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Original Article

EMPIRICAL ANALYSIS OF EXTENDED REALITY ADOPTION IN STEM EDUCATION: A FACULTY-CENTRIC STUDY USING STATISTICAL AND PREDICTIVE MODELLING

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ABSTRACT

Extended Reality (XR) - a combination of virtual, augmented, and mixed reality technologies- is emerging as an innovative tool in STEM education. XR technologies provide faculty and students with engaging and interactive teaching and learning experiences. However, the factor that is relatively less researched, but directly influences the successful integration of XR in higher education, i. e., faculty adoption, is overlooked. This study analyzes the factors influencing university faculty's adoption and integration of XR in STEM education by focusing on four-dimensional factors. The **contextual factors** review institutional support and infrastructure of the academic institutions, **individual factors** examine digital literacy levels, and experience with XR for STEM faculty, **social factors** review the influence of peer collaboration and student feedback, and **technological features** examine the usability of XR tools and privacy concerns for the faculty and student data. Using a faculty-centric approach, a survey of 500 STEM faculty members was conducted, and rigorous statistical analyses were employed, including independent t-tests, ANOVA, Chi-square tests, and multiple regression, to evaluate the impact of these factors. Results show that **student feedback** is the major factor influencing XR adoption, followed by **institutional support** and **ease of use**. Contrarily, **data privacy concerns** and **digital literacy gaps** are identified as major barriers to XR integration in STEM education. Based on the findings of the survey, the study outlines (1) the need for XR-based faculty training; (2) the need for increased institutional support; and (3) the need for user-centric design of XR tools as the main considerations to enable effective use of XR in higher education. The results emphasize the need to factor both technical and social aspects, facilitating a successful XR integration; thereby creating a foundation for potentially new and more interactive forms of pedagogy.

Keywords: Extended Reality (XR), STEM education, faculty adoption, technology integration, predictive modelling, institutional support, data privacy

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INTRODUCTION

Recent technological advancements, including artificial intelligence, gamification, mobile learning, etc., have transformed the higher educational ecosystem, enabling innovation in learning interaction and engagement (Pan & Mow, 2023). One of these technologies, Extended Reality (XR) — an umbrella term for virtual reality (VR), augmented reality (AR) and mixed reality (MR) — can create immersive and experiential learning experiences (Ajit, 2021).

XR enables students to visualize complex scientific concepts, simulate real-world experiments, and interact with educational content in ways that were previously unattainable in traditional classrooms (Doolani et al., 2020; Khlaif et. al., 2024). These capabilities make XR particularly valuable in **STEM education**, where bridging the gap between abstract concepts and practical applications is critical (Lai & Cheong, 2022; Guo et al., 2021).

In spite of its potential, the adoption of XR in higher education remains irregular, with faculty members playing a crucial role in its integration into curricula. While prior research has explored the technical and pedagogical benefits of XR, there is a notable gap in understanding the factors that influence **faculty adoption** of these technologies. Current research mainly explores the conditions of student outcomes or technical feasibility, and does not consider the views of educators who have the final decision to implement XR in the class (Hoyer et al., 2020; Salinas et al., 2022; Alnagrat et al., 2021; Meccawy, 2023). This gap is even more pronounced in STEM, where the technical nature of materials and the necessity for hands-on learning make XR adoption challenging. This study bridges the current research gap by evaluating the factors that determine the adoption of XR in STEM education by university faculty.

This research introduces a multi-dimensional framework (Table 1) that dives into several aspects:

1. Contextual Factors: How much support does the institution provide? What is the infrastructure quality?
2. Individual Factors: Are teachers digitally literate? Does the technology fit with how they like to teach?
3. Social Factors: What is the influence and support from colleagues or students?
4. Technological Features: Is the technology easy to use? How well does it protect data privacy?
5. These four dimensions, integrated, give a complete picture of all factors that make-or-break XR adoption.

The novelty of this study lies in its focus on faculty perspectives, combining real-world survey data with advanced statistical techniques to identify the main factors behind the adoption of XR in STEM education. Studies already done in the field of XR in education focused on qualitative methods, while this study takes a different approach by using quantitative tools - like independent t-tests, ANOVA, Chi-square tests, and multiple regression analysis - to thoroughly examine the factors influencing adoption.

This study is focused on the following research questions:

1. What is the role of contextual, individual, social, and technological factors in adopting XR for STEM education?
2. What are the factors that have the most significant impact on faculty willingness to use XR?
3. What challenges are preventing widespread XR adoption, and how can they be overcome?

By analyzing these research questions through the survey responses, the study provides valuable insights for educational institutions, faculties, XR technology engineers planning to enhance XR integration in STEM education.

The results highlight the need to address both technical hurdles and social dynamics to successfully bring XR into the classroom. Ultimately, this research paves the way for more creative and impactful teaching methods in STEM education.

Table 1. Multidimensional Factors affecting the adoption of XR technologies in STEM education.

Dimension	Description	Associated Factors
1: Contextual Factors	Institutional and environmental conditions influencing adoption	• Institutional Support • Funding Availability • Infrastructure • Policy Frameworks
2: Individual Factors	Faculty characteristics and prior experience	• Digital Literacy • Prior Experience with XR • Pedagogical Alignment
3: Social Factors	Collaborative and cultural influences	• Peer Collaboration • Student Feedback • Institutional Culture
4: Technological Factors	System usability and technical characteristics	• Ease of Use • Immersion Level • Data Privacy Concerns

METHODOLOGY

This research uses a quantitative approach to analyze the perspective of STEM faculty on the adoption of XR technologies in teaching pedagogy. A structured survey was designed and distributed to faculty members across multiple universities to identify the main institutional, individual, social, and technological factors that influence the willingness of faculty members to integrate XR tools into their teaching practices (Meccawy, 2023; Scherer et al., 2019; Xue et al., 2024).

The survey focused on faculty perceptions, challenges, and readiness regarding XR adoption, particularly in the context of institutional support, digital literacy, pedagogical alignment, and data privacy concerns. A variety of statistical analyses were conducted, including t-tests, ANOVA, Chi-square tests, and multiple regression analysis, to assess the significance of these factors in predicting XR adoption intent (Makransky & Petersen, 2021; Ledger et al., 2022). The structured nature of the survey allowed for a rigorous, data-driven evaluation of the adoption landscape, providing general insights across different academic ranks and levels of XR familiarity (Guo et al., 2021; Upadhyay et al., 2024). Figure 1 explains the complete research methodology in detail.

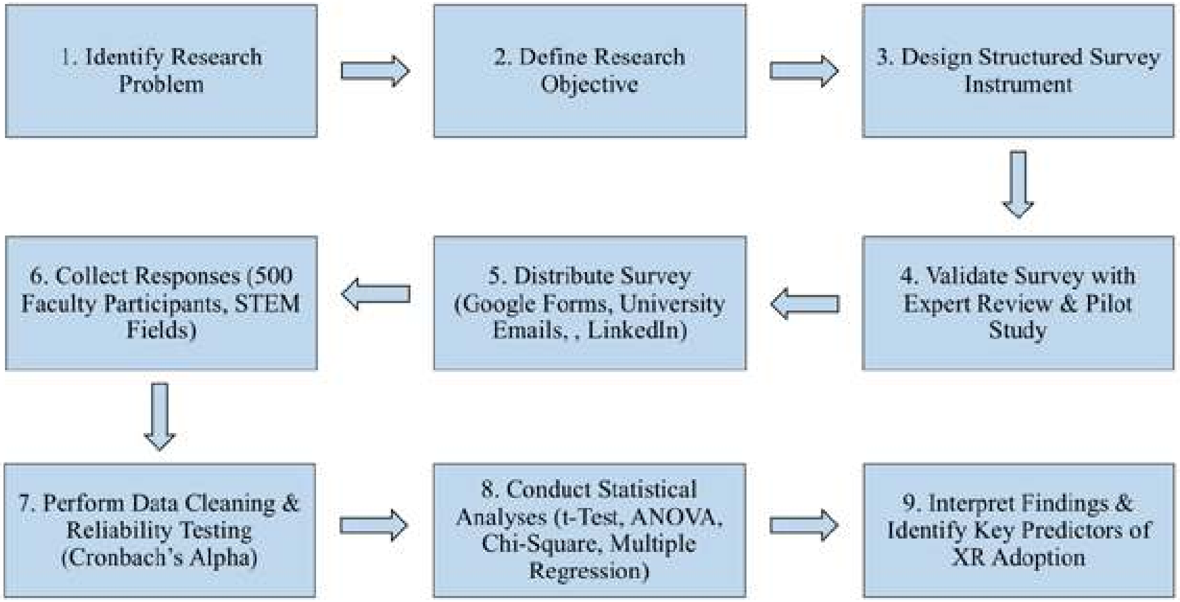


Figure 1. Preliminary research model proposal
Source: Author.

The following sections describe the survey design, participant demographics, and data analysis procedures in detail.

Survey Design

The survey was designed based on validated instruments from prior studies on technology adoption, including the **Technology Acceptance Model (TAM)** and the **Unified Theory of Acceptance and Use of Technology (UTAUT) (Scherer et al., 2019; Neves et al., 2025; Xue et al., 2024)**. A panel of three subject-matter experts reviewed the survey to ensure **face validity** and **content validity**. A pilot study was conducted with 20 faculty members to refine the clarity, wording, and response format of the survey items. Feedback from the pilot study was used to finalize the survey (Meccawy, 2023; Al-Rahmi et al., 2018).

The survey was structured around four key dimensions of XR adoption as depicted in Table 1, and sample questions in each dimension category are depicted in Table 2 (Guo et al., 2021; Upadhyay et al., 2024; Fernández-Cerero et al., 2024). Each dimension included multiple Likert-scale items (1 = strongly disagree, 5 = strongly agree), Yes/No questions, and open-ended responses to capture nuanced perspectives. The survey also included demographic questions about academic rank, teaching experience, and familiarity with XR technologies.

Table 2. Survey Questions on Factors Influencing XR Adoption in STEM Education.

Q. No.	Survey Question	Question Type	Context/ Explanation	Response Options/ Scale	Expected Analysis
DIMENSION 1: CONTEXTUAL FACTORS					
1	Your institution provides sufficient funding for implementing XR-based learning tools in STEM courses	Likert Scale	Assesses institutional funding support for XR	Strongly Disagree - Strongly Agree	Correlation with institutional adoption rates and perceived barriers
2	What are the primary institutional barriers preventing the adoption of XR in your teaching?	Multiple Choice	Identifies institutional barriers to XR adoption	Lack of funding, Lack of technical support, Institutional resistance, Other (please specify)	Factor Analysis to identify barrier patterns and correlations with institutional support
3	How often does your institution offer training or professional development programs for faculty on XR integration in STEM education?	Frequency Scale	Measures the frequency of institutional support in faculty development programs for XR	Never - Always	Descriptive statistics; Cross-tabulation with faculty adoption levels
DIMENSION 2: INDIVIDUAL FACTORS					
4	How confident are you in your ability to integrate XR tools into your teaching practices?	Likert Scale	Self-assessment of faculty confidence with XR tools	Not Confident at All -Very Confident	Correlation with actual use of XR in teaching and perceived technical support
5	Which of the following best describes your experience with XR technologies?	Multiple Choice	Categorises faculty experience with XR tools	Beginner, Intermediate, Advanced, Expert	Descriptive statistics; Cross-tabulation with adoption motivation and technical support satisfaction
6	What motivates you most to adopt XR in your teaching?	Multiple Choice	Identifies faculty motivations for adopting XR	Improving student engagement, enhancing learning outcomes, staying current with technology, and Institutional requirement	Factor Analysis to explore motivation types and correlation with adoption behaviors
DIMENSION 3: SOCIAL FACTORS					
7	To what extent do your colleagues influence your decision to adopt XR in teaching?	Likert Scale	Assesses the influence of peer interactions on XR adoption	Not at all - Very much	Correlation with collaborative behavior in curriculum design and peer discussions
8	Does your department provide opportunities for faculty collaboration on XR-based curriculum development?	Yes/No	Measures the availability of departmental collaboration opportunities on XR	Yes/No	Descriptive statistics; Cross-tabulation with faculty collaboration habits and adoption
9	How often do you discuss XR integration with your peers or attend departmental meetings on emerging educational technologies?	Frequency Scale	Assesses frequency of peer-to-peer discussions about XR	Never -Always	Frequency analysis; Correlation with adoption rates and peer influence

Table 2. Cont.

Q. No.	Survey Question	Question Type	Context/ Explanation	Response Options/ Scale	Expected Analysis
DIMENSION 4: TECHNOLOGICAL FACTORS					
10	How user-friendly do you find the current XR tools available for STEM education?	Likert Scale	Evaluates the ease of use and accessibility of XR tools	Very Difficult -Very Easy	Descriptive statistics; Cross-tabulation with technical support satisfaction
11	What are the biggest technical challenges you face when using XR in your courses?	Multiple Choice	Identifies common technical barriers to XR use	Lack of equipment, Software compatibility issues, Steep learning curve, Student access to XR tools, Other (please specify)	Factor Analysis to group technical challenges and correlation with available support
12	How satisfied are you with the level of technical support provided for XR implementation in your institution?	Likert Scale	Assesses satisfaction with technical support available for XR	Very Dissatisfied -Very Satisfied	Descriptive statistics; Cross-tabulation with institutional funding support and technical challenges

Survey Reliability and Validity

To conduct a reliability analysis of the survey, the internal consistency of the complete survey and individual dimensions were tested before circulating it to the participants using Cronbach's Alpha (Al-Rahmi et al., 2018; Scherer et al., 2019). The overall Cronbach's Alpha value for the survey was 0.87, indicating strong reliability. The reliability value for each dimension was as follows:

Table 3. The reliability value for each dimension

	Contextual Factors	**Individual Factors**	**Social Factors**	**Technological Factors**
Reliability Value, α	0.85	0.82	0.84	0.86

The values in Table 3 confirm that the survey items were reliable and consistent in measuring the intended constructs (Xue et al., 2024). To confirm the validity of the survey, subject-matter experts reviewed the survey and also pilot-tested it with a small faculty sample to ensure content validity (Meccawy, 2023; Al-Rahmi et al., 2018).

Participant Details

The targeted participants for the study were STEM faculty members across multiple universities in diverse geographic regions. The survey was distributed across various universities, and a total of **500 responses** were collected. The sample included a balanced representation of academic ranks, teaching experience, and familiarity with XR technologies (Upadhyay et al., 2024). The demographic breakdown of the survey participants is presented in Figure 2.

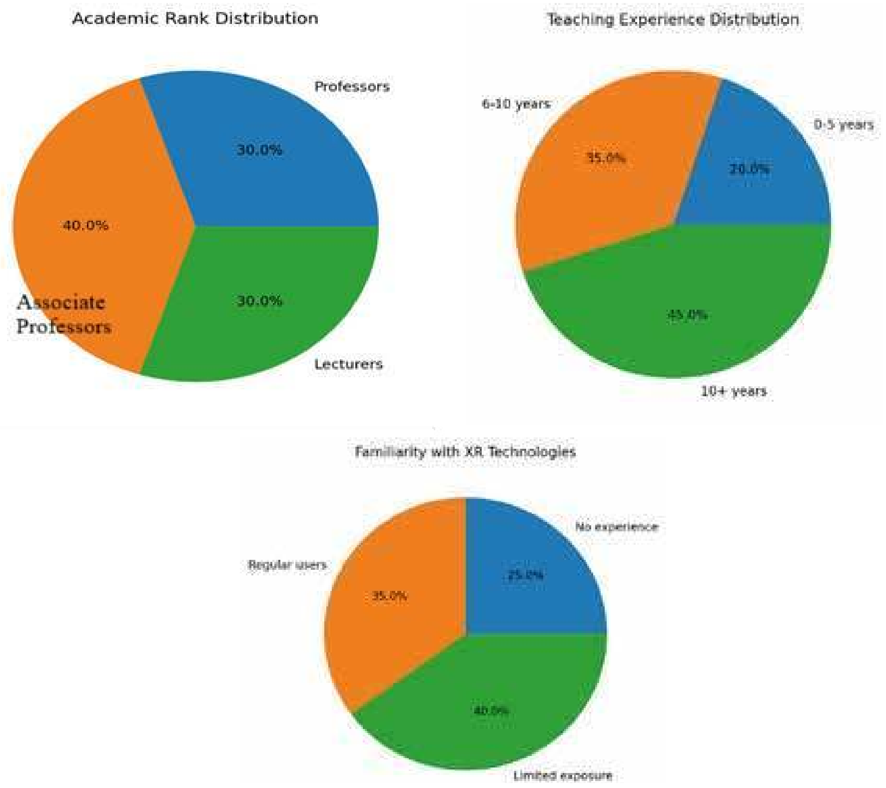


Figure 2. Demographic Profile of Survey Participants

Source: Author

Data Collection and Analysis

Data was collected via **Google Forms** and **Qualtrics**, distributed through university email lists, professional networks (e.g., LinkedIn, ResearchGate), and academic conferences. Follow-up reminders were sent after two weeks to encourage participation. Ethical considerations included voluntary participation, informed consent, anonymity, and approval from the Institutional Review Board (IRB).

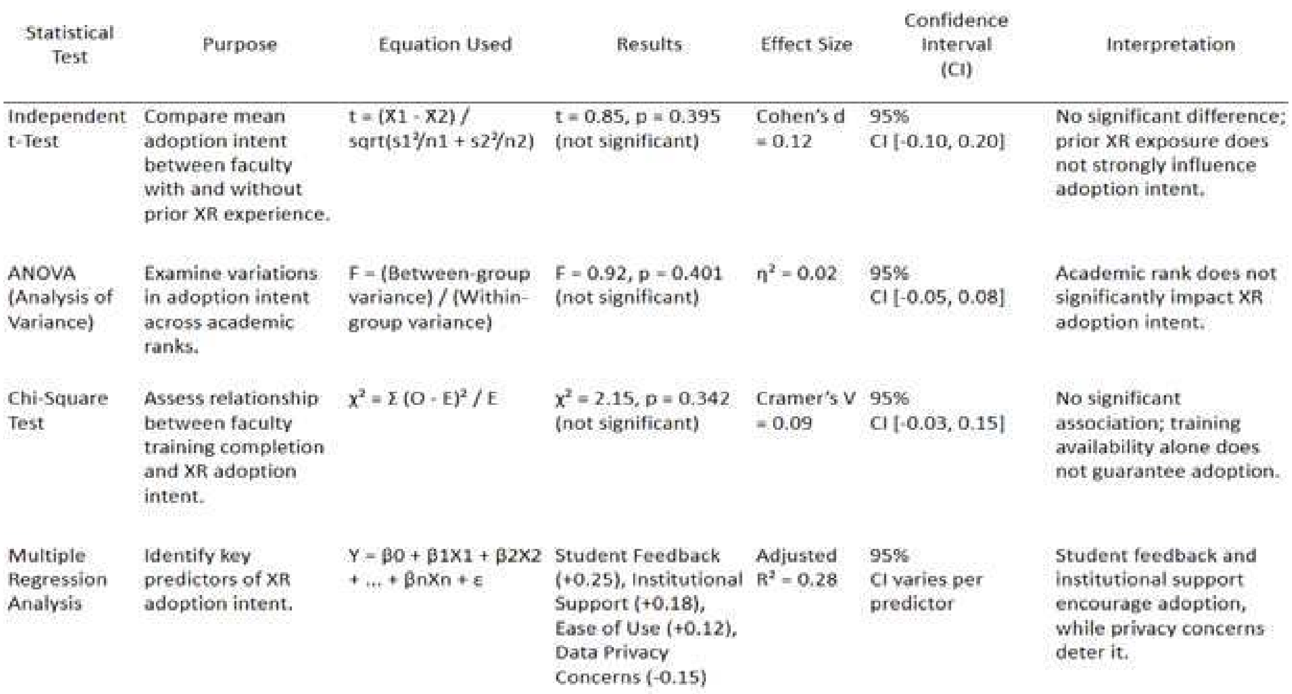
The collected data were analysed using a combination of statistical methods:

- **Independent t-tests**: To compare adoption intent between faculty with and without prior XR experience (Makransky & Petersen, 2021).
- **ANOVA**: To examine variations in adoption intent across different academic ranks (Ledger et al., 2022).
- **Chi-square tests**: To assess the relationship between faculty training and adoption intent (Guo et al., 2021).
- **Multiple Regression Analysis**: To identify key predictors of XR adoption intent (Upadhyay et al., 2024).
- Statistical significance was set at **$p < 0.05$**, and all analyses were conducted using **SPSS 28.0**.

Statistical Analyses

To rigorously evaluate the factors influencing faculty adoption of XR in STEM education, multiple statistical tests were conducted. Table 4 summarizes the statistical tests conducted to evaluate the factors affecting faculty adoption of XR in STEM education (Ledger et al., 2022; Makransky & Petersen, 2021).

Table 4. Summary of Statistical Analyses on XR Adoption in STEM Faculty.



Statistical Test	Purpose	Equation Used	Results	Effect Size	Confidence Interval (CI)	Interpretation
Independent t-Test	Compare mean adoption intent between faculty with and without prior XR experience.	$t = (\bar{X}1 - \bar{X}2) / sqrt(s1^2/n1 + s2^2/n2)$	$t = 0.85$, $p = 0.395$ (not significant)	Cohen's $d = 0.12$	95% CI [-0.10, 0.20]	No significant difference; prior XR exposure does not strongly influence adoption intent.
ANOVA (Analysis of Variance)	Examine variations in adoption intent across academic ranks.	F = (Between-group variance) / (Within-group variance)	$F = 0.92$, $p = 0.401$ (not significant)	$\eta^2 = 0.02$	95% CI [-0.05, 0.08]	Academic rank does not significantly impact XR adoption intent.
Chi-Square Test	Assess relationship between faculty training completion and XR adoption intent.	$\chi^2 = \Sigma (O - E)^2 / E$	$\chi^2 = 2.15$, $p = 0.342$ (not significant)	Cramer's $V = 0.09$	95% CI [-0.03, 0.15]	No significant association; training availability alone does not guarantee adoption.
Multiple Regression Analysis	Identify key predictors of XR adoption intent.	$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots + \beta nXn + \varepsilon$	Student Feedback (+0.25), Institutional Support (+0.18), Ease of Use (+0.12), Data Privacy Concerns (-0.15)	Adjusted $R^2 = 0.28$	95% CI varies per predictor	Student feedback and institutional support encourage adoption, while privacy concerns deter it.

RESULTS AND DISCUSSION

Table 5 summarizes the key findings of the study, highlighting the factors affecting the XR adoption in STEM education from the faculty perspective. The findings are analyzed in detail as follows:

Institutional and Financial Support

The survey results revealed mixed perceptions of institutional support for XR integration (Oakley et al., 2025; Cumberbatch et al., 2023). The mean rating for institutional support was **3.45 (SD = 1.22)**, indicating moderate levels of support were provided to the faculty members for the adoption of XR in the teaching and learning process. However, significant variability was observed, with 45% of respondents reporting inadequate funding and 40% citing a lack of policy guidance (Zolezzi et al., 2024; Mourtzis et al., 2023). These findings suggest that while some institutions are actively promoting XR adoption, others lag due to structural limitations. Figure 3a presents the relationship between institutional support and the availability of funding for XR adoption in academia. It analyzes the survey responses regarding the institutional support and funding for XR and depicts that there is a strong correlation between institutional support and funding availability (Zhao et al., 2023; Zatarain-Cabada et al., 2023). As institutional support for XR in academia increases, the chances of receiving funding significantly improve. Among those faculty members who strongly agree that they have institutional support, 80% have received funding, whereas only 20% have not. Conversely, among those who strongly disagree, only 10% have received funding, while 90% have not.

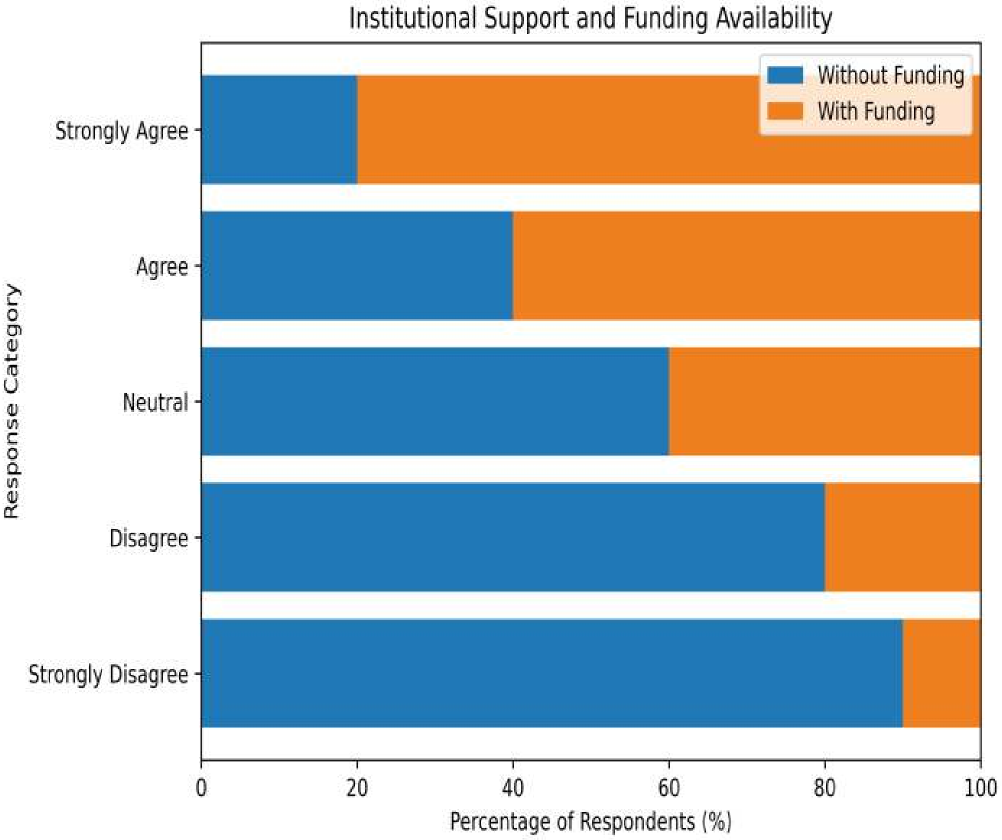


Figure 3a. Institutional Support vs. Funding Availability for XR Adoption.
Source: Author.

The variability in institutional support highlights the importance of the **Resource-Based View (RBV)** theory, which emphasizes the role of organisational resources in technology adoption. Institutions that fail to provide adequate funding, infrastructure, and policy frameworks are unlikely to achieve successful XR integration (Boss et al., 2015; Hornbæk & Hertzum, 2017). This underscores the need for targeted investments in XR-ready labs, hardware, and training programs (Yi et al., 2023; Pellas et al., 2020).

Faculty Training and Digital Literacy

Figure 3b represents the relationship between the effectiveness of faculty training and their confidence in digital literacy. Analysis of survey responses highlights the linear correlation between the effectiveness of higher Training with higher digital literacy. Faculty who rated the institutional training as "Very Effective" had the highest digital literacy confidence (~4.0), and those who found training to be "Very Ineffective" reported the lowest confidence (~2.0). Faculty training programs received a mean rating of 3.25 (SD = 1.18), indicating that there is room for improvement in the faculty training programs on the XR technologies (Makransky & Petersen, 2021; Pellas et al., 2020). Similarly, the digital literacy confidence was rated 3.50 (SD = 1.15), suggesting that while many faculty members are comfortable with digital tools, additional training is needed to bridge gaps in XR-specific skills.

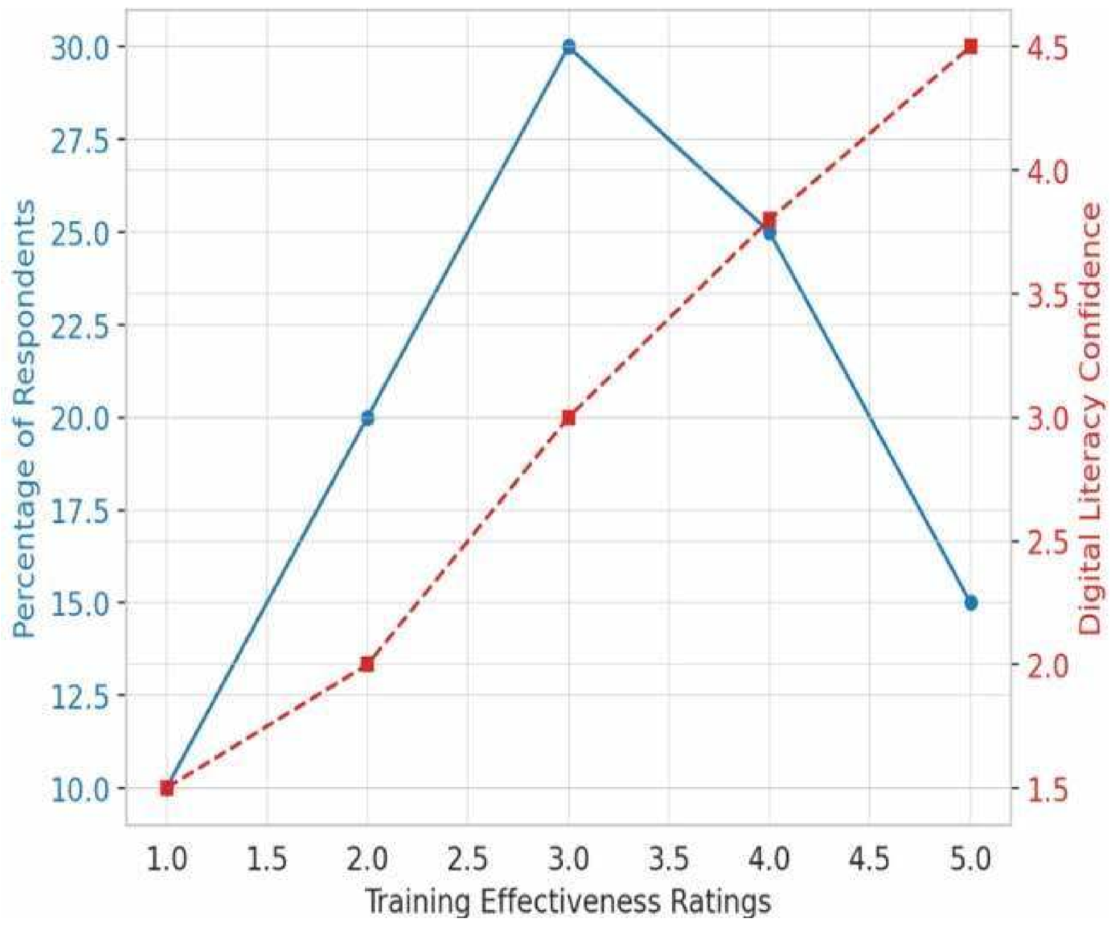


Figure 3b. Training Effectiveness vs. Digital Literacy Confidence.
Source: Author

These findings align with Bandura's Self-Efficacy Theory (Scherer, R. 2019), which posits that individuals' confidence in their abilities influences their willingness to adopt new technologies (Xue et al., 2024; Meccawy, 2023). The moderate ratings for training effectiveness and digital literacy suggest that institutions should invest in hands-on, practical training programs to enhance faculty confidence and competence in using XR tools (Pellas et al., 2020; Meccawy, 2023).

Social and Pedagogical Factors

Survey questions related to social and pedagogical factors were designed to assess the extent of peer encouragement and XR's alignment with teaching philosophies. The survey responses demonstrated in Figure 3c suggest that the peer collaboration was limited, with only 52% of respondents reporting encouragement from colleagues (Chen et al., 2022; Meccawy, 2023). Pedagogical alignment received a mean rating of 3.60 (SD = 1.10), indicating that 60% of faculty believe XR aligns with their pedagogy, while 40% do not (Oakley et al., 2025; Cumberbatch et al., 2023).

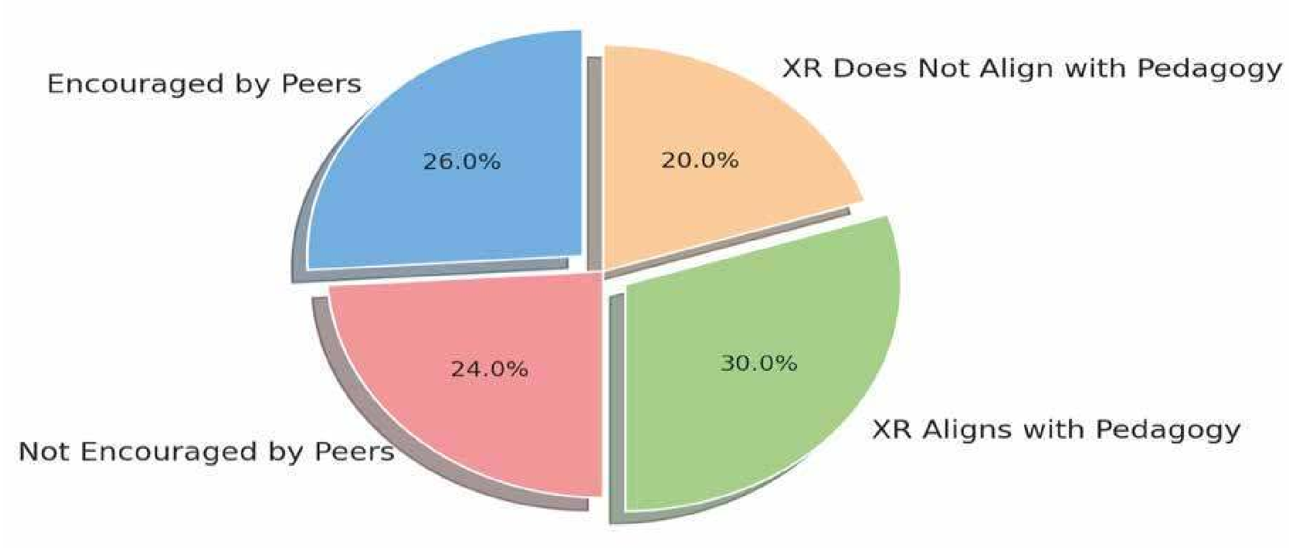


Figure 3c. Peer Collaboration and Pedagogical Alignment.
Source: Author

These findings suggest that there is a need for fostering a culture of innovation and collaboration to enhance XR adoption. According to Rogers' Diffusion of Innovation Theory (Al-Rahmi, et. al., 2018), peer influence plays a critical role in the adoption of new technologies (Neves et al., 2025; Zhao et al., 2023). Institutions should create platforms for faculty to share experiences, collaborate on XR projects, and learn from one another.

Technology and Data Security Concerns

Technological factors analyse the usability of XR tools for faculty members and their concerns regarding data privacy. Survey responses were analyzed to reveal that the ease of use was rated 3.10 (SD = 1.30), with 48% of respondents describing XR tools as difficult to use, while the rest 52% considered the usability of XR as neutral, easy or very easy. Secondly, data privacy concerns were also prevalent among faculty members, with 55% of faculty expressing apprehensions about student data security (Radianti et al., 2020; Zolezzi et al., 2024). These findings are shown in Figure 3d.

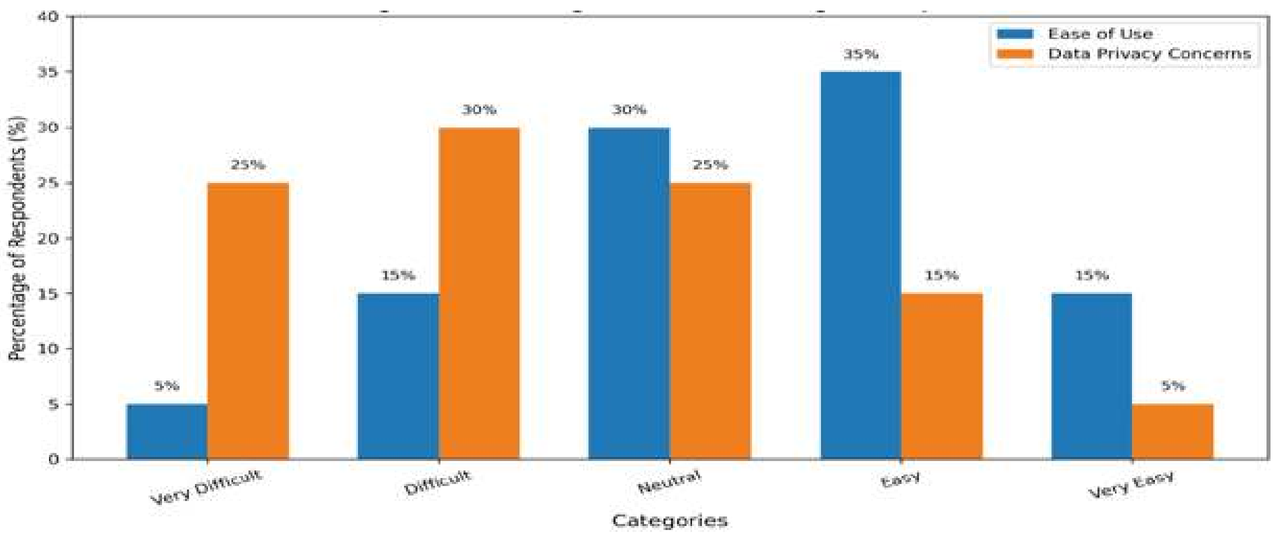


Figure 3d. Ease of Use and Data Privacy Concerns.
Source: Author

The usability challenges align with Usability Theory (Hornbæk, K., & Hertzum, M., 2017), which emphasizes the importance of intuitive and user-friendly interfaces (Sırakaya & Alsancak Sırakaya, 2022; Ledger et al., 2022). The high level of data privacy concerns reflects the Protection Motivation Theory (Boss, S. R., Galletta, D. F., Lowry, P. B., Moody, G. D., & Polak, P., 2015), suggesting that faculty members may avoid adopting XR if they perceive risks to student data. To address these issues, developers should prioritise user-centred design and provide transparent information about data security measures.

Predictive Modelling of XR Adoption

Multiple regression analysis identified the following predictors of XR adoption intent (Figure 3e):

- **Student Feedback (+0.25)**: The strongest positive predictor, indicating that positive student experiences encourage faculty adoption (Al-Rahmi et al., 2018).
- **Institutional Support (+0.18)**: Positive correlation, highlighting the importance of organizational backing (Mourtzis et al., 2023; Neves et al., 2025).
- **Ease of Use (+0.12)**: Moderately positive, suggesting that user-friendly tools enhance adoption intent (Yi et al., 2023).
- **Data Privacy Concerns (-0.15)**: Negative correlation, underscoring the deterrent effect of security apprehensions (Zatarain-Cabada et al., 2023; Pellas et al., 2020).

The regression results provide empirical evidence for the factors driving XR adoption (Neves et al., 2025; Al-Rahmi et al., 2018). The strong influence of **student feedback** and **institutional support** aligns with prior research on technology adoption in education. However, the negative impact of **data privacy concerns** highlights a critical barrier that must be addressed through robust security frameworks and clear communication (Pellas et al., 2020; Zatarain-Cabada et al., 2023)

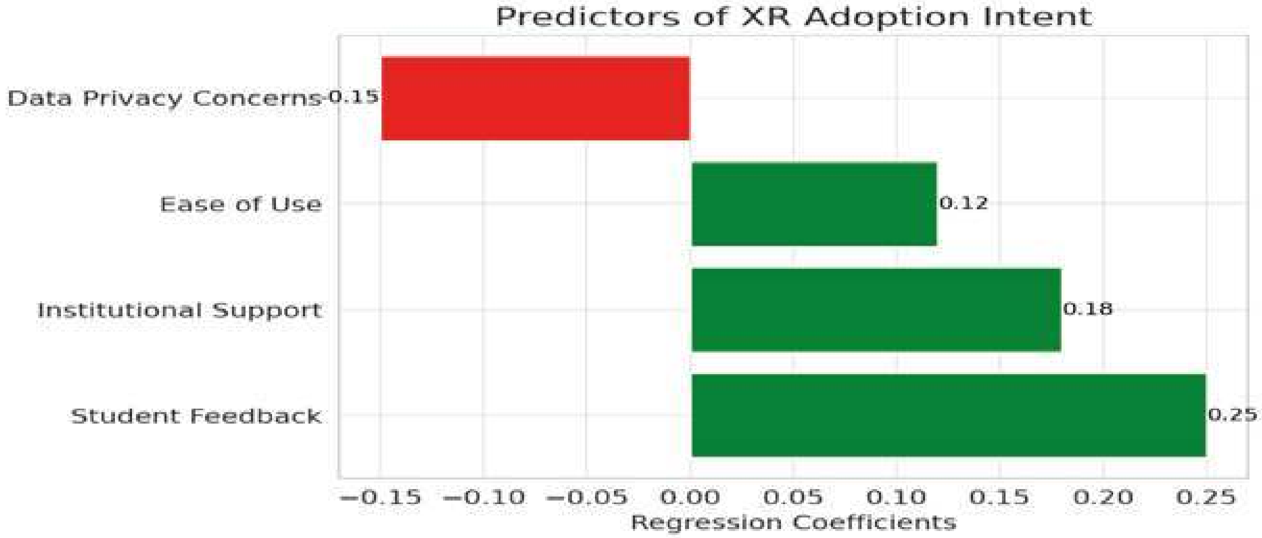


Figure 3e. Predictors of XR Adoption Intent.
Source: Author

Table 5. Summary of Key Factors Influencing XR Adoption in Higher Education..

Factors Evaluated	Key Findings	Statistical Results	Implications
3.1 Institutional and Financial Support	XR adoption is limited by funding gaps and policy issues.	Institutional support = 3.45 (SD = 1.22). 45% report lack of funding, 40% lack policy guidance.	Increased funding and clear policies are needed to boost adoption.
3.2 Faculty Training and Digital Literacy	Effective training increases digital literacy and XR adoption.	Training effectiveness = 3.25, Digital literacy = 3.50. Faculty with “Very Effective” training has Confidence 4.0, “Very Ineffective” has Confidence 2.0.	Hands-on training programs can bridge the skill gap.
3.3 Social and Pedagogical Factors	Peer collaboration is limited; mixed pedagogical alignment.	Peer support = 52%. Pedagogical alignment = 3.60.	Faculty networks and collaborative initiatives can enhance XR integration.
3.4 Technology and Data Security Concerns	Usability and data security are key barriers.	Ease of use = 3.10, 55% report data privacy concerns.	Better UX design and stronger security measures are needed.
3.5 Predictive Modeling of XR Adoption	Student feedback and institutional support drive adoption.	Student Feedback (+0.25), Institutional Support (+0.18), Ease of Use (+0.12), Privacy Concerns (-0.15).	Student-centered XR experiences increase adoption.

CONCLUSION

This study examined the key factors influencing the adoption of Extended Reality (XR) technologies in higher education, particularly among STEM faculty. By analyzing institutional support, faculty training, social and pedagogical influences, technological concerns, and predictive modelling, the research provides valuable insights into the current state of XR integration and the challenges that must be addressed for widespread adoption.

The findings highlight that while some institutions actively promote XR adoption, funding constraints and lack of policy guidance remain significant barriers. The strong correlation between institutional support and funding availability suggests that well-supported faculty are far more likely to receive necessary resources for XR integration. Additionally, faculty training programs play a crucial role in determining digital literacy confidence, with faculty who received high-quality training exhibiting greater confidence in using XR tools. This emphasizes the need for structured, hands-on training programs to enhance adoption rates.

Social and pedagogical factors also influence XR adoption, with peer collaboration remaining limited, as only 52% of faculty members reported receiving encouragement from colleagues. Despite this, 60% of faculty believe XR aligns with their pedagogy, suggesting that XR has significant potential to enhance teaching effectiveness if better faculty support networks and collaborative initiatives are established. On the technological front, usability challenges and data privacy concerns emerged as major deterrents. Faculty members with lower confidence in XR usability were less likely to integrate it into their teaching, while concerns over student data security discouraged adoption due to perceived risks.

The predictive modelling of XR adoption identified student feedback (+0.25) and institutional support (+0.18) as the strongest positive predictors of XR adoption, reinforcing the importance of student engagement and administrative backing. Conversely, data privacy concerns (-0.15) negatively impacted adoption intent, highlighting the need for improved security measures and transparent data protection policies. These findings suggest that for successful XR adoption in STEM education, institutions must enhance institutional support by establishing clear policies, providing consistent funding, and building XR-ready infrastructure. Investments in faculty training programs with hands-on experiences are essential to bridge digital literacy gaps and improve adoption rates. Encouraging peer collaboration and knowledge-sharing initiatives among faculty members can further accelerate XR integration, while improvements in user experience (UX) design and data security frameworks will address concerns that currently hinder adoption.

While this study provides valuable insights, future research should explore longitudinal studies to track XR adoption trends, comparative studies across disciplines, and student-centered perspectives on XR learning outcomes. Further examination of data security frameworks and their impact on faculty adoption is also necessary to develop more effective privacy protection strategies.

The integration of XR in higher education presents a transformative opportunity to enhance engagement, improve learning outcomes, and bridge the gap between theoretical and practical applications in STEM fields. However, overcoming barriers such as funding limitations, training gaps, and data security issues is crucial to ensuring widespread adoption. By addressing these challenges, institutions can pave the way for a more immersive, innovative, and technology-driven future in education.

LIMITATIONS AND FUTURE WORK

This study provides useful insights into how faculty members adopt **Extended Reality (XR) technologies** in STEM education. However, there are areas that future research can explore further. For example, **long-term studies** could help understand how XR adoption changes over time and how faculty attitudes and institutional support evolve.

Future research could also compare **XR adoption across different academic fields** to see if STEM faculty face different challenges than those in other disciplines. Additionally, since this study focused on **faculty perspectives**, future studies could examine **student experiences** to understand how XR impacts learning outcomes and engagement. Improving **predictive models** with **advanced**

data analysis techniques, such as machine learning, could help create **better faculty training programs** tailored to individual needs. As XR technology continues to develop, future studies could also look at **new innovations**, like AI-driven XR tools, and their role in education.

Lastly, **data security and privacy** remain important concerns. Future research could focus on how universities can **better protect student data** and build faculty confidence in using XR tools. Addressing these areas will help institutions make **more informed decisions** about integrating XR into education and maximizing its benefits for both faculty and students.

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