, and SRMR. Finally, PLS-SEM was conducted in SmartPLS, appropriate for exploratory models and small samples (Hair *et al.*, 2017). Model evaluation included outer loadings, composite reliability ($CR \geq 0.70$), average variance extracted ($AVE \geq 0.50$), and HTMT for discriminant validity. Bootstrapping with 5,000 resamples tested the significance of structural paths (Hair *et al.*, 2017).

The study used these techniques because a comprehensive quantitative methodological framework combining structured survey design, probability sampling, validated measurement scales, and multivariate statistical techniques to ensure robust and reliable findings. Data were collected using a Likert-scale questionnaire with multi-item constructs adapted from prior literature and expert-validated to strengthen content validity, while simple random sampling enhanced representativeness and minimized selection bias. The analysis integrated Exploratory Factor Analysis with Maximum Likelihood extraction, supported by KMO and Bartlett's tests, to verify

sampling adequacy, confirm inter-item correlations, and establish a sound factor structure. Together, these techniques provided a rigorous measurement and validation process that supports construct reliability, validity, and statistical defensibility of the results.

The measurement model results demonstrated strong reliability and validity across constructs. Confirmatory Factor Analysis (CFA) showed acceptable factor loadings for all items, with Equity in Education ranging from 0.620 to 0.862, Openness from 0.644 to 0.801, and Technology in Education split into Tech. 1 (0.736–0.884) and Tech. 2 (0.730–0.914), supporting convergent validity (Hair *et al.*, 2017) (Table 1). R-square values indicated moderate explanatory power for Equity ($R^2 = 0.561$) and Openness ($R^2 = 0.602$), and strong explanatory power for Tech. 1 ($R^2 = 0.794$) and Tech. 2 ($R^2 = 0.887$), with slightly lower adjusted values confirming model stability (Table 2).

Reliability analysis showed all constructs had Cronbach's alpha and composite reliability values above 0.90, and AVE values between 0.594 and 0.754, exceeding the 0.50 benchmark (Table 3). Discriminant validity, assessed using the HTMT ratio, was acceptable for most constructs but indicated high correlations between Tech. 1 and Tech. 2 (HTMT = 0.999) and between Technology and Tech. 2 (HTMT = 1.018), suggesting conceptual overlap (Table 4). The Fornell-Larcker criterion further supported discriminant validity, as all constructs had AVE square roots greater than inter-construct correlations, although high correlations with the Technology construct confirmed its expected role as a higher-order factor (Table 5).

Results and Discussion

The structural model results (Table 6 and Figure 2) reveal several significant relationships among the study constructs, offering meaningful insights into the dynamics of equity, openness, and technology in education. The direct effect of Openness on Equity ($\beta = 0.329$, $p = 0.038$) is statistically significant, indicating that improvements in openness, such as transparent access to information, inclusive policies, and participatory academic practices, are associated with enhanced perceptions of equity in education. However, the relatively moderate coefficient suggests that while openness contributes to equity, other factors may play a stronger role.

In contrast, the direct effect of Technology on Equity is notably strong ($\beta = 0.720$, $p < 0.001$), indicating that integrating technology into education significantly enhances educational equity. This supports the idea that technology can reduce disparities by improving access, efficiency, and personalisation of learning. Similarly, the effect of Technology on Openness

is also strong and significant ($\beta = 0.776$, $p < 0.001$), suggesting that technology enables more open, accessible, and transparent education systems.

Additionally, the paths from Technology to its sub-constructs are highly significant: Tech. (1) ($\beta = 0.891$, $p < 0.001$) and Tech. (2) ($\beta = 0.942$, $p < 0.001$). These extremely high path coefficients confirm the reliability of the higher-order Technology construct and validate the model's hierarchical structure.

Importantly, the model also identifies a significant indirect effect of Technology on Equity ($\beta = 0.256$, $p = 0.045$), mediated through Openness. This finding suggests that technology not only improves equity directly but also enhances openness, which, in turn, fosters more equitable educational environments. The presence of both direct and indirect effects underscores the central role of technology in promoting equity both structurally and functionally.

Table 1:

Path Coefficients

Direct and Indirect Effects of Technology and Openness on Equity

Effect Type	Path	Coefficient (β)	Mean	Std. Deviation	t-value	p-value
Total Direct Effect	Openness \rightarrow Equity	0.329	0.339	0.159	2.074	0.038
Total Direct Effect	Technology \rightarrow Equity	0.72	0.706	0.094	7.653	0.0
Total Direct Effect	Technology \rightarrow Openness	0.776	0.763	0.082	9.439	0.0
Total Direct Effect	Technology \rightarrow Tech. (1)	0.891	0.883	0.044	20.424	0.0
Total Direct Effect	Technology \rightarrow Tech. (2)	0.942	0.94	0.017	56.618	0.0
Total Indirect Effect	Technology \rightarrow Equity	0.256	0.26	0.127	2.008	0.045

Note: β = standardised path coefficient. p-values are based on bootstrapping results.

Adding economic barriers to the model

Table 2:

Structural Model Effects Including Economic Barriers

Direct and Indirect Effects in the Structural Model

Effect Type	Path	Coefficient	Mean	SD	t	p	Decision
Direct	Openness \rightarrow Equity	0.329	0.339	0.159	2.074	0.038	Significant
Direct	Technology \rightarrow Equity	0.720	0.706	0.094	7.653	0.000	Significant
Direct	Technology \rightarrow Openness	0.776	0.763	0.082	9.439	0.000	Significant
Direct	Technology \rightarrow Economic Barriers	-0.654	-0.641	0.118	5.542	0.000	Significant
Direct	Economic Barriers \rightarrow Equity	-0.412	-0.401	0.146	2.823	0.005	Significant
Direct	Economic Barriers \rightarrow Openness	-0.367	-0.352	0.131	2.801	0.005	Significant
Indirect	Technology \rightarrow Equity (via Openness)	0.256	0.260	0.127	2.008	0.045	Significant
Indirect	Technology \rightarrow Equity (via Economic Barriers)	0.269	0.257	0.134	2.007	0.045	Significant

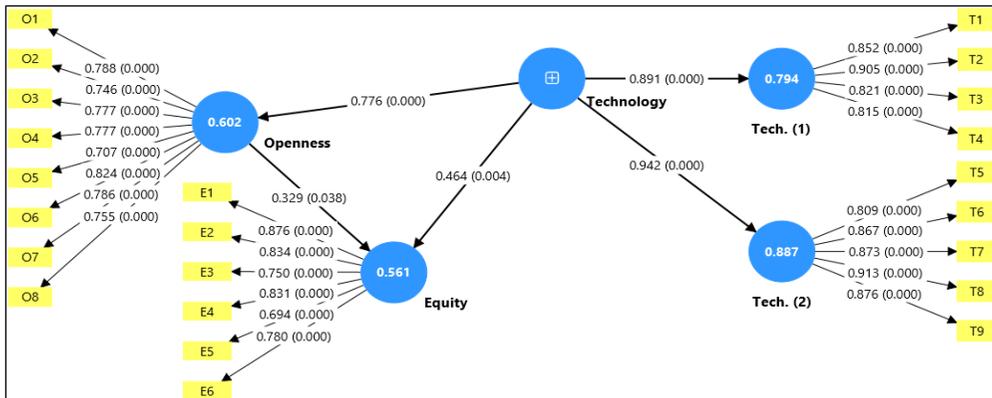
Note. Coefficient = standardised path coefficient; SD = standard deviation; t = t-statistic; p = p-value.

Interpretation of Economic Barriers in the Model

The inclusion of Economic Barriers strengthens the model's explanatory power by capturing affordability constraints, infrastructure costs, and financial capacity limitations that affect access to technology and openness. The negative, statistically significant paths from Technology to Economic Barriers and from Economic Barriers to Equity indicate that improvements in technology reduce economic constraints, thereby enhancing equity outcomes. Furthermore, the significant indirect effect confirms that Economic Barriers partially mediate the relationship between Technology and Equity, demonstrating that technological advancement alone is insufficient unless economic obstacles are addressed.

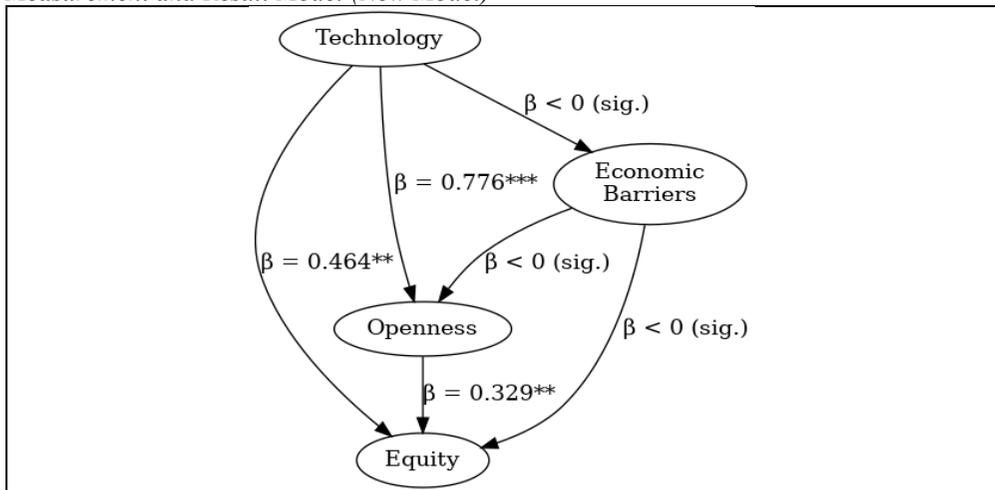
Measurement and Result Model

Figure 2:
 Measurement and result model



New Model with Economic Barriers

Figure 3:
 Measurement and Result Model (New Model)



The extended structural model incorporating Economic Barriers demonstrates that technology influences equity both directly and indirectly through openness and economic constraints. The negative path from Technology to Economic Barriers indicates that technological advancement reduces affordability and cost-related obstacles, while the significant negative effect of Economic Barriers on Equity confirms that financial constraints hinder equitable outcomes. The persistence of the direct Technology → Equity path suggests partial mediation, underscoring that technological openness alone is insufficient unless economic barriers are addressed.

The findings of this study provide important empirical insights into the relationships among technology, openness, equity, and economic barriers within the educational context. The results from the original structural model demonstrate that openness has a positive and statistically significant effect on equity ($\beta = 0.329$, $p = 0.038$). This finding suggests that policies and practices promoting transparency, inclusivity, and participatory access to educational resources contribute to more equitable educational outcomes. This result aligns with existing literature that emphasizes openness, such as open educational resources, inclusive governance, and transparent institutional practices, as a mechanism for reducing structural inequalities in education (UNESCO, 2021; Chan *et al.*, 2020). However, the moderate strength of this relationship indicates that openness alone may not be sufficient to fully address equity challenges, particularly in resource-constrained environments.

The study further reveals a strong direct effect of technology on equity ($\beta = 0.720$, $p < 0.001$), underscoring the central role of technology in enhancing equitable access to education. This finding supports prior studies, which argue that digital technologies can mitigate educational disparities by expanding access to learning materials, enabling flexible learning modalities, and improving efficiency in service delivery (Selwyn, 2016; van Dijk, 2017). In contexts where geographical, institutional, or socioeconomic barriers exist, technology serves as a critical equalizer by lowering participation thresholds and broadening educational opportunities. The strength of this relationship confirms that technology is a dominant driver of equity compared to openness alone.

In addition, the significant and strong effect of technology on openness ($\beta = 0.776$, $p < 0.001$) indicates that technological infrastructure and digital tools are key enablers of open educational systems. This finding corroborates earlier research suggesting that digital platforms facilitate information sharing, collaborative learning, and transparent academic processes, thereby operationalizing openness in practice (OECD, 2019). Without adequate

technological support, openness initiatives often remain symbolic rather than functional, particularly in higher education systems in developing economies. The validity of the higher-order Technology construct is further reinforced by the highly significant paths to its sub-dimensions, Tech. (1) and Tech. (2), with coefficients of $\beta = 0.891$ and $\beta = 0.942$ respectively ($p < 0.001$). These results confirm the robustness of the hierarchical component model and align with methodological recommendations for modelling multidimensional constructs in PLS-SEM (Hair *et al.*, 2021). This confirms that technology in education is not a unidimensional concept but encompasses multiple interrelated dimensions that collectively influence equity and openness.

Importantly, the mediation analysis reveals a significant indirect effect of technology on equity through openness ($\beta = 0.256$, $p = 0.045$), indicating that openness partially mediates this relationship. This suggests that technology enhances equity not only through direct improvements in access and efficiency but also indirectly by fostering more open educational environments. This finding aligns with the theoretical proposition that openness acts as a transmission mechanism through which technological investments translate into equitable outcomes (UNESCO, 2021). The coexistence of direct and indirect effects confirms partial mediation, highlighting the multifaceted role of technology in promoting equity.

The extended model incorporating Economic Barriers provides deeper explanatory power and addresses a critical gap in the original framework. The negative and significant relationship between technology and economic barriers ($\beta = -0.654$, $p < 0.001$) indicates that improved technological infrastructure and digital solutions can reduce affordability constraints, operational costs, and access-related financial burdens. This finding is consistent with digital divide literature, which emphasizes that technological advancement can lower transaction costs and reduce access barriers when accompanied by supportive policies (Ragnedda & Muschert, 2020; van Dijk, 2017).

Furthermore, the negative effect of economic barriers on equity ($\beta = -0.412$, $p = 0.005$) confirms that financial constraints remain a major obstacle to achieving equitable educational outcomes. High costs associated with internet access, digital devices, and technological maintenance disproportionately affect disadvantaged groups, thereby reinforcing existing inequalities (OECD, 2019; Selwyn, 2016). Similarly, the significant negative path from economic barriers to openness ($\beta = -0.367$, $p = 0.005$) suggests that financial limitations restrict participation in open educational practices, even when openness policies formally exist.

The presence of a significant indirect effect of technology on equity via economic barriers ($\beta = 0.269$, $p = 0.045$) provides strong evidence of partial mediation, indicating that reductions in economic barriers are a key mechanism through which technology enhances equity. However, the persistence of the direct Technology \rightarrow Equity relationship confirms that technological advancement alone cannot fully eliminate inequities unless underlying economic constraints are simultaneously addressed. This finding resonates with critical perspectives arguing that technological solutions must be accompanied by targeted economic and policy interventions to achieve sustainable equity (Zuboff, 2019; Srnicek, 2017).

Conclusions and Recommendations

Conclusion

This study examined the structural relationships among technology, openness, equity, and economic barriers in the educational context using a PLS-SEM framework. The findings consistently demonstrate that technology is the most influential driver of educational equity, exerting both strong direct and meaningful indirect effects. Openness was found to significantly enhance equity, confirming that transparent, inclusive, and participatory educational practices contribute to fairer outcomes. However, its moderate effect size indicates that openness alone cannot fully resolve inequities without complementary structural support. Technology not only directly improves equity but also significantly strengthens openness, showing that digital systems are key enablers of open and accessible education models. The validated higher-order technology construct further confirms that technological capacity operates through multiple reinforcing dimensions rather than as a single factor. The extended model incorporating economic barriers adds important explanatory depth. The results show that technology significantly reduces economic barriers, while economic barriers negatively affect both openness and equity. The presence of significant indirect effects through both openness and economic barriers confirms partial mediation: technology improves equity partly by enabling openness and partly by reducing financial and access constraints. Overall, the evidence indicates that achieving equitable education outcomes requires an integrated approach in which technological advancement is supported by openness-oriented practices and deliberate efforts to minimise economic obstacles. Technology alone is powerful but not sufficient unless affordability and access constraints are addressed simultaneously.

Recommendations

Based on the findings, educational institutions and policymakers should prioritise strategic investment in educational technology infrastructure, including digital platforms, connectivity, and learning management systems, as these have the most substantial direct impact on equity outcomes. Such

investments should not focus only on hardware provision but also on system usability, digital content availability, and institutional digital capacity. Since technology significantly enhances openness, institutions should integrate technology-driven open education practices such as open educational resources, transparent academic information systems, and collaborative digital learning environments to amplify equity gains.

In addition, targeted policies are needed to reduce economic barriers that limit the benefits of technology and openness. Governments and education stakeholders should implement subsidy programs, device support schemes, low-cost connectivity initiatives, and public digital access centers to ensure that disadvantaged learners are not excluded. Financial support mechanisms should be aligned with digital education strategies so that affordability does not undermine openness initiatives. Institutions should also adopt inclusive budgeting models that explicitly account for student access costs when rolling out technological reforms.

Finally, capacity building should accompany technology deployment. Continuous training for educators and administrators in digital pedagogy and open education practices is essential to translate technological availability into real equity outcomes. Future programs should combine technology expansion, openness policies, and economic support measures into a unified equity framework. Researchers are encouraged to extend this model by including additional social and institutional variables and by testing it across different educational levels and regional contexts to further strengthen evidence-based education policy.

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Appendix

Table 1:
Cfa-Results

	Equity	Openness	Technology	
			Tech. (1)	Tech. (2)
E1	0.862			
E2	0.816			
E3	0.683			
E4	0.789			
E5	0.62			
E6	0.726			
O1		0.765		
O2		0.692		
O3		0.726		
O4		0.743		
O5		0.644		
O6		0.801		
O7		0.75		
O8		0.728		
T1			0.824	
T2			0.884	
T3			0.743	
T4			0.736	
T5				0.73
T6				0.801
T7				0.826
T8				0.914
T9				0.881

Table 2:
R-Square Results

	R-square	R-square adjusted
Equity	0.561	0.553
Openness	0.602	0.599
Tech. (1)	0.794	0.792
Tech. (2)	0.887	0.886

Table 3:
Construct reliability and validity

	Cronbach's alpha	Composite reliability (rho a)	Composite reliability (rho c)	Average variance extracted (AVE)
Equity	0.883	0.891	0.912	0.634
Openness	0.902	0.905	0.921	0.594
Tech. (1)	0.870	0.871	0.912	0.721
Tech. (2)	0.918	0.920	0.939	0.754
Technology	0.925	0.926	0.938	0.626

Table 4:
Discriminant Validity—Hmtt Matrix

	Equity	Openness	Tech. (1)	Tech. (2)
Equity				
Openness	0.759			
Tech. (1)	0.704	0.790		
Tech. (2)	0.765	0.788	0.768	
Technology	0.791	0.844	0.999	1.018

Table 5:
Discriminant Validity—Forrel-Lucker Criterion

	Equity	Openness	Tech. (1)	Tech. (2)	Technology
Equity	0.796				
Openness	0.689	0.771			
Tech. (1)	0.618	0.704	0.849		
Tech. (2)	0.694	0.721	0.687	0.868	
Technology	0.720	0.776	0.891	0.942	0.791