IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# DETERMINANTS OF EXTENDED REALITY (XR) ADOPTION IN HIGHER EDUCATION: A REVIEW OF THEORETICAL AND EMPIRICAL LITERATURE WITH REFERENCE TO SUB-SAHARAN AFRICA

*A synthesis of learning and technology-adoption theory against global, African and Ugandan evidence on immersive learning*

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***Abstract:*** Extended Reality (XR), covering augmented reality, virtual reality and mixed reality, is increasingly proposed as a tool for transforming teaching and learning in higher education. Much of the existing evidence on XR adoption comes from well-resourced institutions in North America, Europe and East Asia, which leaves open the question of whether the same theoretical explanations hold in resource-constrained settings such as Sub-Saharan Africa. This paper reviews the theoretical and empirical literature on XR adoption in higher education, drawing on constructivism, experiential learning theory, the Technology Acceptance Model, Diffusion of Innovations theory, situated learning theory and the Resource-Based View. The review synthesizes evidence from global, African and Ugandan sources to identify the internal institutional factors, namely technological readiness, human capacity, contextual adaptability and economic viability, that shape XR adoption, and it examines institutional support as a factor that strengthens or weakens these relationships rather than acting as an independent predictor. The review finds that existing frameworks explain individual and organizational adoption behavior reasonably well but rarely account for the infrastructural and cultural conditions typical of low-resource universities. It closes by identifying gaps around the localization of XR content, the sustainability of donor-funded pilots, and the limited empirical treatment of institutional support as a moderating variable, and it proposes a consolidated framework to guide future empirical research in this area.

***Index Terms*** - Extended Reality, Technology Adoption, Higher Education, Technology Acceptance Model, Diffusion of Innovations, Institutional Support, Sub-Saharan Africa, Uganda

## I. INTRODUCTION

Extended Reality has moved from a novelty demonstration technology to a recognised instructional tool in universities worldwide, and interest in its classroom use has grown alongside falling hardware costs and the spread of mobile-based augmented reality. A systematic review covering 295 studies published in higher education between 2020 and 2024 found that research activity has increased sharply over that period, with virtual reality remaining the most studied modality and science-related disciplines the most common setting [1].

Most of this evidence base, however, originates in institutions with dependable electricity, campus-wide connectivity and dedicated XR laboratories. Universities in Sub-Saharan Africa, including Uganda, operate under materially different conditions, and the transferability of adoption models developed elsewhere cannot simply be assumed. This review therefore asks a narrower question than whether XR improves learning outcomes: it asks what combination of theoretical explanation and contextual evidence best accounts for whether and how XR is adopted in universities that face real infrastructural, financial and human-capacity constraints.

The review draws on theoretical literature on learning and technology adoption, systematic reviews of XR in higher education published between 2020 and 2026, and empirical and grey literature specific to Uganda and neighbouring countries, including institutional reports, pilot project documentation and government policy papers. Sources were selected for their relevance to the determinants of adoption rather than to the instructional outcomes of XR use, since the outcome literature is already well covered by existing systematic reviews [1], [2].

## II. Theoretical Foundations of XR Adoption

No single theory captures both why learners benefit from immersive environments and why institutions choose to adopt or reject the technology that delivers them. This review therefore combines five bodies of theory: two that explain the pedagogical value of XR (constructivism and experiential learning theory), one that explains individual user acceptance (the Technology Acceptance Model), one that explains how innovations spread through organisations (Diffusion of Innovations), and one that explains the institutional conditions under which adoption is strengthened or weakened (the Resource-Based View). Table 1 summarises these theories and their relevance to XR adoption, and Figure 1 shows how they combine into a single explanatory structure.

### *2.1 Constructivism and Experiential Learning*

Constructivism holds that learners build knowledge through active engagement rather than passive reception, and that social interaction, in Vygotsky's account, allows a more capable peer or instructor to support a learner within their zone of proximal development until the support can gradually be withdrawn [3]. XR platforms operationalise this directly: a student can manipulate a three-dimensional model, repeat a procedure until it is understood, and receive guided correction from an instructor inside the same virtual space. Kolb's experiential learning cycle, moving through concrete experience, reflective observation, abstract conceptualisation and active experimentation, offers a closely related account of why simulation-based XR tools such as virtual laboratories are pedagogically effective: they let a learner experience a procedure, reflect on the outcome, connect it to theory, and try again with a modified approach, without the safety or resource constraints of a physical laboratory [4].

### *2.2 Technology Acceptance Model*

Davis's Technology Acceptance Model argues that a user's intention to adopt a technology depends on two beliefs: that the technology will improve their performance, described as perceived usefulness, and that using it will not require excessive effort, described as perceived ease of use [5]. In educational technology research, TAM remains the most frequently applied acceptance framework, including in recent systematic reviews of XR use in medical education, where perceived usefulness has consistently outperformed ease of use as a predictor of continued adoption [6]. For XR specifically, ease of use is not a fixed property of the technology but a function of training: lecturers who receive structured, hands-on exposure to a platform report markedly higher confidence and a stronger intention to use it in regular teaching than those given only a brief demonstration [7].

### *2.3 Diffusion of Innovations*

Rogers' Diffusion of Innovations theory explains adoption as a social process that moves through identifiable adopter categories, from innovators and early adopters through to the early majority, late majority and laggards, and it identifies five attributes, relative advantage, compatibility, complexity, trialability and observability, that determine how quickly an innovation spreads [8]. Applied to XR in higher education, institutions in Sub-Saharan Africa remain overwhelmingly in the innovator or early-adopter categories, with uptake concentrated in isolated pilot projects rather than institution-wide deployment. Diffusion theory predicts, and the evidence reviewed in Section IV supports, that adoption accelerates once early users can demonstrate a visible, relatable advantage over existing teaching methods within a curriculum that recognisably reflects the institution's own courses [2].

### *2.4 Situated Learning Theory*

Lave and Wenger's situated learning theory argues that knowledge is best acquired through participation in authentic, socially embedded practice rather than abstract instruction detached from context [9]. Applied to XR, this suggests that the pedagogical value of a virtual environment depends less on its technical sophistication than on how closely it reflects the learner's own professional, cultural and curricular context. A virtual laboratory built around imagery, terminology and case material unfamiliar to the learner offers a weaker situated-learning experience than one built around locally recognisable content, even where the two are technically identical.

### *2.5 Resource-Based View as a Moderating Lens*

The Resource-Based View treats organisational resources, including leadership commitment, budget allocation and cross-departmental coordination, as the mechanism through which individual and technological capabilities are converted into institutional outcomes [10]. Applied to XR adoption, the Resource-Based View supports treating institutional support not as a standalone predictor of adoption but as a moderator: an institution with strong technological readiness and capable staff will still under-perform on adoption if leadership does not allocate budget, coordinate departments or formally recognise XR-based teaching, whereas the same readiness and staff capability translate more fully into adoption where institutional backing is present.

### *2.6 Toward an Integrated Framework*

Figure 1 draws these five bodies of theory together. Constructivism and experiential learning explain the pedagogical layer, that is, why immersive experience improves learning; the Technology Acceptance Model explains the individual layer, why a lecturer or student chooses to use the tool; Diffusion of Innovations explains the institutional and social layer, why adoption spreads unevenly across a university; situated learning theory explains the content layer, why localisation determines whether the experience is meaningful; and the Resource-Based View explains the moderating layer, why institutional backing determines whether readiness and capability actually convert into adoption. None of these theories was developed with resource-constrained universities in mind, and the empirical literature reviewed in Section IV tests how well they hold up once electricity, connectivity, funding and locally relevant content are taken into account.

TABLE 1: SUMMARY OF THEORETICAL FRAMEWORKS UNDERPINNING XR ADOPTION RESEARCH

| Theory | Originator | Core premise | Relevance to XR adoption |
|---|---|---|---|
| Constructivism | Piaget; Vygotsky | Learners actively build knowledge through experience and guided social interaction. | Explains why immersive, manipulable XR content deepens understanding. |
| Experiential Learning Theory | Kolb (1984) | Learning is a cycle of concrete experience, reflection, conceptualisation and experimentation. | Explains why simulation-based XR tools support skill acquisition. |
| Technology Acceptance Model | Davis (1989) | Adoption intention depends on perceived usefulness and perceived ease of use. | Explains individual lecturer and student acceptance of XR tools. |
| Diffusion of Innovations | Rogers (1962) | Innovations spread through adopter categories based on relative advantage, compatibility, complexity, trialability and observability. | Explains how XR moves from isolated pilots to institution-wide use. |

| | | | |
|---|---|---|---|
| Situated Learning Theory | Lave and Wenger (1991) | Knowledge is acquired through participation in authentic, contextualised practice. | Explains why locally relevant XR content is adopted more readily. |
| Resource-Based View | Barney (1991) | Organisational resources determine whether capability converts into performance. | Explains institutional support as a moderator of adoption, not a direct predictor. |

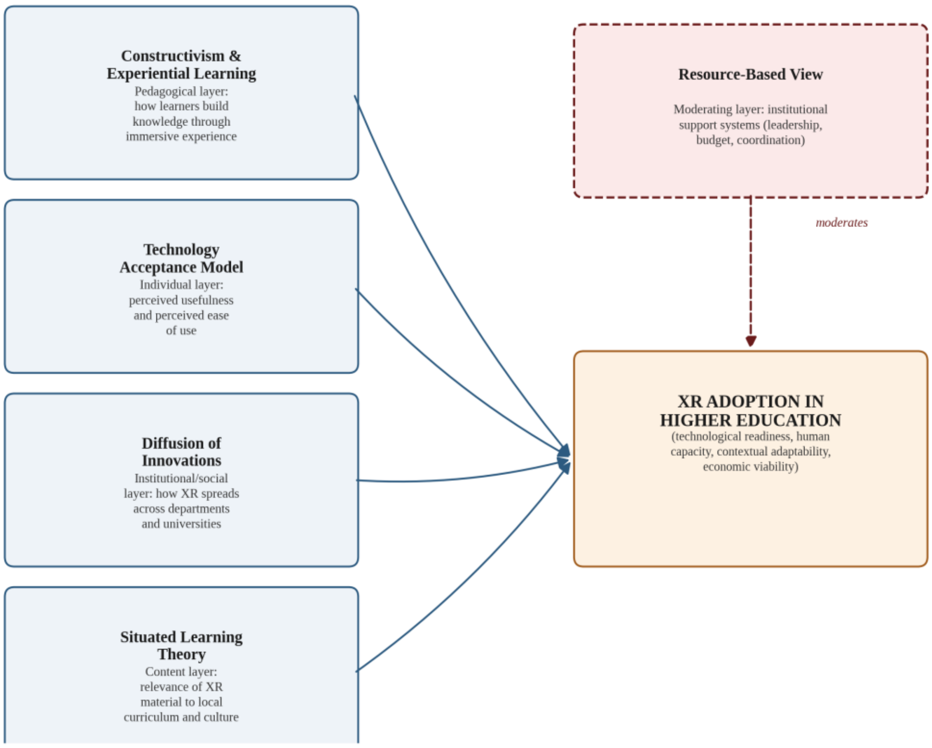


fig. 1: an integrated theoretical framework for xr adoption in higher education

## III. Global and Regional Evidence on XR Adoption

### *3.1 Evidence from High-Income Countries*

The largest body of empirical evidence on XR in higher education originates from North America, Europe and parts of East Asia. The systematic review referenced in Section I found that publication activity in this field is concentrated in the United States and that undergraduate science courses are the most common setting for XR-based instruction [1]. Google Expeditions offered a widely used model for virtual field trips before its discontinuation, Labster's virtual science laboratories are now embedded in numerous European and American university curricula, and platforms such as EON-XR support role-play based soft-skills training. A parallel systematic review of XR in engineering education identified consistent gains in engagement and skill acquisition but also flagged a persistent gap between demonstrated classroom benefit and institution-wide deployment, attributing the gap to cost, infrastructure requirements and the training burden placed on faculty [2].

### *3.2 Evidence from the Global South*

Where XR research exists outside high-income settings, it points to a different adoption pathway. Studies from India and Kenya report that smartphone-based augmented reality scales more readily than headset-based virtual reality in low-resource environments, since it removes the hardware cost barrier while retaining much of the pedagogical benefit [11]. A review of immersive technology adoption across African education systems found that most implementations remain donor-funded pilots rather than institutionally embedded programmes, and it identified teacher training, not device cost alone, as the more persistent constraint on scale [12]. A related review of augmented reality use in South African higher education reached a similar conclusion, noting that engagement gains were well documented at the pilot stage but that sustained, curriculum-wide use required institutional coordination that most of the reviewed cases lacked [13].

### *3.3 Evidence from Uganda*

Uganda's National ICT Policy recognises the potential of digital and immersive learning tools but does not set out an implementation pathway specific to XR [14], [15]. Documented pilot projects illustrate both the promise and the fragility of current adoption. Makerere University has used virtual reality for medical training, relying on donor-funded headsets [16]. The Uganda Institute of Information and Communications Technology partnered with EON Reality to develop localised content, but the initiative has faced scalability constraints tied to cost [17]. At ISBAT University, Meta Quest 3 devices have been used to deliver virtual laboratory and anatomy content for medical laboratory technology students, and a separate pilot introduced a collaborative 3D review platform to engineering and medical lecturers for classroom demonstration. Table 2 summarises the success factors, limitations and lessons drawn from these Ugandan cases alongside a wider regional comparison.
Infrastructure remains the binding constraint across nearly all of the Ugandan evidence. The great majority of the country's primary schools are not connected to the national electricity grid, and institutions that rely on solar power report materially more stable XR access than those dependent on an unreliable grid connection [18], [19]. Teacher and lecturer attitudes compound the infrastructural gap: surveys of Kampala-based educators report broad interest in XR but consistently cite a lack of training and curricular misalignment as the reason adoption stalls after an initial pilot [20].

TABLE 2: XR PILOT PROJECTS ACROSS UGANDA AND THE WIDER AFRICAN REGION

| Project / country | Success factor | Limitation | Lesson learned |
|---|---|---|---|
| ISBAT University (Uganda) | Affordable devices, educator training, localised content | Uneven readiness across departments | Low-cost AR is workable if funding policy supports curriculum integration. |
| Makerere University (Uganda) | Curriculum-aligned VR in medical training | Infrastructure limits and accessibility challenges | Structured device and curriculum training is essential before scale-up. |
| Victoria University (Uganda) | Improved grasp of practical skills, international partnerships | Device cost and scalability | XR increases engagement with complex, spatial or abstract subject matter. |
| Regional Global South projects | Multi-stakeholder engagement, adaptable content | Infrastructure gaps, limited cultural relevance | Collaboration and localisation are consistent enablers of adoption. |

## IV. Factors Influencing XR Adoption: A Thematic Synthesis

Read together, the theoretical and empirical literature converges on four internal institutional factors that determine whether XR moves beyond a pilot, and one factor that determines how strongly those four translate into actual adoption.

### *4.1 Technological Readiness*

Reliable electricity, device availability and adequate connectivity remain the most frequently cited precondition for XR adoption in the literature reviewed, and the evidence from Uganda and the wider region suggests this constraint is more binding than in the high-income settings where most XR theory was developed. Diffusion of Innovations theory frames this as a question of trialability: a technology that cannot be reliably tested in a classroom because of power interruptions will struggle to move past the innovator stage regardless of its pedagogical merit.

### *4.2 Human Capacity*

TAM's twin constructs of perceived usefulness and perceived ease of use map closely onto the training gap documented across the Ugandan and regional literature. Educators who receive structured, hands-on exposure to an XR platform consistently report higher confidence and stronger adoption intention than those given only a brief demonstration, a pattern consistent with recent systematic evidence from medical education, where training exposure was the strongest single predictor of continued TAM-based acceptance [6].

### 4.3 Contextual Adaptability

Situated learning theory and the empirical literature agree that content relevance, not technical sophistication, determines whether XR material is adopted into regular teaching. Reviews of both African and Ugandan cases identify a persistent mismatch between predominantly Western-produced XR content and the curricular, linguistic and cultural context of local learners, a gap that several reviewed studies treat as a stronger barrier to sustained use than cost [21], [22].

### 4.4 Economic Viability

Diffusion theory's concept of relative advantage only operates where an institution can plausibly afford to sustain the technology once a pilot ends. The literature is consistent in identifying ongoing financing, rather than the initial cost of a pilot cohort of headsets, as the more durable barrier, since donor-funded pilots repeatedly demonstrate feasibility without establishing a funding model that survives beyond the grant period [23], [17].

### 4.5 Institutional Support as a Moderating Factor

Consistent with the Resource-Based View, the literature increasingly treats institutional support, meaning leadership commitment, budget allocation and cross-departmental coordination, not as a fifth independent predictor alongside the other four but as the mechanism that determines whether readiness, capacity, adaptability and viability actually convert into adoption. Figure 2 sets out this relationship as a conceptual model: the four internal factors act on XR adoption directly, while institutional support strengthens or weakens each of those paths rather than acting on adoption independently.

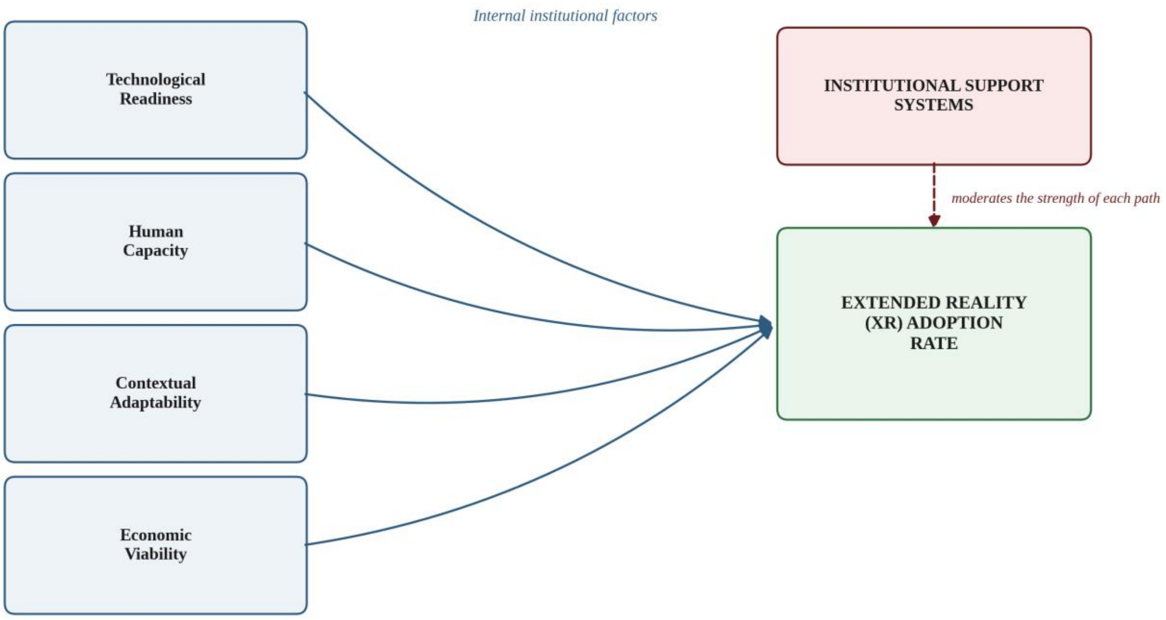


fig. 2: conceptual model of internal factors and institutional support in xr adoption

## V. Research Gaps

Three gaps stand out from the literature reviewed. First, the evidence base on XR adoption remains heavily weighted toward high-income institutions, and frameworks such as TAM and Diffusion of Innovations, while broadly applicable, have rarely been tested under the infrastructural and financial constraints typical of Ugandan and comparable Sub-Saharan African universities. Second, most of the available African and Ugandan evidence documents individual pilot projects rather than testing a unified model that accounts for technological readiness, human capacity, contextual adaptability and economic viability together. Third, institutional support is usually treated descriptively, as one barrier among several, rather than tested statistically as a moderating variable that changes the strength of the other relationships. Table 3 maps these gaps against the theoretical and empirical literature reviewed above.

TABLE 3: RESEARCH GAP MATRIX

| Theory | Empirical evidence | Context | Identified gap |
|---|---|---|---|
| Constructivism | XR supports hands-on and social learning | Locally produced, interactive XR content remains limited | Need for curriculum-relevant, culturally embedded XR material. |
| Technology Acceptance Model | Training improves perceived usefulness and acceptance | Technical ease of use remains a barrier despite training | Insufficient funding for ongoing professional development. |
| Diffusion of Innovations | Pilot projects at Makerere, ISBAT and UICT | Adoption concentrated in donor-funded, uneven pilots | Sustainable funding and policy alignment beyond pilot phase. |
| Situated Learning / cultural context | Authentic, localised practice improves learning | Most XR content remains Western-centric | A systematic approach to localising content with local educators. |
| Resource-Based View | Institutional backing enables sustained technology use | Support is documented descriptively rather than tested as a moderator | Empirical models that treat institutional support as moderating, not direct. |

## VI. Conclusion

The literature reviewed here supports a central conclusion: the barrier to wider XR adoption in universities such as those in Kampala is not an absence of theoretical explanation. Constructivism, experiential learning theory, the Technology Acceptance Model, Diffusion of Innovations and situated learning theory together offer a reasonably complete account of why immersive technology should improve learning and how adoption should be expected to spread. What the literature has not yet done, particularly for Sub-Saharan African higher education, is test these explanations jointly against the infrastructural, financial and cultural conditions that determine whether a promising pilot becomes an embedded institutional practice. Positioning institutional support as a moderator of internal readiness, rather than as a separate barrier, offers one route toward closing that gap and provides the conceptual basis for the empirical study that follows this review.

## Acknowledgment

The authors acknowledge the Faculty of Information and Communication Technology, ISBAT University, Kampala, for institutional support during the preparation of this review.

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