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How to Effectively Implement eXtended Reality into Higher Education Curricula? A Report on Stakeholder Analysis and Diverging Needs

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Immersive technologies like eXtended Reality (XR) are becoming more mature and prevalent, presenting significant opportunities to enhance learners' motivation, engagement, comprehension, and long-term knowledge retention. This incentivizes higher education institutions (HEIs) to adopt XR. However, HEIs are bureaucratic organizations that are notoriously difficult to change, with a large number of decision-makers distributed across various levels of the organizational hierarchy. Thus, understanding stakeholder roles and needs is essential for successful XR integration. This study presents findings from a case study on XR implementation processes at Virginia Tech (VT), approaching the challenge as a systems engineering (SE) problem. A stakeholder identification exercise — a key step in problem formulation — documents the stakeholders involved, their roles, nuanced needs, and how these factors influence XR implementation and long-term sustainment. Findings indicate that even a relatively simple project requires the involvement of many stakeholders, leading to unpredictable latencies between stakeholder actions to overcome barriers. Furthermore, high costs associated with hardware, software, infrastructure, and content development, along with faculty skepticism and institutional resistance to change, further hinder adoption. Effective integration requires a pedagogically driven approach, prioritizing clear learning objectives over technological novelty. Although this case study focuses on VT's socio-technical system, its findings contribute to a broader understanding of the complexities associated with XR integration in HEIs. The insights guide stakeholders in navigating similar challenges. Future research should continue exploring XR's effectiveness across diverse educational contexts and refine user experiences for broader adoption.

Keywords
eXtended Reality (XR), Systems Engineering (SE), Higher Education Institution (HEI), Technology Integration, Educational Technology.

1. Introduction

As educational institutions strive to prepare students for a dynamic and increasingly digital workforce, the incorporation of eXtended Reality (XR) into higher education curricula has emerged as a promising avenue for fostering deeper learning and skill acquisition. XR is an umbrella term encompassing a range of immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). As XR technology becomes more mature and prevalent, it presents significant opportunities to enhance traditional educational methodologies by increasing learners' motivation, engagement, and long-term knowledge retention through interactive and self-regulated experiential learning opportunities that are often absent in traditional teaching methods [1]. Consequently, this places pressure on higher education institutions (HEIs) to adopt and utilize emerging technologies like XR. However, socio-technical barriers impede the integration of XR into HEI curricula [2]. Therefore, understanding the roles and relationships of associated stakeholders is essential for the successful integration of XR into educational systems.

This use case study presents results from an ongoing XR implementation at Virginia Tech (VT), a land-grant university classified as an R1 institution by the Carnegie Foundation for its high level of research activity. By adopting an SE perspective, we identify key stakeholders associated with the process; and then conduct focus group interviews to capture their perspectives, roles, and relationships in creating, implementing, and sustaining an effective XR system. We contend that characterizing the socio-technical barriers associated with XR integration could lead to actionable insights regarding how to modernize HEIs. These findings could be organized in an XR development guideline, similar to a playbook, that HEIs could leverage to enhance overall teaching and learning experiences and outcomes.

2. Related Research

XR technology is still in its evolving stage and HEIs, in particular, have been lagging in adopting new technologies and practices, such as XR [7]. According to Gartner's Hype Cycle, XR currently resides in the *Trough of Disillusionment* phase, where initial enthusiasm diminishes, and implementations often fail to meet immediate return of investment (ROI) expectations [8]. During this phase, many organizations struggle to sustain the financial and technical burdens of XR projects, leading some to exit the market. However, as technologies progress towards the *Slope of Enlightenment*, where their potential benefits become more widely recognized, and second-and third-generation products begin to emerge [9]. Strategic decision-making approaches, as outlined by the Hype Cycle, vary from risk-taking early adoption to cautious, cost-benefit-driven investments or waiting until the technology reaches the *Plateau of Productivity,* where it achieves maturity and widespread adoption [9]. At this junction, HEIs are piloting XR, recognizing their potential to enhance student recruitment, engagement, and operational readiness. Nevertheless, significant financial, technological, and socio-technical barriers hinder broader adoption in educational contexts.

Financial constraints present one of the most significant challenges to XR adoption in HEIs [6, 10]. The high initial investment required for XR hardware [4, 6, 8, 11, 12, 13], software [3, 4], and supplemental equipment (e.g., microphones, projectors, high-speed internet, advanced VR-ready computers, 360 cameras) [4, 8, 12], along with essential supporting resources (e.g., VR Lab, training, enhanced data storage) [4, 8], makes implementation particularly difficult [4]. This financial burden is further compounded by ongoing costs such as maintenance, software updates, and licensing fees, which limit scalability and the long-term effectiveness of XR tools [5, 8, 11, 13]. For many HEIs—particularly public or underfunded institutions within lower-middle-income countries—these expenses are unsustainable [3, 14] exacerbating the digital divide [2, 11, 15] and perpetuating inequalities in access to advanced educational technologies [12, 15]. Additionally, XR adoption introduces privacy and security concerns. The collection and processing of sensitive data raise compliance issues [2, 5, 15], necessitating costly cybersecurity measures [15] and increasing the complexity of legal implementation [2]. Technological limitations also pose significant hurdles. Many HEIs lack the necessary infrastructure [5, 16] to support XR integration, including compatibility with existing IT systems and Learning Management Systems (LMS) [13]. Furthermore, current XR systems face challenges such as lag [4, 8, 12], tracking inaccuracies, and simulation sickness, further complicating implementation.

The successful adoption of XR technologies requires collaboration among stakeholders, including educators, administrators, instructional designers, technical support staff, and others. However, socio-technical barriers such as resistance to change [6, 13, 16], lack of a shared vision, and insufficient institutional policies [7, 16] propose significant challenges. Many educators and administrators remain skeptical about XR's benefits, questioning its alignment with learning objectives [5, 13, 17] and the potential for unintended consequences (e.g., reducing face-to-face interaction or causing distractions) [5]. Faculty members may also feel overwhelmed by the additional workload of developing XR content [4, 5], which demands significant coordination [1, 5, 13], and the acquisition of necessary hardware and software [6, 11]. Without institutional support, including clear leadership [2, 5, 16], funding [5, 16], and pedagogical frameworks [2, 8, 16, 17], these challenges will remain unaddressed. Ensuring accessibility and inclusivity is another pressing concern [2, 11, 18], particularly for students with visual impairment or disabilities [12, 15]. XR environments must be designed to accommodate diverse learners [2, 12, 13, 17], yet many institutions lack the policies and technical expertise to do so effectively. Additionally, digital literacy gaps hinder effective XR adoption. Many educators require professional development to familiarize themselves with XR tools, integrate them into curricula, and apply active learning strategies [1, 6, 8, 11, 13]. Meanwhile, students, despite their enthusiasm, vary in their readiness and confidence to engage with advanced technologies [2, 4, 5, 8, 19], leading to disparities in learning experiences. To bridge this gap, institutions must provide social support [4], technical assistance [5, 13], and user experience (UX) research [4, 6] to enhance adoption.

3. Methodology

This study employed a single-case study approach, focusing on the integration of XR at VT Environmental Health & Safety's (EHS) Portable Fire Extinguisher (PFE) module. EHS PFE was selected because of its generalizability to a multidisciplinary community of students, faculty, and staff who are responsible for using fire extinguishers. PFE certification is mandatory before they can engage in maintenance, and class/lab activities. While the single-case approach may limit generalizability, it offers the depth and contextual richness necessary for identifying complex stakeholder dynamics and real-world barriers. This study serves as an exploratory phase in a broader research agenda.

We then treated this implementation challenge as a systems engineering (SE) problem and adopted a SE lens for stakeholder identification [20, 21]; an essential problem formulation task that is critical for any new system design or implementation activity [22, 23]. This allows us to characterize the entire ecosystem of stakeholders involved in planning, deploying, supporting, and using the technology, leading to key stakeholders associated with the process. More specifically, it allows us to categorize these stakeholders into two main classes: *active* (directly engaged in use, implementation, and sustainment after deployment) and *passive* (indirectly affected or providing peripheral support). Based on the literature, relevant stakeholders and their roles were identified. Subsequently, interested stakeholders were invited to participate in focus group discussions to explore their perspectives in greater depth. These discussions aimed to capture needs, roles, relationships, experiences, and potential barriers in the XR implementation process. Participants were solicited through the XR_Community of Practice listserv. Two focus groups were conducted with a total of fourteen (N = 14) participants across 10 departments at VT, consisting of nine (n = 9) faculty (F) and five (n = 5) staff (S) university stakeholders interested in XR adoption, as shown in Table 1. We chose to focus on faculty and staff in these discussions because they are ultimately responsible for selecting, designing, and implementing XR modules in alignment with course objectives and institutional policies. While we recognize the importance of student perspectives, students are end-users of these technologies who typically do not have decision-making authority for curricular integration. Focus group sessions were conducted in a hybrid format. A Canva presentation slide deck (screen-shared via Zoom) guided the discussions and was audio/video recorded (with participant consent) for transcription and in-depth analysis. Focus group sessions lasted approximately 90 minutes. Then, focus group recordings were transcribed verbatim and exported to a Word document for thematic analysis. The transcripts were manually coded to identify common themes, patterns, and insights related to stakeholder perspectives, roles, and needs.

Table 1: Participant Specialties and Roles

Department	Role	Count
Veterinary Medicine (Vet Med)	Associate Professor of Practice	1
Interior Design (ITDS)	Assistant Professor	1
Computer Science (CS)	Professor; HCI Deputy Director	1
	Assistant Professor	2
Food Sciences & Technology (FS&T)	Assistant Professor of Practice	1
Sustainable Biomaterials (SBIO)	Assistant Professor	1
Industrial & Systems Engineering (ISE)	Professor	1
General Chemistry (CHEM)	Lab Manager	1
General Engineering (GE)	Director	1
Undergraduate Education (UG)	Assistant Vice Provost	1
Construction Engineering & Management (CEM)	Adjunct Professor; EHS Health and Safety Training Coordinator	1
University Library (UL)	Assistant Director, Studios & Innovative Technologies	1
	Executive Director, ARIES	1
	Total	**14**

4. Results

4.1. Perceived Benefits and Limitations of XR in Education

When asked, "How do you envision XR enhancing education and classrooms in the next five years?", responses revealed a mix of cautious optimism and critical reflection. On the positive side, one faculty member envisioned XR as a means to enhance team-based collaboration and simulation-based learning. Two participants (1F/1S) described XR's potential to support immersive "field trip" experiences, which could engage students in novel ways. Another faculty participant saw promise in combining XR with artificial intelligence to foster active learning, although they emphasized that AI and XR bring distinct cost-benefit considerations. Despite these possibilities, three participants (2F/1S) raised concerns about the cost and scalability of XR technologies, particularly in large lecture-based settings. Two participants questioned the incentive for adoption, citing the limited impact of earlier technologies like Zoom on learning outcomes. Other concerns included over-reliance on hardware such as head-mounted displays (HMDs), which participants noted could lead to motion sickness and limit accessibility. One faculty participant suggested that XR experiences should be offered in diverse modalities, including tablet-based formats, to increase usability and inclusion.

4.2. Stakeholder Perspectives on XR Adoption

Participants were first asked, "Are there any other stakeholders essential in enhancing the XR implementation process?" In response, several participants highlighted the importance of expanding the stakeholder group beyond faculty and students to include instructional designers, IT staff, administrators, and curriculum planners. The full stakeholder map is presented in Figure 1. Two staff participants emphasized that XR adoption should align with subject-specific needs and account for individual learning differences, as certain disciplines may not benefit equally from the technology. A faculty member stressed the need for robust collaboration among departments to address challenges in implementing XR effectively. Several participants also noted that without pedagogical creativity and institutional support, XR runs the risk of being underutilized or simply replicating traditional teacher-centered models.

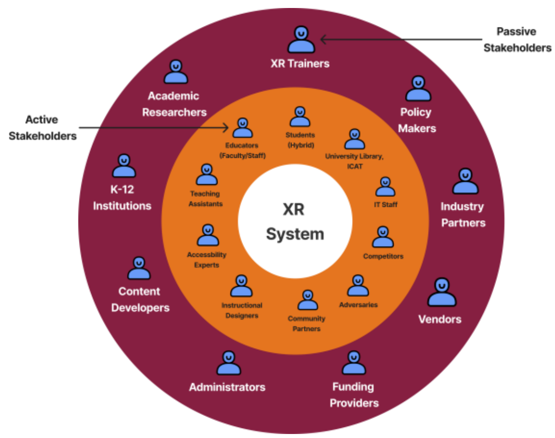

Figure 1: Active & Passive Stakeholder Map

4.3. Barriers to Implementation and Recommendations

In discussing concerns and prior experiences with XR in classrooms, participants identified several barriers to effective implementation. Two faculty members pointed to logistical difficulties such as managing and sanitizing equipment for large classes, as well as inequities for students lacking access to necessary devices. Another faculty member expressed concern over the sustainability of XR platforms, given the rapid evolution of hardware and software, and the unreliability of vendors. One staff member emphasized the importance of designing XR experiences that are accessible to students with disabilities and adaptable to diverse learning styles to avoid deepening the digital divide. Participants agreed that XR should not be integrated superficially as a visual novelty. Instead, two (1F/1S) participants stressed the importance of clear learning objectives, structured curricular planning, and robust instructional design to ensure meaningful use. A faculty member noted that poor preparation and lack of faculty training in a past XR deployment had led to student discomfort and simulation sickness. She emphasized that successful implementation requires weeks of planning, defined goals, and faculty buy-in. Other participants reiterated the need for centralized institutional support and emphasized that cost-benefit analyses are critical to justify XR's value relative to traditional instructional methods. Figure 2 visualizes the relationships among stakeholders involved in XR implementation.

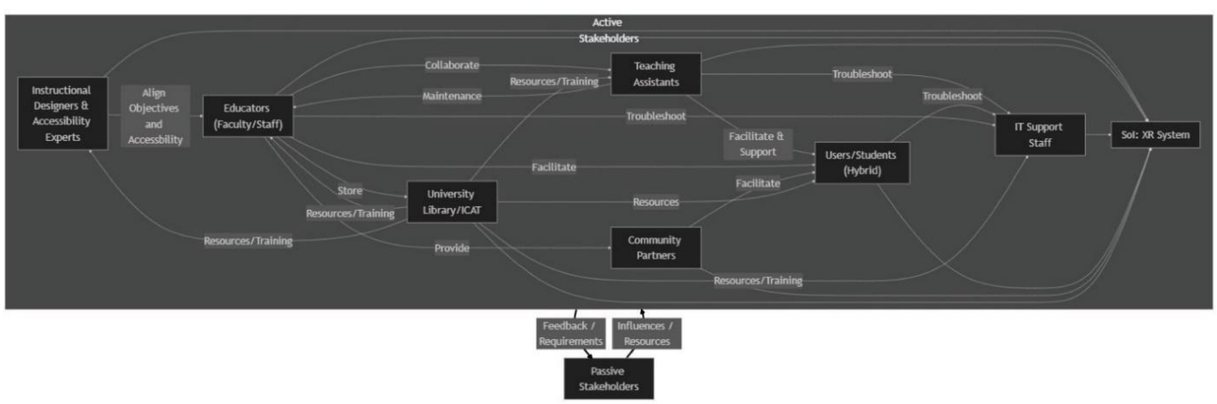

Figure 2: XR Integration Stakeholder Context Diagram

5. Discussion & Conclusion

The findings underscore both the potential and the challenges of adopting XR technologies in HEIs. While XR offers transformative opportunities for safety training, conceptual visualization, and experiential learning, its adoption is hindered by financial, logistical, and pedagogical barriers. High costs for hardware [4, 6, 8, 11, 12, 13], software [3, 4], and infrastructure [4, 8], combined with challenges in content development [4, 5], need for ongoing maintenance [5, 8, 11, 13], and training [1, 6, 8, 11, 13], pose significant challenges. Faculty and institutional hesitance to change further complicates adoption [6, 13, 16], driven by skepticism about XR's pedagogical value [5, 13, 17] and the absence of clear frameworks [2, 8, 16, 17] that align the technology with educational objectives.

Participants emphasized the need to focus on the pedagogical "why" rather than the technological "wow" of XR. Effective implementation requires clear instructional goals and demonstrable benefits over traditional methods [5, 13, 17]. Instructional design teams play a key role in aligning XR with teaching strategies, ensuring that it enhances learning rather than serving as a novelty. There are significant disparities in XR expertise and adoption across different disciplines. Engineering fields lead the way in XR due to existing familiarity with emerging technologies. In contrast, departments such as general education and chemistry remain at an exploratory stage. Cross-disciplinary collaboration can help share knowledge and resources, accelerating broader adoption by pooling expertise and guiding less tech-focused disciplines. Another critical theme is accessibility and equity. Participants called for affordable, inclusive solutions that accommodate a wide range of learning styles [1, 3, 6, 18] and students with disabilities [12, 15]. Ensuring equitable access is essential to avoid exacerbating the digital divide [2, 11, 15]. This underscores the need for institutions to prioritize funding and support so that XR tools remain accessible to all learners.

An emerging trend noted by participants is the integration of AI with XR, which has the potential to deliver innovative assessment practices focused on formative evaluations and process-based learning over traditional methods. This combination could enable more adaptive feedback loops and personalized learning experiences [2, 12, 13, 17], though research on its long-term effectiveness is still needed. While participants were cautiously optimistic about XR's potential, they emphasized that adoption is likely to be gradual and most impactful in targeted, high-value use cases – such as safety training and conceptual visualization - rather than as a replacement for traditional instruction. However, there is a need to balance cost and fidelity, with many advocates for supplemental, lower-fidelity experiential tools to manage resource constraints effectively. While the identified socio-technical barriers — cost, scalability, training, and accessibility — are well-documented in the literature, this study contributes a structured stakeholder framework grounded in systems engineering that offers a new lens for strategic planning in XR integration. By focusing on ecosystem-level dynamics, this approach moves beyond individual-level adoption to identify systemic leverage points, including institutional support mechanisms, cross-departmental collaboration, and instructional design infrastructure.

These insights provide a foundation for developing targeted implementation strategies and informed policy recommendations that can better align XR initiatives with institutional priorities. This case study serves as an early phase in a broader, longitudinal research program aimed at building both conceptual and empirical contributions. Future work will focus on developing stakeholder-informed insights, designing and evaluating pilot XR modules across varied disciplines, and analyzing the effects on teaching, student engagement, and learning outcomes. Comparative studies across institutions and disciplines will further assess the scalability and transferability of the proposed stakeholder framework. These steps are essential to building a robust evidence base that informs sustainable XR adoption and contributes methodological rigor to the evolving XR-in-education research landscape.

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