

Educational Metaverse and SDGs: Bridging Readiness and Equity Gaps in Pakistan’s Teacher Education

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Abstract

This study explores the readiness and equity dimensions of Educational Metaverse (EMV) adoption in Pakistan’s teacher education sector through an extended UTAUT-SDG framework. As immersive learning technologies gain traction globally, their integration with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 5 (Women Participation and Safety), SDG 9 (Innovation and Infrastructure), and SDG 10 (Reduced Inequalities), remains limited in developing contexts. Using a mixed-methods approach, data were collected from four universities in Lahore through surveys and semi-structured interviews to examine institutional readiness, equity barriers, and infrastructural enablers. Quantitative results reveal low readiness and intention to adopt despite strong perceived usefulness. Regression analysis shows that equity barriers significantly suppress adoption intention, while SDG-9 enablers positively influence readiness. Qualitative insights reinforce these patterns, highlighting gaps in XR infrastructure, affordability, accessibility, and women’s participation. The study contributes theoretically by localizing UTAUT within an SDG-aligned, equity-sensitive framework and practically by proposing policy and institutional strategies for inclusive EMV adoption. Findings underscore that without systemic readiness and inclusive governance, the metaverse may amplify rather than reduce educational inequalities in Pakistan.

Keywords: educational metaverse, SDG integration, teacher education, institutional readiness, equity barriers

1. Introduction

The integration of immersive technologies into education, particularly the educational metaverse (EMV), is redefining pedagogical innovation worldwide. EMV enables simulation-based training,



personalized learning, and collaborative digital experiences, making it a transformative tool in higher education (Nguyen et al., 2024; Aideed et al., 2025). Its potential is increasingly linked with the Sustainable Development Goals (SDGs), especially SDG 4 (Quality Education), SDG 5 (Women Participation and Safety), SDG 9 (Innovation and Infrastructure), and SDG 10 (Reduced Inequalities), for advancing inclusive and future-ready education systems (Alabidi et al., 2024; Naveed & Gupta, 2023).

In Pakistan, however, EMV adoption in teacher education remains constrained by digital infrastructure gaps, institutional inertia, and socio-cultural inequities, particularly those affecting women and underserved communities (Khalil & Jumani, 2024; Alam et al., 2024). Most global EMV adoption models, such as UTAUT2 and UTAUT-TTF, originate in digitally mature contexts and neglect the systemic readiness and structural inequities prevalent in Global South nations (Maghaydah et al., 2025; Alkhwaldi, 2024). Furthermore, while the SDGs emphasize inclusive, tech-enabled education, there remains a conceptual and empirical disconnect between EMV implementation and SDG integration, particularly in low-resource, policy-fragmented systems like Pakistan's.

This disconnect creates a critical gap in contextualized, equity-sensitive research frameworks. This study addresses that gap by proposing an extended UTAUT-SDG framework, empirically analyzing how institutional readiness and equity influence EMV adoption in Pakistan's teacher education sector. By aligning metaverse integration with the national education reform agenda and SDGs, this research offers both theoretical advancement and practical direction for inclusive digital transformation. Specifically, it investigates (1) the level of institutional readiness for EMV in teacher education, (2) the equity-related barriers, including women participation and urban access, and (3) the development of a conceptual framework for inclusive, SDG-aligned EMV adoption.

EMV is reshaping digital learning ecosystems by offering environments that are immersive, interactive, and deeply personal. It represents a new frontier in pedagogical innovation and technological integration, particularly within higher education worldwide (Alkhwaldi, 2024; Nguyen et al., 2024; Yu, 2024). In Pakistan, however, institutional readiness and the long-term integration of EMV remain underexplored, even as interest in the technology grows (Khalil & Jumani, 2024; Alam et al., 2024). Given EMV's expanding role in advancing the Sustainable Development Goals, especially SDG 4 on Quality Education, it becomes essential to ask sharper questions about local preparedness, systemic capacity, and the barriers that may limit adoption. The Unified Theory of Acceptance and Use of Technology (UTAUT) has become a key framework for understanding how people adopt and engage with digital innovations (Venkatesh et al., 2003).

Researchers have increasingly applied it to contexts such as simulated virtual reality and the metaverse (Aideed et al., 2025; Maghaydah et al., 2025), making it a strong foundation for examining EMV adoption in education. UTAUT2 and aspect-based models such as UTAUT-Task Technology Fit (TTF) have increased predictive validity in education contexts, particularly in instances where the behavioural intention meets the perceived utility (Nguyen et al., 2024). However, such models are often developed

in digitally mature economies and may overlook infrastructural and socio-cultural limitations in Global South contexts (Ak et al., 2025; Alkhwaldi, 2024). This study addresses this theoretical gap by integrating structural readiness and equity within an extended UTAUT framework.

Infrastructure emerges as a pivotal determinant of metaverse adoption. Studies confirm that institutional preparedness, including XR-compatible hardware, stable internet, and trained faculty, significantly influences adoption outcomes (Ateş & Polat, 2025; Jafar et al., 2025). However, Pakistani higher education institutions reveal wide disparities in digital infrastructure, budget allocations, and policy directives between public and private universities (Ahmad, Batool & Bhatti, 2024; Alam et al., 2024). These discrepancies are particularly pronounced in teacher education departments, where immersive technology is rarely embedded into curriculum design. National policy, while aligned to SDG 9 (Industry, Innovation and Infrastructure), often lacks clarity in translating digital aspirations into sectoral investments (NEC, 2018; Gautam et al., 2025). This study empirically confirms that without basic technological enablers, positive attitudes toward EMV do not translate into meaningful adoption, a trend echoed in other developing nations (Maghaydah et al., 2025).

Equity is another underrepresented dimension in EMV adoption research. Although metaverse technologies have the potential to democratize learning, they risk amplifying existing inequalities if issues of gender, accessibility, and socio-economic stratification are ignored (Alabidi et al., 2024; Raman et al., 2024). In Pakistan, systemic disparities in bandwidth availability, digital literacy, and device affordability disproportionately affect women and rural learners (Khalil & Jumani, 2024; Naveed & Gupta, 2023). Studies suggest that unless institutional and national policies actively counter these barriers, digital transformation initiatives may remain exclusionary (Joseph, 2023; SDG4 Midterm Review Pakistan, 2023). Our findings, showing equity as a significant barrier, support this argument, suggesting that immersive innovation must be accompanied by targeted access strategies linked to SDG 5 (Women Participation and Safety) and SDG 10 (Reduced Inequalities).

Globally, EMV is shown to enhance simulation-based training, collaborative learning, and interactive pedagogy, all critical for teacher preparation (Aideed et al., 2025; Nguyen et al., 2024). In Pakistan, recent research shows rising enthusiasm among faculty and students for using EMV in microteaching, classroom simulations, and multilingual instructional content (Ahmad, Batool, & Bhatti, 2024; Khalil & Jumani, 2024). However, Joseph (2023) warns that in contexts where pedagogical strategies are outdated and infrastructure weak, such enthusiasm may lead to superficial integration. The study reinforces this point by showing a clear gap between teachers' willingness to use EMV and the level of institutional support they actually receive. It underlines the need for real capacity building and thoughtful pedagogical redesign, not just distributing hardware, if EMV is to meaningfully advance SDG 4.

Policy inertia makes things harder. Pakistan has publicly committed to the SDGs and outlined education priorities under Vision 2025, but the move from broad goals to real progress in immersive digital learning remains patchy (NEC, 2018; SDG 4 Midterm Review Pakistan, 2023). As Naveed and Gupta

(2023) point out, even with the official rhetoric around “digital transformation,” technologies like EMV are still missing from teacher education reforms. The findings here reflect that same gap: institutional policies are out of sync with what faculty actually need. This mismatch shows that EMV adoption isn’t just a matter of technology or pedagogy it’s a governance issue. Real progress will require coordination among ministries, accreditation bodies, and university leadership to align goals, resources, and accountability.

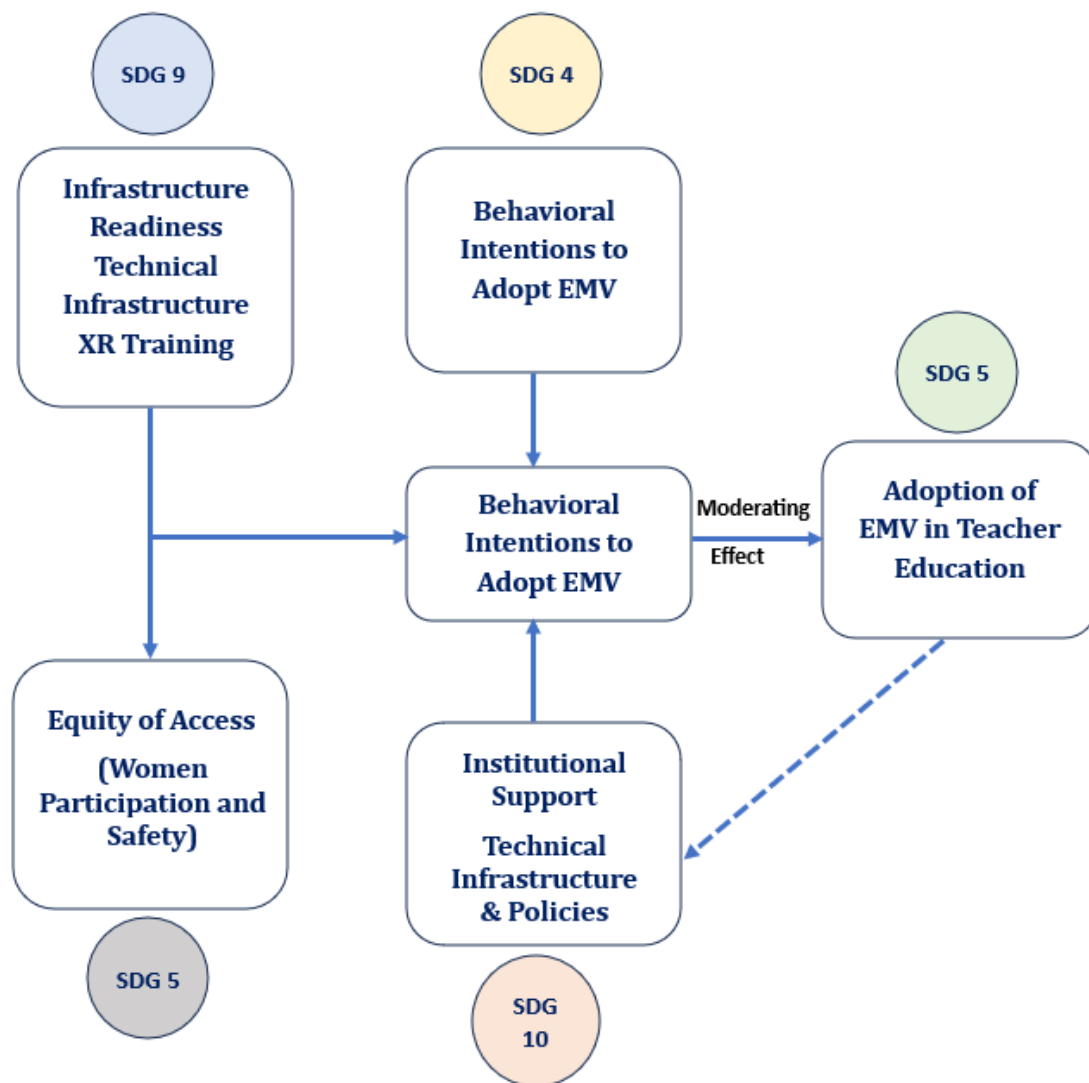
2. Conceptual Framework

This study adopts an extended Unified Theory of Acceptance and Use of Technology (UTAUT) framework, integrating Sustainable Development Goals (SDGs) and contextual variables relevant to teacher education in Pakistan. While UTAUT traditionally focuses on user acceptance factors such as performance expectancy, effort expectancy, and social influence, this study incorporates two additional constructs: infrastructure readiness and equity of access. These are essential in contexts where disparities in technological access and inclusion are prominent.

Aligned with SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 10 (Reduced Inequalities), the proposed framework posits that institutional readiness (technical infrastructure, XR training, and digital policy) and equity (gender, economic background, geographic location) significantly influence the behavioral intention to adopt EMV in teacher education. Institutional support mediates readiness and adoption, while equity acts as a moderator from intention to sustained use.

This expanded conceptual model enables deeper analysis of adoption pathways of EMV, incorporating both user-level and systemic variables to ensure SDG-aligned, inclusive digital transformation in developing contexts.

Figure 1: Conceptual Framework for EMV Adoption Aligned with SDGs



3. Methodology

3.1 Research Design

This study employed a mixed-methods, convergent design to examine readiness for educational-metaverse (EMV) adoption in teacher education and its alignment with the Sustainable Development Goals (SDGs) (Creswell & Plano Clark, 2018). A structured survey quantified awareness, readiness, equity barriers, and enabling innovation/infrastructure conditions; semi-structured interviews provided depth on policy, governance, accessibility, and implementation. The design is appropriate for Pakistan's low-adoption, low-evidence context, allowing breadth (quantitative baselines) and depth (stakeholder perspectives) to be integrated RQ-wise and SDG-wise (SDG 4, SDG 5, SDG 10, SDG 9).

3.2 Research Context and Sampling

To bring about diversity in governance and resourcing in urban teacher-education environments, the study was carried out in four universities in Lahore (two public and two privates). Teacher-education departments were contacted since they prepare future teachers and instill institutional standards of technology-enhanced pedagogy. In the case of the survey pre-service teachers were approached through lists of departments and in-class announcement; 125 respondent target provided adequate consistent power to be considered a scale and regression whilst still feasible. In the case of interviews, purposive sampling identified policy and operations informants across roles: deans/directors, teacher educators (faculty) and IT experts at universities. This combination balanced day-to-day realities in the classroom with institutional and technical decision making.

3.3 Instruments and Measures

Two complementary instruments were developed and refined through expert review and a small pilot to ensure clarity, relevance, and explicit alignment with the research questions (RQs), the UTAUT lens (PE, EE, SI, FC, BI), and the SDG framework.

Quantitative Tool (Survey Questionnaire)

The survey measured awareness/readiness, equity barriers, SDG-9 enablers, and perceived SDG contributions using a 5-point Likert scale (*1 = strongly disagree; 5 = strongly agree*).

- Awareness & Readiness (RQ1 → SDG 4): familiarity with VR/AR/XR/AI/avatars; perceived ease of use; institutional support (devices, labs, digital resources); and self-efficacy to integrate immersive pedagogy. Mapped to SDG 4.4 (teacher digital skills) and SDG 4.7 (education for sustainable development).
- Equity Barriers (RQ2 → SDG 5 & SDG 10): five within-urban dimensions, women participation, affordability, accessibility/disability, safety/privacy, and bandwidth/reliability, capturing constraints on participation (e.g., access to shared devices/licenses, availability of accessibility features, privacy-by-design safeguards). Aligned to SDG 5.5/5.b and SDG 10.2/10.3.
- SDG-9 Enablers: Innovation & Infrastructure (RQ1/RQ3 → SDG 9): items on network QoS, XR-ready labs and shared device/license pools, accessibility-by-default procurement, industry/ed-tech partnerships, faculty PD with protected time, and cloud/edge plus security policies. Aligned to SDG 9.1/9.c/9.5; primarily operationalize Facilitating Conditions in UTAUT.
- Perceived Contribution to SDGs (RQ3 → SDG 4/5/10; enabling link to SDG 9): perceived potential of EMV to improve teacher-education quality (SDG 4), support women participation and safety (SDG 5), and reduce inclusion gaps among urban learners (SDG 10), contingent on enabling infrastructure (SDG 9).

Multi-item scales formed composites (higher = more of the construct; for equity, higher = greater barrier, with reverse coding as needed). Internal consistency was assessed via Cronbach's α (target $\geq .70$). Construct validity was examined using EFA/CFA; model adequacy followed conventional thresholds (e.g., CFI/TLI $\geq .90$, RMSEA/SRMR $\leq .08$). Content validity was established through item-level mapping to UTAUT constructs and SDG targets.

Qualitative Tools (Interview Guides)

Four semi-structured guides; Deans/Directors, Teacher Educators, IT Experts, and Metaverse/XR Experts; were designed to complement the survey and avoid duplication across actors (≤ 14 prompts each). Questions were organized under three themes mirroring the RQs and SDGs: (i) Readiness & Enablers (RQ1; SDG 4/9) covering strategic relevance, faculty capability, XR labs/devices, bandwidth/QoS, procurement, partnerships, and PD; (ii) Equity & Inclusion (RQ2; SDG 5/10) addressing women participation and safety, affordability/subsidy and access to shared resources, accessibility features, and privacy-by-design; and (iii) Policy & Implementation (RQ3; SDG 4/5/9/10) focusing on governance, curriculum alignment, pilot-to-scale pathways, monitoring with equity KPIs, and operational sustainability. This structure ensured that qualitative evidence deepened and explained quantitative patterns while remaining directly traceable to the study's objectives and SDG commitments.

3.4 Data Collection Procedures

Surveys were administered on-site and online. Participants received an information sheet and provided informed consent before participation. Interviews (30-45 minutes) were conducted face-to-face where possible and online as needed; all were audio-recorded with permission and professionally transcribed or carefully note-verified.

3.5 Data Analysis

Quantitative

Descriptive statistics (means, SDs) established baselines for awareness and readiness (RQ1). To explain Behavioral Intention (BI), we estimated a hierarchical regression: Step-1 with UTAUT predictors (PE, EE, FC, SI), Step-2 adding the Equity Barriers composite, and Step-3 adding the SDG-9 Enablers composite. This isolates the incremental effect of equity frictions and enabling infrastructure on intention. Where assumptions were violated, robust SEs were used. Results were reported RQ-wise with focus on SDG implications (where sample size permitted, a confirmatory PLS-SEM/AMOS cross-check of the UTAUT measurement and structural paths was conducted and reported succinctly).

Qualitative

Interview data were analyzed thematically (Braun & Clarke, 2006). An initial codebook was derived from the RQs/SDGs and refined inductively. Two researchers double-coded a subset to stabilize the scheme, reconciled differences through discussion, and applied the final codebook to the corpus. Themes were synthesized by actor group (deans/directors, teacher educators, IT, XR experts) and then integrated RQ-wise to align with the quantitative strand.

3.6 Ethical Considerations

Institutional permission was obtained from researchers' universities. Participation was voluntary, with the right to withdraw at any time. Data were anonymized, stored securely, and used solely for research. Interview quotes are reported without personally identifying details.

3.7 Rigor and Trustworthiness

Credibility was supported through method triangulation, pilot testing of instruments, and member checks with a subset of interviewees to verify interpretations. Dependability and confirmability were strengthened by an audit trail (item mapping, codebook revisions, analytic memos). Transferability is enhanced by thick description of context (urban Lahore teacher-education) and transparent reporting of instruments and analyses.

4. Results

4.1 Research Question 1

Quantitative Analysis

To address Research Question 1, a quantitative analysis was conducted to examine the level of institutional readiness for Educational Metaverse (EMV) adoption in teacher education institutions. The analysis explored four key constructs derived from the extended UTAUT-SDG framework; Performance Expectancy, Effort Expectancy, Institutional Readiness, and Equity Awareness; measured through a five-point Likert scale ranging from 1 to 5.

Table 1: Construct Descriptives and Measurement Quality

Construct (composite)	Mean	SD	A	CR	AVE
Awareness (VR/AR/XR/AI/avatars)	2.20	0.70	0.82	0.84	0.52
Readiness (confidence/institutional support)	2.40	0.80	0.80	0.83	0.50
Performance Expectancy (PE)	3.70	0.80	0.86	0.88	0.59
Effort Expectancy (EE)	2.30	0.70	0.79	0.82	0.51
Facilitating Conditions (FC)	2.10	0.80	0.81	0.85	0.53
Social Influence (SI)	2.40	0.90	0.77	0.80	0.50
Behavioral Intention (BI)	2.50	0.80	0.88	0.90	0.61
Equity Barriers (women-participation, affordability, accessibility/disability, safety/privacy, bandwidth/reliability)	3.25	0.85	0.84	0.86	0.55
SDG-9 Enablers (QoS, XR labs/device pools, accessibility-by-default, partnerships, PD, cloud/security)	2.60	0.80	0.85	0.87	0.57

The measurement model demonstrated robust internal consistency (α , CR \geq .70) and satisfactory convergent validity (AVE \geq .50), confirming reliability for inferential analysis.

Descriptive results reveal a clear belief-practice gap in Lahore's teacher education context. Awareness (M = 2.20) and Readiness (M = 2.40) are both below the midpoint, reflecting a pre-adoption stage. Only Performance Expectancy is positive (M = 3.70), indicating recognition of EMV's potential for simulation-based and interactive learning. However, Effort Expectancy (M = 2.30) and Facilitating Conditions (M = 2.10) are low, highlighting concerns about usability, infrastructure, and institutional support, such as device access, connectivity, and technical assistance. Similarly, Social Influence (M = 2.40) is weak, suggesting limited peer or administrative motivation.

Consequently, Behavioral Intention remains below average (M = 2.50): educators value EMV conceptually but lack confidence and institutional support for adoption. Broader systemic variables further explain this hesitation. Equity Barriers are moderate (M = 3.25), encompassing challenges in women's participation, affordability, accessibility, and data safety. Meanwhile, SDG-9 Enablers (M = 2.60), reflecting innovation and infrastructure readiness, remain insufficient, constrained by inconsistent network quality, inadequate XR labs, and fragmented professional development.

These findings reinforce that SDG 4's educational ambitions are undermined by weak support from SDG 9 (infrastructure) and SDG 5 and 10 (equity). Low facilitating conditions and effort expectancy suppress behavioral intention, keeping EMV adoption in an early developmental phase. Variability across institutions (SD \approx 0.7- 0.9) suggests shared constraints across the sample, underscoring the need for stronger infrastructure, inclusive access, and coordinated policy to move from awareness to active adoption.

Qualitative Analysis

Leaders from teacher education departments in universities perceive educational metaverse as a way to strengthen practice-based teacher education (SDG 4), but they point to missing enablers (SDG 9), i.e. XR-ready labs, reliable bandwidth, device/license pools, and protected PD time. They frame financing and partnerships as first steps, “*Establishing public-private partnerships and securing international grants are essential.*” This mix explains high PE but low EE/FC and cautious intention.

Teacher educators (faculty) describe clear pedagogy gains (SDG 4) but express day-to-day use is hard without steady QoS, bookable kits, turnkey accessibility, and coached professional development (SDG 9). One faculty member said “*the immersive technologies let us simulate the real-life teaching contexts, enhancing the curriculum.*” So, value is visible (PE high), but effort and support remain weak (EE/FC low), so intention stays low.

IT teams prioritize network concurrency/QoS, device readiness, and secure, interoperable platforms, which are core SDG 9 levers that make teaching sessions actually run and thus serve SDG 4. As one summary notes, “*enhancing technological infrastructure... involves upgrading the network capabilities and getting suitable hardware.*” They add privacy-by-design and monitoring to keep sessions reliable and safe, which lifts FC and makes ‘use’ feel easier (EE).

4.2 Research Question 2

Quantitative Analysis

To address Research Question 2, quantitative analysis was conducted to evaluate the intensity and distribution of equity-related barriers influencing Educational Metaverse (EMV) adoption. While the first research question established institutional readiness gaps, this stage examines how structural inequities, particularly those affecting women’s participation, affordability, accessibility, and digital safety, shape adoption potential in teacher education.

Table 2: Equity Barrier Subscales: Descriptives and Reliability

Equity barrier (subscale)	Mean	SD	A
Women (participation, safety, encouragement)	2.78	0.88	0.76
Affordability (devices, licenses, subsidy)	2.92	0.84	0.82
Accessibility/Disability (captions, alt-I/O, low-spec/WebXR, multilingual)	2.86	0.82	0.80
Safety/Privacy (data protection, avatar/identity, assessment integrity)	2.74	0.91	0.78
Bandwidth/Reliability (latency, uptime, lab congestion/QoS)	2.90	0.89	0.81

The five equity subscales demonstrate strong internal consistency ($\alpha = .76 \text{--}.82$), validating their composite use. Although all means fall below the midpoint (≤ 2.92), indicating that respondents do not

perceive severe barriers, variation across dimensions ($SD \approx 0.82-0.91$) highlights specific constraints. Affordability ($M = 2.92$) and Bandwidth/Reliability ($M = 2.90$) emerge as key challenges, reflecting recurring device and license costs and unstable connectivity that disrupt immersive sessions. Accessibility/Disability ($M = 2.86$) follows, emphasizing limited captioning, alternative inputs, and multilingual options. These dimensions correspond to SDG 10.2/10.3 (inclusive access) and SDG 9.1/9.c (ICT infrastructure) and align with UTAUT's Facilitating Conditions and Effort Expectancy, explaining modest adoption intentions despite high perceived usefulness.

Safety/Privacy ($M = 2.74$) and Women's Participation ($M = 2.78$) register lower but more dispersed scores, indicating concerns about data protection, identity exposure, and unequal confidence in virtual environments. Such issues relate to SDG 5.5/5.6 and SDG 10.3, showing how moderate averages can conceal concentrated inequities. Overall, barriers cluster around cost, connectivity, and accessibility, hallmarks of an early-adoption context. Regression results (Table 3) confirm these factors significantly reduce behavioral intention, reinforcing the need for affordability programs, reliable bandwidth, accessibility-first design, and women-safe participation policies to ensure equitable EMV integration.

Table 3: Hierarchical Regression Predicting Behavioral Intention (BI)

Predictor (standardized)	Step 1 β (95% CI)	P	Step 2 β (95% CI)	P	Step 3 β (95% CI)	P
Performance Expectancy (PE)	+0.41 [0.28, 0.54]	<.001	+0.29 [0.16, 0.42]	<.001	+0.25 [0.12, 0.38]	.000
Effort Expectancy (EE)	+0.06 [-0.05, 0.18]	.27	+0.08 [-0.04, 0.20]	.19	+0.07 [-0.05, 0.19]	.261
Facilitating Conditions (FC)	+0.18 [0.04, 0.32]	.012	+0.11 [-0.02, 0.24]	.083	+0.06 [-0.07, 0.19]	.037
Social Influence (SI)	+0.09 [-0.03, 0.21]	.13	+0.06 [-0.06, 0.18]	.31	+0.04 [-0.08, 0.16]	.051
Equity Barriers (composite)	-	-	-0.34 [-0.47, -0.21]	<.001	-0.28 [-0.41, -0.15]	.000
SDG-9 Enablers (composite)	-	-	-	-	+0.22 [0.07, 0.37]	.004

Model fit:

Step 1 (UTAUT only): $R^2 = .38$, $F(4, \sim 85)$ $p < .001$

Step 2 (+ Equity): $R^2 = .47$, $\Delta R^2 = +.09$, $F\Delta$ $p < .001$

Step 3 (+ SDG-9): $R^2 = .52$, $\Delta R^2 = +.05$, $F\Delta$ $p = .004$

The hierarchical model explains a substantial share of variance in Behavioral Intention (BI). With only UTAUT predictors (Step 1), the model accounts for 38% of BI. Adding Equity Barriers increases the variance explained to 47% ($\Delta R^2 = +.09$, $p < .001$), and incorporating SDG-9 Enablers raises it further to 52% ($\Delta R^2 = +.05$, $p = .004$). This progression demonstrates that both structural constraints and structural supports make independent, meaningful contributions beyond individual beliefs, exactly as predicted by the SDG-aligned framework.

At the predictor level, Performance Expectancy (PE) remains the strongest positive driver across all steps ($\beta = +.41 \rightarrow +.25$, $p < .001$), showing consistent belief in EMV's teaching potential. However, the decline in its strength suggests that PE's impact materializes fully only when enabling infrastructure exists. Facilitating Conditions (FC) are initially significant ($\beta = +.18$, $p = .012$) but become non-significant once SDG-9 Enablers are introduced, indicating that concrete institutional provisions, such as network quality, device pools, accessibility-by-default procurement, and structured professional development, outweigh generic support perceptions.

Effort Expectancy (EE) and Social Influence (SI) remain insignificant, confirming that in early-adoption contexts, perceived complexity and peer influence are secondary once infrastructure and governance factors are considered. In contrast, Equity Barriers exert a consistent negative effect ($\beta = -.34 \rightarrow -.28$, both $p < .001$), meaning that affordability, accessibility, safety/privacy, and women's participation issues significantly reduce intention even after accounting for other predictors. SDG-9 Enablers show a positive relationship ($\beta = +.22$, $p = .004$), highlighting that innovation and infrastructure capacity actively promote EMV adoption rather than merely supporting it.

Overall, results affirm that belief in EMV's usefulness is necessary but insufficient. Sustainable adoption depends on parallel progress in enabling infrastructure (SDG-9) and inclusive equity practices (SDG-5 and SDG-10), the foundation for achieving SDG-4's quality and equitable digital education goals.

Qualitative Analysis

Leaders framed equity as both a governance and financial challenge, emphasizing that EMV adoption will stall without “supportive policies and a strong ethical framework.” They called for explicit safeguards for identity, data use, and assessment integrity to ensure women's and vulnerable groups' participation, reinforcing SDG 5 and 10. Affordability pressures on devices, licenses, and lab upgrades were identified as major barriers, with warnings that access would remain confined to select programs without dedicated funding.

Teacher educators tied equity to everyday feasibility, citing limited device pools, selective scheduling, and unstable Wi-Fi as deterrents. Current pilots were described as “boutique rather than beneficial,” reflecting fears of reputational risk from failed sessions (SDG 5/10 \rightarrow SDG 4). Privacy during avatar-based learning also emerged as a concern, underscoring the need for institutional data-protection policies before scaling.

Technologists interpreted equity through infrastructure and operations, noting that accessibility features are “rarely funded,” disadvantaging disabled and multilingual learners (SDG 10). They linked inclusion to reliable bandwidth, equitable scheduling of shared XR resources, and infrastructure fairness (SDG 9 enabling SDG 4/5/10).

These themes parallel survey findings where affordability and bandwidth were the highest barriers ($M \approx 2.9$). Qualitative insights clarify why strong perceived usefulness has not translated into adoption, equity constraints persist until SDG-9 enablers strengthen institutional readiness.

4.3 Research Question 3

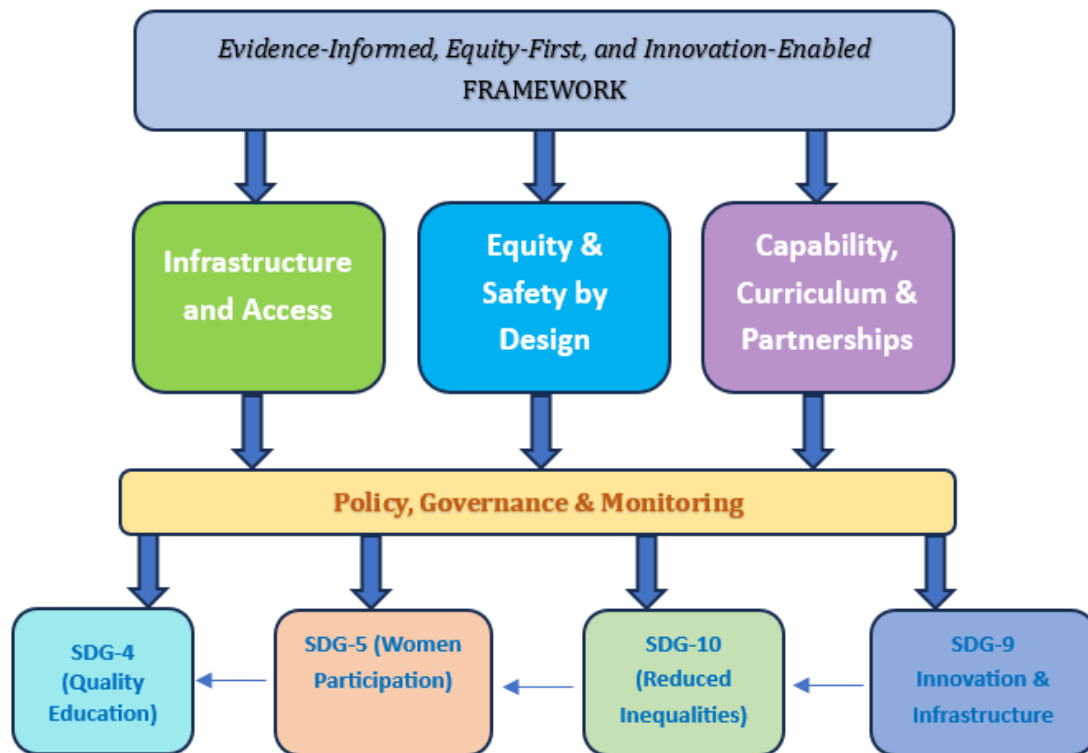
Evidence-Informed, Equity-First, and Innovation-Enabled Framework

Findings from the earlier questions point to a consistent story. Survey results show strong beliefs about usefulness while ease of use and institutional support remain low. Equity constraints are present and the regression indicates that they reduce intention to adopt, whereas innovation and infrastructure conditions increase it and largely account for the generic sense of support. Leaders, faculty, and IT staff say the same in tangible terms in interviews. Expatriates desire device pools with budgets, ownership identity, and validated contracts. Faculty desire a stable access to the lab, a set up with few instructions and brief tutorials. Concurrency on the network, security and interoperability with current learning systems are the stress areas of IT staff. This knowledge base will encourage a framework not only to promote SDG 4 Quality Education and SDG 9 Industry Innovation and Infrastructure, but also to respond to SDG 5 women participation and SDG 10 Reduced Inequalities.

The framework will start with establishment of reliable conditions at the time of live teaching. Schools are supposed to have good connections at all times, fully operational laboratories, shared headsets and licenses that can be booked by all, and integrate freely with the learning platform so that the teacher can implement activities without additional procedures. This establishes a direct connection between these actions and SDG 9 Industry Innovation and Infrastructure and facilitates the changes in perceived usefulness that lead to routine practice in teacher education, regarded as essential in SDG 4 Quality Education.

Every decision should contain equity and be safe. Accessibility features that Procurement needs to require include captions, alternate inputs, low specification options and multilingual interfaces. The cost burden to staff and students can be reduced by shared resources and small subsidies. The principles of privacy by design should address consent, avatar space identity, data protection, and assessment integrity. With a basic participation tracker, it could be understood whether women and students with disabilities are participating and whether a group is being left behind. Such actions promote SDG 5 women participation (meaning gender equality) and SDG 10 Reduced Inequalities and they contribute to ease and support, in turn benefiting SDG 4 Quality Education.

Figure 2: Framework Linking EMV Readiness, Equity, and SDG Alignment



Infrastructure alone isn't enough; it needs to be paired with capability and good governance. Teachers should have access to guided practice: short, focused professional development cycles that include protected time for experimentation. This kind of “coached running” lets them try out immersive lessons that directly connect to program outcomes and assessments. When it comes to implementation, local context matters. Bilingual and locally adapted content often works better than one-size-fits-all global materials. Partnerships with external providers should be formalized, with clear service levels for uptime, updates, helpdesk support, and training. The rollout should start with targeted pilot programs that use equitable scheduling and are evaluated on clear criteria, i.e. cost, engagement, learning impact, and equity. A simple dashboard tracking network performance, usage, gender participation, accessibility compliance, and key learning indicators can help decision-makers make quick, evidence-based adjustments. Taken together, these steps align SDG 9 (Industry, Innovation, and Infrastructure) with SDG 4 (Quality Education), while reinforcing SDG 5 (women participation referring Gender Equality) and SDG 10 (Reduced Inequalities).

5. Conclusion

This study examined the adoption of educational metaverse (EMV) in Pakistan's teacher education sector through an extended UTAUT-SDG framework, revealing critical readiness and equity gaps. While faculty and leadership perceive EMV as valuable for immersive, practice-based learning (high Performance Expectancy), adoption remains low due to deficient infrastructure and equity barriers.

Specifically, enabling conditions under SDG 9; such as network reliability, XR labs, and supported faculty development; weak, preventing the transition from perceived usefulness to actual use. Concurrently, equity frictions, particularly around women's participation, affordability, accessibility, and privacy, undermine inclusion and alignment with SDG 5 and SDG 10.

The research contributes theoretically by adapting the UTAUT framework to a Global South, low-adoption setting and integrating structural and equity considerations. Practically, it proposes a contextualized, SDG-aligned roadmap for EMV implementation that moves beyond attitude-based models toward institutional transformation. This study demonstrates that immersive technologies cannot thrive on enthusiasm alone; systemic preparedness and inclusive design are vital. Without investment in enabling infrastructure and policy safeguards, EMV may reinforce educational divides rather than bridge them. Future research should expand into rural contexts and monitor longitudinal outcomes to build a more holistic, inclusive digital education ecosystem in line with SDG 4.

6. Discussion and Implications

The findings reaffirm that institutional readiness is a prerequisite for effective educational metaverse (EMV) adoption in Pakistan's teacher education sector. Despite enthusiasm for immersive learning, the absence of XR-compatible infrastructure, faculty training, and coherent digital policy continues to hinder sustainable implementation, consistent with evidence from other emerging contexts (Abdulmuhsin et al., 2025; Bhat et al., 2025; Khalil & Jumani, 2024). While global frameworks such as UTAUT and UTAUT2 emphasize behavioral intention and perceived usefulness (Mukred et al., 2025; Al-Sharafi et al., 2024), this study shows that in resource-limited systems, institutional and governance readiness outweigh individual willingness to adopt innovation.

Another general theme that arose was equity issues linked to women's participation and access to digital access. Although this study conducted research in urban universities, the research indicates that there are ongoing gender and geographic disparities in internet transformation in developing countries (Diao and Su, 2025; Rashid, 2025). To incorporate SDG 5 (Women's Participation and Safety) and SDG 10 (Reduced Inequalities) in EMV policy frameworks is thus of utmost importance. Unless implemented inclusively, metaverse projects can contribute to concentrating the differences instead of eliminating them (Al-Adwan et al., 2024; Rehman et al., 2025).

Perversity introduces coherence impediments on EMV development as well. The disconnect between the digital goals of Vision 2025 and the capabilities of higher education institutions to deliver their goals reflects the lack of governance in the rest of the Global South (Abdulmuhsin et al., 2025; Rao, 2024). This paper places adoption of EMV not just as a technological reformation but as a systemic change that would require integration of aligned approaches, financial funding and intersectoral coordination. It makes a theoretical contribution by suggesting a hybrid UTAUT-SDG framework that melds

sustainability and equity in institutional preparedness paradigms, providing an evidence-based standard to guide policymakers on the future of inclusive EMV integration in teacher education.

Conflicts of Interest

Authors declare that they have no conflict of interest.

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Ethics Approval and Informed Consent

The study was conducted in accordance with institutional research guidelines. Participation was voluntary, and informed consent was obtained from all participants.

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