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**Research Article**

# Teachers' perceptions of the challenges in integrating augmented reality, virtual reality, and extended reality into higher education

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**ABSTRACT**

This study investigates the perceptions of university faculty regarding the challenges of integrating augmented reality, virtual reality, and extended reality technologies into higher education. Using a non-experimental design, a Likert-type questionnaire was administered to a sample of 775 faculty members from Spanish and Ibero-American universities to assess difficulties across five dimensions: technical, pedagogical, economic, resistance to change, and ethical-social. The results indicate that faculty perceive these challenges as significant, with economic (mean [M] = 8.04) and pedagogical (M = 7.40) barriers being rated as the most prominent. The most highly rated issues include insufficient faculty training (M = 8.50), the lack of clear educational models (M = 8.22), and the absence of financial incentives (M = 8.08). While no significant gender-based differences were found in the overall score or in four of the five dimensions, female faculty rated ethical-social barriers significantly higher. The analysis also identified statistically significant variations based on university location (with Ibero-American faculty perceiving greater difficulties than their Spanish counterparts), as well as age and teaching experience, where older and more experienced faculty reported a stronger perception of the challenges. The study concludes that overcoming these barriers requires strategic institutional measures, including faculty training programs with a strong pedagogical focus, robust financial planning that accounts for maintenance and updates, and the promotion of a culture of innovation to facilitate the effective adoption of these technologies.

**Keywords:** augmented reality, virtual reality, extended reality, higher education, faculty perceptions, adoption barriers

## INTRODUCTION

The integration of augmented reality (AR), virtual reality (VR), and extended reality (XR) technologies into higher education has gained increasing attention due to their potential to enhance teaching and learning processes. These technologies offer immersive and interactive experiences that can facilitate the understanding of complex concepts, simulate real-world scenarios, and foster student engagement. However, despite their growing presence in educational research and practice, their effective implementation in university contexts remains uneven and challenging.

A substantial body of literature has examined the pedagogical benefits and technological possibilities of AR, VR, and XR. Nevertheless, there is still a lack of comprehensive empirical evidence regarding the specific barriers faced by university faculty when attempting to integrate these technologies into their teaching practices. While previous studies have identified various challenges—such as technical limitations, high costs, and pedagogical constraints—few have systematically analyzed these difficulties from a multidimensional perspective that includes technical, pedagogical, economic, institutional, and ethical-social factors, particularly across different geographical contexts.

This gap is significant because faculty perceptions play a crucial role in the adoption and effective use of educational technologies. Understanding how educators perceive these challenges is essential for designing institutional strategies, training programs, and policy interventions that facilitate meaningful integration. Without this knowledge, efforts to promote immersive technologies in higher education risk remaining superficial or unsustainable.

In response to this need, the present study aims to explore university faculty perceptions of the challenges associated with integrating AR, VR, and XR technologies into higher education. Specifically, the study addresses the following research questions:

(1) What are the main technical, pedagogical, economic, resistance-related, and ethical-social difficulties perceived by faculty in the integration of AR, VR, and XR?

(2) Are there statistically significant differences in these perceptions based on demographic and professional variables such as gender, age, teaching experience, field of knowledge, and university location?

### Research Objectives

The objectives of this research are as follows:

- To identify the perceptions of university faculty (users of AR, VR, or XR objects) regarding technical, pedagogical, and economic difficulties, resistance to change from institutions and faculty, as well as ethical, social, and psychological challenges.
- To analyze whether perceptions of these difficulties are influenced by variables such as gender, age, years of teaching experience, field of knowledge, and the faculty's technical knowledge of AR, VR, and XR, along with their expertise in the pedagogical use of these technologies.

## CONCEPTUAL FRAMEWORK

Although recent meta-analyses and review studies have identified a broad set of barriers to the adoption of AR, VR, and XR in educational contexts, their contributions are mainly synthetic and descriptive, as they systematize findings reported in previous studies rather than generating new empirical evidence from university faculty. In this sense, studies such as Obeidallah et al. (2023) and Sales et al. (2023) provide a valuable overview of recurring obstacles, including technical, economic, pedagogical, usability, and content-production barriers. However, they do not offer primary empirical data on how university teachers themselves currently perceive and prioritize these challenges across different institutional and geographical contexts.

The five-dimension structure adopted in this study was not intended to replicate a single technology acceptance model (TAM), but to organize the main barriers identified in the literature into an analytical framework suited to the integration of AR, VR, and XR in higher education. In this sense, the study draws on complementary perspectives from technology adoption and educational technology integration models, particularly the TAM (Davis, 1989), UTAUT and UTAUT2 (Venkatesh et al., 2003, 2012), and TPACK (Mishra & Koehler, 2006). From TAM and UTAUT/UTAUT2, the study incorporates the idea that technology adoption is influenced not only by perceived usefulness or ease of use, but also by facilitating conditions, effort expectancy, social influence, and resistance or behavioral intention (Al-Adwan et al., 2023; Nilashi & Abumalloh, 2025; Poupard et al., 2025). These assumptions justify the inclusion of technical difficulties, economic and infrastructural conditions, and resistance to change as relevant dimensions. From TPACK, the study takes the premise that meaningful educational technology integration requires the articulation of technological, pedagogical, and content knowledge. This supports the inclusion of the pedagogical dimension, especially issues related to faculty training, instructional design, assessment, and the transformation of academic content into meaningful immersive experiences. However, AR, VR, and XR also raise specific concerns that go beyond conventional adoption models, including accessibility, equity, privacy, psychological discomfort, cognitive load, and the potential widening of institutional and student digital divides. For this reason, ethical, social, and psychological dimensions were incorporated. Thus, the five dimensions—technical, pedagogical, economic, resistance to change, and ethical-social-psychological—were selected because they synthesize both established technology adoption frameworks and the specific barriers highlighted in prior research on immersive technologies. This multidimensional framework makes it possible to examine the integration of AR, VR, and XR not merely as a matter of individual acceptance, but as a complex process shaped by technological infrastructure, pedagogical competence, institutional resources, organizational culture, and ethical-social conditions. The five dimensions measured in the instrument were derived from the main clusters of barriers identified in the literature. Technical difficulties are supported by studies that highlight problems related to infrastructure, connectivity, device compatibility, software and hardware failures, technical support, and the need for continuous updates. These issues are especially relevant for AR, VR, and XR, as immersive experiences require stable devices, adequate bandwidth, and reliable technological ecosystems.

Pedagogical difficulties refer to the challenges involved in transforming these technologies into meaningful learning experiences. Prior studies emphasize that AR, VR, and XR do not automatically improve learning; their educational value depends on careful instructional design, alignment with learning objectives, adequate assessment strategies, and the availability of adapted educational content. This dimension is also linked to the need for faculty training, not only in technical use but also in pedagogical integration. Economic difficulties are one of the most frequently cited barriers in literature. They include the initial cost of hardware, software, licenses, and immersive devices, but also the ongoing costs of maintenance, updates, content development, and technical support. This dimension is particularly important because the sustainability of AR, VR, and XR integration depends on long-term institutional investment rather than isolated or occasional acquisition of equipment. Resistance to change is connected to studies that point to institutional culture, teacher attitudes, fear of emerging technologies, and preference for traditional methodologies as relevant factors affecting adoption. The literature suggests that even when technological infrastructure is available, innovation may be limited if faculty do not perceive these tools as useful, manageable, or compatible with their teaching practices, or if institutions do not actively support methodological change.

Finally, ethical, social, and psychological difficulties are supported by research addressing accessibility, equity, privacy, security, cognitive load, fatigue, anxiety, dizziness, and the possible widening of the digital divide. These barriers are especially relevant in immersive environments because AR, VR, and XR may intensify existing inequalities among students and institutions, while also raising new concerns related to data protection, inclusive access, and user well-being.

The present study addresses this gap by providing original quantitative evidence from a large sample of 775 university faculty members from Spanish and Ibero-American universities. Unlike previous reviews, this research examines faculty perceptions through a multidimensional instrument that considers technical, pedagogical, economic, resistance-to-change, and ethical-social difficulties. Moreover, it analyzes whether these perceptions vary according to gender, age, teaching experience, field of knowledge, and university location. Therefore, the study moves beyond identifying barriers in the literature and contributes empirical evidence on their perceived intensity, relative importance, and differential distribution among faculty profiles and geographical contexts. This makes it possible to inform institutional decision-making, faculty training policies, and strategic planning for the sustainable integration of AR, VR, and XR in higher education.

Otherwise, AR, VR, and XR are technologies that are incorporated into higher education, fulfilling a variety of functions (from simulating phenomena and educational practices or presenting facilities and instruments otherwise inaccessible to students, to offering the chance to be immersed in the human body) and serving scientific disciplines such as medicine, architecture, or engineering (Cabero-Almenara et al., 2025).

**Table 1.** Barriers and difficulties for the integration of AR, VR, and XR

| Obstacles | Authors |
|---|---|
| Costs – financial investment | Angulo et al. (2023), Cooper et al. (2019), Familoni and Onyebuchi (2024), Kavanagh et al. (2017), Menjivar et al. (2021), Mulders et al. (2020), Obeidallah et al. (2023), Sales et al. (2023), Toala-Palma et al. (2020) |
| Not suitable for long periods of use | Huang et al. (2010) |
| Learning object designs overly focused on entertainment | Jensen and Konradsen (2018) |
| Limited research | Kavanagh et al. (2017), Radianti et al. (2020), Sales et al. (2023) |
| Tends to be non-inclusive | Garzón et al. (2019) |
| Teacher training | AlGerafi et al. (2023), Cooper et al. (2019), Marín-Díaz et al. (2022), Nikou et al. (2023), Perifanou et al. (2023), Sales et al. (2023) |
| Safety – secure use – health and psychological issues | Cevikbas et al. (2023), Cooper et al. (2019), Mogrovejo-Zambrano et al. (2024), Mulders et al. (2020), Obeidallah et al. (2023) |
| Difficulty integrating into learning scenarios | Mulders et al. (2020) |
| Ethical issues | Angulo et al. (2023) |
| Increased cognitive load – mental fatigue – anxiety | Angulo et al. (2023), Bautista et al. (2025), Bermejo et al. (2023), Cevikbas et al. (2023), del Cid et al. (2020), Yu (2021) |
| Complexity of content design and development | Familoni and Onyebuchi (2024), Sales et al. (2023) |
| Lack of connection to learning theories | Caballero-Garriazo et al. (2023) |
| Accessibility – access | Mogrovejo-Zambrano et al. (2024), Obeidallah et al. (2023) |
| Equity | Mogrovejo-Zambrano et al. (2024) |
| Limited content production | Sales et al. (2023), Upadhyay et al. (2024) |
| Technical difficulties – connectivity | Sales et al. (2023), Subirats-Blanco and Conde del Rio (2024) |

This growing interest is also reflected in the increase in research on their educational possibilities, the principles that can be leveraged for designing effective learning objects, and the degree of motivation and acceptance their use generates among teachers and students. This trend is evident in the rising number of meta-analyses focusing on specific issues such as student learning acquisition (Victoria Maldonado et al., 2024; Yu & Xu, 2022), the pedagogical theories and approaches used for their design and implementation (Marougkas et al., 2024; Mohsen & Alangari, 2024), the ethical and psychological aspects arising from their use (Mogrovejo-Zambrano et al., 2024), and their potential in both desktop and immersive versions (Liu et al., 2024).

Specifically, a series of meta-analyses are also being conducted on the topic of our study—that is, on the various difficulties and barriers perceived by teachers and educational managers in incorporating these technologies into learning environments. These include challenges related to content production, finances, user acceptance, usability, and fatigue (Obeidallah et al., 2023; Sales et al., 2023).

## DIFFICULTIES AND BARRIERS TO THE INTEGRATION OF AR, VR, AND XR

The difficulties in incorporating AR, VR, and XR technologies are of various types: some are caused by the technological systems themselves, others by educational institutions, and a third group is related to the resistance from teachers to integrate them into university-level education.

A summary of the barriers identified by various authors is presented in **Table 1**, drawn from meta-analyses, individual research studies, or theoretical reflections.

As observed, the identified difficulties vary in scope and significance. Among them, economic aspects are one of the most frequently cited. This refers not only to implementation costs (acquisition of equipment, software, and licenses) but also to maintenance and updates, as the rapid evolution of these technologies requires frequent renewal.

Related, to some extent, to acquisition and maintenance costs are the connectivity issues present in some educational institutions. Achieving an acceptable sense of immersion and movement within the virtual object requires a stable, high-bandwidth internet connection, which is not always available and thus becomes a challenge.

These same connectivity limitations create another difficulty related to equity in the use of these technologies, affecting both institutions and students. In fact, one could even speak of a widening digital divide between students and institutions, as not all have access to the necessary devices to fully participate in AR, VR, or XR-based activities. However, these difficulties are not exclusively economic or technical. They are also evident in the lack of necessary skills among a significant number of faculty members to integrate these technologies into their classes. This is compounded by a lack of time for training and the absence of adequate training plans to help them manage and integrate the technologies from both a technical and pedagogical standpoint. Also related to the teaching role is resistance to change and innovation, often stemming from a fear or mistrust that progressively develops towards technology. Indeed, when faced with technological innovations, some teachers prefer traditional methods, considering them more reliable or effective, and feel more comfortable using them.

Nevertheless, these fears and reservations may also be driven by the difficulties in integrating AR, VR, or XR into the curriculum. This is due to several factors: the lack of a consolidated educational theory for their design and use, limited research on their impact on performance, and the absence of "best practice" guidelines for their implementation. In this regard, it is important to remember that creating effective and immersive learning experiences with these technologies requires careful and well-planned pedagogical design and action. Otherwise, they can become distractions that undermine their educational purpose.

Synthesizing across these barriers, two broad clusters emerge. The first is resource-dependent (costs, infrastructure, connectivity, content production) and shows strong convergent empirical support, appearing consistently across all meta-analyses reviewed (Familoni & Onyebuchi, 2024; Obeidallah et al., 2023; Sales et al., 2023). The second is capacity-dependent (faculty training, pedagogical design, resistance to change) and is more context-sensitive, with divergent findings: some studies indicate that training alone is insufficient without accompanying changes in evaluation culture (Jensen & Konradsen, 2018), while others emphasize the role of institutional leadership in sustaining adoption (Radianti et al., 2020). A third, less studied cluster—psychological and ethical barriers (anxiety, cognitive overload, data privacy, and equity)—has received growing attention since 2022 but lacks primary quantitative data in the Ibero-American context (Cevikbas et al., 2023; Mogrovejo-Zambrano et al., 2024). It is also worth noting that even where AR/VR interventions yield significant learning gains, the effect sizes are frequently small to moderate, as confirmed by the meta-analysis of Coban et al. (2022), a finding that further underscores the importance of addressing adoption barriers if these technologies are to realize their potential at scale.

Another set of difficulties for their incorporation arises from the costly and often complex process of content production, which demands specific knowledge from teachers, coupled with the scarcity of platforms offering access to high-quality content in these formats.

A final group of difficulties, which can be added to the previous ones, includes the various psychological impacts produced by some types of these technologies, such as immersive versions, and the cognitive load they impose on anxiety, fatigue, and/or a sense of disorientation.

## THE RESEARCH STUDY

The focus on Spanish and Ibero-American university faculty is grounded in both contextual relevance and research feasibility. First, these regions share important linguistic, cultural, and educational affinities that allow for meaningful comparison while maintaining a degree of homogeneity in higher education systems. At the same time, they present notable structural and technological differences, particularly in terms of resource availability, institutional investment, and levels of digital development, which are reflected in disparities such as the digital divide identified in prior reports and studies. This combination of shared frameworks and differentiated conditions makes the comparison between Spanish and Ibero-American contexts especially valuable for understanding how environmental factors influence faculty perceptions of emerging technologies. Second, the selection of this geographical scope responds to the study's objective of examining variability in perceived challenges across contexts that are comparable but not identical. As the results indicate, faculty from Ibero-American universities report greater perceived difficulties than their Spanish counterparts, suggesting that contextual factors such as infrastructure, funding, and institutional support play a decisive role. Therefore, focusing on these two regions enables the study to identify patterns that might be obscured in a more heterogeneous global sample. Finally, the chosen scope is also justified by the accessibility and relevance of the sample. Participants were selected based on their documented experience with AR, VR,

**Table 2.** Instrument reliability index

| Variable | Cronbach's α | McDonald's Ω |
|---|---|---|
| Technical difficulties | .783 | .778 |
| Pedagogical difficulties | .847 | .830 |
| Economic difficulties | .789 | .783 |
| Difficulties from resistance to change | .736 | .734 |
| Ethical, social, and psychological difficulties | .799 | .792 |
| Total | .915 | .909 |

and XR in Spanish-speaking academic environments, ensuring both the quality of responses and the coherence of the data collected. This targeted approach strengthens the validity of the findings while contributing to a region that, despite its growing research output, remains underrepresented in large-scale international studies on immersive technologies in higher education. This study employs a non-experimental design, specifically an ex post facto study, as the researchers did not manipulate any variables (Hernández Sampieri, 2017).

## Data Collection Instrument

The data collection instrument was developed ad hoc for this study following a structured validation procedure. Item generation was grounded in the theoretical framework described in the Conceptual Framework section (TAM/UTAUT2 and TPACK) and in the systematic review of barriers presented in **Table 1**, producing an initial pool of 30 candidate items. This pool was submitted to content validity review by a panel of eight experts in educational technology and immersive technologies, using the content validity index (CVI) (Lawshe, 1975); items with a CVI below .78 were eliminated, yielding the final 23-item scale. A pilot administration with 45 university faculty (not included in the main sample) confirmed adequate item comprehensibility and supported the five-dimension grouping. The five subscales should be understood as theoretically motivated conceptual groupings derived from TAM/UTAUT2 and TPACK rather than as empirically validated latent factors; formal confirmatory factor analysis is identified as a priority for future research. The instrument consists of two main sections. The first section gathered demographic information on characteristics such as gender and age, among others. The second was a 23-item Likert-type scale, where participants rated the perceived impact of specific difficulties on a scale from 1 to 10. The 23 items were distributed across the following dimensions: technical difficulties (4 items), pedagogical difficulties (9 items), economic difficulties (3 items), resistance to change from institutions and faculty (2 items), and ethical, social, and psychological difficulties (5 items).

The study fully complies with the ethical principles of the Declaration of Helsinki and with regulation (EU) 2016/679. All participants provided informed electronic consent prior to completing the questionnaire; participation was voluntary, anonymous, and no incentives were offered. The questionnaire was administered online via Google Forms between October 2024 and February 2025. The survey was distributed electronically to identified participants through institutional email and research network contacts. Given the purposive nature of the sampling frame, a formal response rate could not be calculated from a probabilistic denominator; however, 775 complete and valid responses were obtained and included in the analysis. The full sample was used for sample characterization and overall item- and dimension-level descriptive analyses. For all differential group comparisons and their accompanying group-specific descriptives, a common analytical sample of $n = 767$ was used; the eight respondents who selected 'prefer not to answer' for gender were excluded to maintain the same analytical sample across comparisons.

**Table 2** shows reliability index achieved using Cronbach's alpha and McDonald's omega, both for the total instrument and its different dimensions. As suggested by Oviedo and Campo-Arias (2005), George and Mallery (2003), and Roco-Videla et al. (2024), the obtained scores indicate a high level of reliability for the instrument.

## Research Hypotheses and Analytical Strategy

In line with the two research questions stated in the Introduction, the following null hypotheses (**H0**) and their corresponding alternative hypotheses (**H1**) were formulated. Each hypothesis was tested both for the total instrument score and separately for each of the five dimensions (technical, pedagogical, economic, resistance to change, and ethical-social):

**Table 3.** Field of knowledge and university location

| | | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Field of knowledge | Arts and humanities | 152 | 19.6 |
| | Sciences | 96 | 12.4 |
| | Health sciences | 82 | 10.6 |
| | Social and legal sciences | 331 | 42.7 |
| | Engineering and architecture | 114 | 14.7 |
| University | Spanish | 395 | 51.0 |
| | Ibero-American | 380 | 49.0 |

**H0a:** There are no statistically significant differences in the difficulties perceived by faculty in the integration of AR, VR, and XR according to gender.

**H1a:** There are statistically significant differences in the perceived difficulties according to gender.

**H0b:** There are no statistically significant differences in the difficulties perceived by faculty according to university location (Spanish vs. Ibero-American universities).

**H1b:** There are statistically significant differences in the perceived difficulties according to university location.

**H0c:** There are no statistically significant differences in the difficulties perceived by faculty according to age group.

**H1c:** There are statistically significant differences in the perceived difficulties according to age group.

**H0d:** There are no statistically significant differences in the difficulties perceived by faculty according to teaching experience.

**H1d:** There are statistically significant differences in the perceived difficulties according to teaching experience.

**H0e:** There are no statistically significant differences in the difficulties perceived by faculty according to field of knowledge.

**H1e:** There are statistically significant differences in the perceived difficulties according to field of knowledge.

All hypotheses were tested two-tailed with a nominal significance level of $\alpha = .05$; rejection at the more demanding $p \leq .01$ level is reported where applicable. Throughout the results section, each hypothesis is referred to by its number (**H0a**-**H0e**).

Prior to hypothesis testing, normality was assessed using the Kolmogorov-Smirnov test with Lilliefors correction; significant departures from normality were found for all dimensions ($p < .05$). Homogeneity of variances was evaluated using Levene's test; violations were observed in a subset of the group comparisons, particularly those involving field of knowledge. Given the ordinal response format, significant departures from normality, and heterogeneity in some comparisons, non-parametric tests were used throughout: the Mann-Whitney U test for two-group comparisons (gender and university location) and the Kruskal-Wallis H test for comparisons involving more than two groups (age, teaching experience, and field of knowledge). Where Kruskal-Wallis yielded significant results, pairwise post-hoc comparisons were conducted using Dunn test with Bonferroni correction to control family-wise error rate. Effect sizes for two-group comparisons were reported as Cohen's *d*, calculated as the difference between group means divided by the pooled standard deviation (SD) (Cohen, 1988). Eta-squared ($\eta^2 = [H-k+1]/[n-1]$) was used for Kruskal-Wallis tests (López & Ardura, 2023). All differential analyses were performed using common analytical sample ($n = 767$) described above.

## The Research Sample

The research sample consisted of 775 participants, of whom 389 (50.2%) were men, 378 (48.8%) were women, and 8 (1.0%) chose not to answer the question. Regarding age, 48 (6.2%) were between 20-30 years old, 190 (24.5%) were between 31-40, 245 (31.6%) were between 41-50, 202 (26.1%) were between 51-60, and 90 (11.6%) were over 61 (total = 775, 100%). Regarding teaching experience, the distribution across the five categories was as follows: 0-5 years: n = 124 (16.0%); 6-10 years: n = 135 (17.4%); 11-15 years: n = 134 (17.3%); 16-20 years: n = 118 (15.2%); more than 20 years: n = 264 (34.1%) (total = 775, 100%).

**Table 4.** M and SD for the total instrument and each item

| | M | SD |
|---|---|---|
| 1. One of the difficulties we face ... is the lack of adequate infrastructure (obsolete equipment, lack of compatible devices, or insufficient internet connectivity) (DT1) | 7.81 | 2.32 |
| 2. AR, VR, and XR technologies present frequent technical problems (software or hardware failures, incompatibilities, or lack of efficient technical support). (DT2) | 6.62 | 2.34 |
| 3. These technologies require constant updates, which contributes to faculty insecurity. (DT3) | 7.05 | 2.35 |
| 4. Limited connectivity is a common problem in universities, as these technologies often require a stable, high-speed internet connection, which is not always available. (DT4) | 7.08 | 2.56 |
| 5. Insufficient faculty training, for both technical and pedagogical use, can hinder the integration of AR, VR, or XR into the curriculum. (DP1) | 8.50 | 1.79 |
| 6. There is a lack of clear educational models to facilitate the implementation of these tools in higher education. (DP2) | 8.22 | 1.84 |
| 7. There are few meaningful learning experiences, as creating effective immersive experiences... requires careful pedagogical design and planning time. (DP3) | 8.03 | 1.85 |
| 8. Developing assessment methods that effectively measure learning achieved through these technologies can be a challenge. (DP4) | 7.83 | 2.08 |
| 9. Lack of adapted educational content: There is not enough educational material designed for these technologies, forcing teachers to create it from scratch ... (DP5) | 7.94 | 2.00 |
| 10. It is not always easy to transform academic content into meaningful immersive experiences. (DP6) | 7.83 | 2.12 |
| 11. Not all students are comfortable with immersive experiences, which can lead to inequalities in content comprehension. (DP7) | 6.45 | 2.48 |
| 12. Low student receptiveness: Students may use these technologies more for entertainment than for learning, hindering their academic use. (DP8) | 5.85 | 2.75 |
| 13. Distractions: The immersive nature of these technologies can lead to distractions and a loss of focus on educational objectives. (DP9) | 5.95 | 2.68 |
| 14. High implementation costs, as acquiring equipment and licenses can be expensive for many institutions. (DE1) | 7.96 | 2.11 |
| 15. Lack of financial incentives: Universities do not always offer compensation for the extra effort required to integrate these technologies. (DE2) | 8.08 | 2.19 |
| 16. Equipment maintenance and update needs, which require planning for ongoing expenses in addition to the initial investment. (DE3) | 8.07 | 1.83 |
| 17. Fear or mistrust of emerging technologies, as some faculty prefer traditional methods ... (DRC1) | 7.66 | 2.25 |
| 18. Cultural or institutional rejection of innovative methodologies that often clash with deep-rooted pedagogical practices. (DRC2) | 6.73 | 2.49 |
| 19. Lack of equitable access to these technologies can widen the digital divide and create inequalities among students. (DES1) | 7.70 | 2.16 |
| 20. The collection of student data through these technologies raises concerns about data privacy and security. (DES2) | 6.66 | 2.43 |
| 21. The use of AR, VR, and XR can cause disorientation, anxiety, and dizziness in users. (DES3) | 5.87 | 2.44 |
| 22. Universities with fewer resources may be excluded from these innovations, widening the digital divide between institutions. (DES4) | 7.77 | 2.31 |
| 23. Not all students have access to the necessary devices or possess the technological skills to fully participate in AR, VR, or XR-based activities. (DES5) | 7.63 | 2.20 |
| Instrument total | 7.36 | 1.32 |

**Table 3** presents the frequencies and percentages concerning their field of knowledge and whether they worked at a Spanish or Ibero-American university.

Participants were selected using the following criteria: individuals who had published a Spanish-language article on AR, VR, or XR between 2020 and February 2025 or who presented at the Edutec24 conference, and faculty from various research groups and Spanish and Latin American universities who were known to have worked on integrating these technologies into teaching. To gather further information about the sample's characteristics, we also asked the following questions: "How would you rate your technical knowledge of AR, VR, and XR?" and "How would you rate your knowledge of the pedagogical-educational use of AR, VR, and XR?" On a scale of 1 to 10, the first question received a mean (M) score of 6.38 with an SD of 2.16, while the second received an M of 6.50 and a SD of 2.34.

## RESULTS

**Table 4** presents the M scores and SDs for each item, as well as for the instrument.

**Table 5.** M and SD for each instrument dimension and for the total score

| | M | SD |
|---|---|---|
| Technical difficulties | 7.14 | 1.86 |
| Pedagogical difficulties | 7.40 | 1.47 |
| Economic difficulties | 8.04 | 1.71 |
| Difficulties from resistance to change | 7.20 | 2.11 |
| Ethical, social, and psychological difficulties | 7.13 | 1.71 |
| Total instrument score | 7.36 | 1.32 |

**Table 6.** Ms and SDs by gender (n = 767)

| | Male | | Female | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Total | 7.33 | 1.34 | 7.42 | 1.28 |
| Technical | 7.14 | 1.74 | 7.17 | 1.96 |
| Pedagogical | 7.42 | 1.48 | 7.39 | 1.45 |
| Economic | 7.99 | 1.68 | 8.09 | 1.69 |
| Resistance to change | 7.20 | 2.17 | 7.26 | 1.95 |
| Social inequality | 6.98 | 1.71 | 7.34 | 1.63 |

**Table 7.** Mann-Whitney U test for the gender (n = 767)

| Variable | U | p | Effect size (Cohen's d) | Direction of difference |
|---|---|---|---|---|
| Total | 76,506 | 0.330 | - | - |
| Technical | 76,469 | 0.336 | - | - |
| Pedagogical | 72,633 | 0.772 | - | - |
| Economic | 76,540 | 0.323 | - | - |
| Resistance to change | 72,623 | 0.769 | - | - |
| Social inequality | 82,718 | 0.003 | 0.211 | Women |

Analysis of item-level scores reveals a consistent pattern: the lowest-rated items cluster around student-centered and psychological barriers, with "low student receptiveness" (DP8, M = 5.85), "disorientation and anxiety" (DES3, M = 5.87), and "distractions" (DP9, M = 5.95) all falling below 6. These are barriers that faculty perceive as less under their control and possibly more contingent on student characteristics. By contrast, the highest-rated items are systemic and institutional: "insufficient faculty training" (DP1, M = 8.50), "lack of clear educational models" (DP2, M = 8.22), and "lack of financial incentives" (DE2, M = 8.08) all exceed 8, pointing to deficiencies in institutional support structures rather than individual resistance as the primary perceived obstacle.

The scores indicate a general tendency to rate the various items, as well as the instrument overall, as significant, with scores generally exceeding 7 on a scale from 1 (strongly disagree) to 10 (strongly agree). The SD values indicate moderate data dispersion. All distributions showed negative skewness, confirming a left-leaning, high-scoring distribution with a ceiling tendency consistent with the high Ms obtained. Together with the significant Kolmogorov-Smirnov (Lilliefors) results reported in the method, these departures from normality support the choice of non-parametric inferential tests throughout the analysis. The Ms and SDs for each dimension and for the total instrument score are presented in **Table 5**.

The five null hypotheses stated in the research hypotheses and analytical strategy subsection of the method (**H0a**-**H0e**) were tested in turn, each for the total instrument score and for every dimension. The analytical procedures (Mann-Whitney U and Kruskal-Wallis H with Dunn-Bonferroni post-hoc comparisons) are described in that subsection.

Beginning with the gender variable, **Table 6** presents the Ms and SDs for the total score and for each dimension.

To test **H0a**, the Mann-Whitney U test was applied to both the total instrument score and each dimension. **Table 7** presents the results of this test, the p-value for rejecting **H0a**, the effect size (Cohen's d) where **H0a** was rejected, and the direction of the difference. The results show that, overall, **H0a** is not rejected at a $p \leq .05$ level. Consequently, it can be stated that there are no differences in the perceptions of male and female faculty regarding the difficulties of incorporating AR, VR, and XR into higher education.

**Table 8.** Ms and SDs by university location (n = 767)

| | Spain | | Ibero-America | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Total | 7.1 | 1.2 | 7.7 | 1.4 |
| Technical | 6.8 | 1.8 | 7.5 | 1.9 |
| Pedagogical | 7.2 | 1.3 | 7.7 | 1.6 |
| Economic | 7.8 | 1.6 | 8.2 | 1.7 |
| Resistance to change | 7.0 | 2.0 | 7.5 | 2.1 |
| Social inequality | 6.8 | 1.7 | 7.5 | 1.6 |

**Table 9.** Mann-Whitney U test for the university location (n = 767)

| Variable | U | p | Effect size (Cohen's d) | Direction of difference |
|---|---|---|---|---|
| Total | 93,103 | < 0.001 | 0.429 | Ibero-American |
| Technical | 89,515 | < 0.001 | 0.337 | Ibero-American |
| Pedagogical | 91,080 | < 0.001 | 0.352 | Ibero-American |
| Economic | 86,089 | < 0.001 | 0.231 | Ibero-American |
| Resistance to change | 85,842 | < 0.001 | 0.251 | Ibero-American |
| Social inequality | 91,071 | < 0.001 | 0.417 | Ibero-American |

**Table 10.** Ms and SDs by age group (n = 767)

| | | Technical | Pedagogical | Economic | Resistance to change | Social inequality | Total |
|---|---|---|---|---|---|---|---|
| 20-30 years | M | 7.2 | 7.4 | 8.4 | 7.3 | 7.2 | 7.4 |
| | SD | 1.9 | 1.4 | 1.8 | 2.3 | 1.5 | 1.2 |
| 31-40 years | M | 7.0 | 7.2 | 7.8 | 7.3 | 7.0 | 7.2 |
| | SD | 1.7 | 1.4 | 1.7 | 1.9 | 1.6 | 1.3 |
| 41-50 years | M | 7.0 | 7.2 | 8.0 | 7.0 | 7.1 | 7.2 |
| | SD | 1.8 | 1.4 | 1.5 | 2.1 | 1.7 | 1.2 |
| 51-60 years | M | 7.4 | 7.7 | 8.1 | 7.1 | 7.3 | 7.5 |
| | SD | 2.1 | 1.5 | 1.8 | 2.3 | 1.7 | 1.4 |
| Over 61 years | M | 7.4 | 7.7 | 8.2 | 8.1 | 7.4 | 7.7 |
| | SD | 1.7 | 1.4 | 1.5 | 1.5 | 1.6 | 1.3 |
| Total | M | 7.2 | 7.4 | 8.0 | 7.2 | 7.2 | 7.4 |
| | SD | 1.9 | 1.5 | 1.7 | 2.1 | 1.7 | 1.3 |

**H0a** was rejected only for the social inequality dimension, where there was a significant difference at $p \leq .01$, with female faculty perceiving greater difficulty. However, it should be acknowledged that the effect size of this difference (0.211) is considered small (Cohen, 1988).

Next, **H0b**, regarding the significance of whether faculty were from Spanish or Ibero-American universities, was analyzed. **Table 8** provides the M scores and SDs, and **Table 9** shows the tests conducted for the acceptance or rejection of **H0b**.

The results allow for the rejection of **H0b**, for the total instrument score and for all five dimensions, at a $p \leq .01$ level. Therefore, it can be concluded that there are differences in the perceptions of faculty from Spanish and Ibero-American universities regarding difficulties, both overall and for each specific type (technical, pedagogical, economic, resistance to change, and social inequality). These differences favored Ibero-American faculty, who perceived greater difficulty. Regarding the effect sizes, they were also small in this case, although the total instrument score approached a medium level.

**Table 10** and **Table 11** present the M values and statistical tests performed to analyze whether significant differences existed based on faculty age (**H0c**). In this case, the Kruskal-Wallis H test was used to accept or reject **H0c**, and eta-squared was used to analyze the effect size (López & Ardura, 2023).

The results allow for the rejection of **H0c**, both for the instrument overall ($p \leq .01$) and for the perceived pedagogical, economic, and resistance-to-change difficulties. In most cases, the differences involved the 31-40 group and the older cohorts; the exception was the economic dimension, where the 20-30 group reported the highest scores. It is noteworthy that the effect sizes found in all cases were not very large.

**Table 11.** Kruskal-Wallis H test for faculty age (n = 767)

| Variable | H | p | Effect size (eta squared) | Significant differences (pairwise) |
|---|---|---|---|---|
| Total | 15.392 | 0.004 | 0.015 | 31-40 < over 61 & 41-50 < over 61 |
| Technical | 9.391 | 0.052 | - | - |
| Pedagogical | 22.035 | 0.001 | 0.024 | 31-40 < 51-60; 31-40 < over 61; 41-50 < 51-60; & 41-50 < over 61 |
| Economic | 12.638 | 0.013 | 0.011 | 20-30 > 31-40 |
| Resistance to change | 18.589 | 0.001 | 0.019 | 31-40 < over 61; 41-50 < over 61; & 51-60 < over 61 |
| Social inequality | 7.902 | 0.095 | - | - |

**Table 12.** Ms and SDs by teaching experience (n = 767)

| | | Technical | Pedagogical | Economic | Resistance to change | Social inequality | Total |
|---|---|---|---|---|---|---|---|
| 0 - 5 years | M | 7.0 | 7.4 | 8.0 | 7.1 | 7.0 | 7.3 |
| | SD | 1.8 | 1.3 | 1.7 | 1.9 | 1.5 | 1.2 |
| 6 - 10 years | M | 7.2 | 7.2 | 8.1 | 7.4 | 7.1 | 7.3 |
| | SD | 1.6 | 1.4 | 1.6 | 2.1 | 1.6 | 1.2 |
| 11 - 15 years | M | 6.8 | 7.3 | 7.8 | 7.2 | 7.1 | 7.2 |
| | SD | 2.0 | 1.5 | 1.8 | 2.2 | 1.8 | 1.4 |
| 16 - 20 years | M | 6.9 | 7.4 | 8.1 | 6.7 | 7.2 | 7.3 |
| | SD | 1.9 | 1.3 | 1.7 | 2.2 | 1.9 | 1.2 |
| Over 20 years | M | 7.5 | 7.6 | 8.2 | 7.4 | 7.3 | 7.6 |
| | SD | 1.9 | 1.6 | 1.7 | 2.0 | 1.6 | 1.4 |
| Total | M | 7.2 | 7.4 | 8.0 | 7.2 | 7.2 | 7.4 |
| | SD | 1.9 | 1.5 | 1.7 | 2.1 | 1.7 | 1.3 |

**Table 13.** Kruskal-Wallis H test for teaching experience (n = 767)

| Variable | H | p | Effect size (eta squared) | Significant differences (pairwise) |
|---|---|---|---|---|
| Total | 12.434 | 0.014 | 0.011 | No significant pairwise differences after Bonferroni correction |
| Technical | 14.601 | 0.006 | 0.014 | > 20 years > 11-15 & > 20 years > 16-20 |
| Pedagogical | 14.122 | 0.007 | 0.013 | > 20 years > 6-10 |
| Economic | 5.719 | 0.221 | - | - |
| Resistance to change | 13.190 | 0.010 | 0.012 | 16-20 years < over 20 years |
| Social inequality | 5.104 | 0.277 | - | - |

**Table 14.** Ms and SDs by field of knowledge (n = 767)

| | | Technical | Pedagogical | Economic | Resistance to change | Social inequality | Total |
|---|---|---|---|---|---|---|---|
| Arts & humanities | M | 7.4 | 7.4 | 8.0 | 7.0 | 7.2 | 7.4 |
| | SD | 2.0 | 1.8 | 1.9 | 2.3 | 1.8 | 1.6 |
| Sciences | M | 6.8 | 7.4 | 7.7 | 7.3 | 7.2 | 7.3 |
| | SD | 1.7 | 1.4 | 1.6 | 1.8 | 1.6 | 1.3 |
| Health sciences | M | 6.9 | 7.6 | 8.0 | 7.6 | 6.8 | 7.4 |
| | SD | 2.0 | 1.1 | 1.9 | 2.2 | 2.0 | 1.2 |
| Social & legal sciences | M | 7.1 | 7.2 | 8.0 | 7.1 | 7.2 | 7.3 |
| | SD | 1.8 | 1.3 | 1.6 | 2.0 | 1.5 | 1.2 |
| Engineering & architecture | M | 7.4 | 7.9 | 8.6 | 7.5 | 7.3 | 7.7 |
| | SD | 1.7 | 1.4 | 1.3 | 2.2 | 1.8 | 1.2 |
| Total | M | 7.2 | 7.4 | 8.0 | 7.2 | 7.2 | 7.4 |
| | SD | 1.9 | 1.5 | 1.7 | 2.1 | 1.7 | 1.3 |

Regarding the significance of teaching experience (**H0d**), the M values, SDs, and the corresponding hypothesis tests are presented in **Table 12** and **Table 13**.

The results allow for the rejection of **H0d**, both for the instrument overall ($p \leq .05$) and for the perceived technical, pedagogical, and resistance-to-change difficulties. Significant Dunn-Bonferroni pairwise differences are reported in **Table 13**.

Finally, the results regarding their fields of knowledge (**H0e**) will be presented. **Table 14** and **Table 15** show the Ms, SDs, and tests for accepting or rejecting **H0e**.

**Table 15.** Kruskal-Wallis H test for field of knowledge (n = 767)

| Variable | H | p | Effect size (eta squared) | Significant differences (pairwise) |
|---|---|---|---|---|
| Total | 12.673 | 0.013 | 0.011 | Social/legal sciences < engineering & architecture |
| Technical | 14.731 | 0.005 | 0.014 | Arts & humanities > sciences |
| Pedagogical | 21.237 | 0.001 | 0.023 | Engineering & architecture > social & legal sciences |
| Economic | 18.061 | 0.001 | 0.018 | Engineering & architecture > sciences<br>Engineering & architecture > social & legal sciences |
| Resistance to change | 10.565 | 0.032 | 0.009 | No significant pairwise differences after Bonferroni correction |
| Social inequality | 3.078 | 0.545 | - | - |

**Table 16.** Differences in ratings of technical and pedagogical knowledge by various variables (n = 767)

| | Variable | U | p | Effect size (Cohen's d) | Direction of difference |
|---|---|---|---|---|---|
| Gender | Technical | 60,558 | 0.001 | 0.328 | Males |
| | Pedagogical | 63,771 | 0.001 | 0.253 | Males |
| University | Technical | 77,893 | 0.151 | - | - |
| | Pedagogical | 74,799 | 0.676 | - | - |
| | | H | p | Effect size (eta-squared) | Significant differences |
| Age range | Technical | 12.007 | 0.017 | 0.010 | 31-40 years < 41-50 years |
| | Pedagogical | 13.546 | 0.009 | 0.012 | 31-40 years < 41-50 years<br>31-40 years < 51-60 years |
| Teaching experience | Technical | 20.321 | 0.001 | 0.021 | +20 years > 11-15 |
| | Pedagogical | 16.748 | 0.002 | 0.017 | +20 years > 11-15 |
| Field of knowledge | Technical | 30.548 | 0.001 | 0.035 | Health sciences < arts & humanities<br>Health sciences < sciences<br>Health sciences < engineering & architecture<br>Social/legal sciences < engineering & architecture |
| | Pedagogical | 15.069 | 0.005 | 0.014 | Health sciences < arts & humanities<br>Health sciences < sciences<br>Health sciences < social/legal sciences<br>Health sciences < engineering & architecture |

The results allow for the rejection of **H0e** regarding the non-existence of significant differences at $p \leq .05$ for the instrument overall and for perceived technical, pedagogical, economic, and resistance-to-change difficulties. The primary pairwise differences were found between faculty in engineering and architecture and those in sciences and social and legal sciences; for perceived technical difficulties, faculty in arts and humanities reported greater difficulties than those in sciences. No Dunn-Bonferroni pairwise comparison remained significant for resistance to change.

As an exploratory, post-hoc analysis extending beyond the stated hypotheses (**H0a**-**H0e**), we examined whether faculty perceptions of their own technical and pedagogical-educational knowledge of AR, VR, and XR differed according to gender, age, teaching experience, field of knowledge, and university location. This analysis was not covered by any of the hypotheses pre-stated in the method; the results, presented in **Table 16**, are therefore to be interpreted as exploratory and hypothesis-generating rather than confirmatory.

The values show no differences in the ratings of technical and pedagogical competencies between faculty at Spanish and Ibero-American universities. Regarding technical skills, significant differences were found among the following groups: men rated themselves higher than women; those aged 31-40 rated themselves lower than those aged 41-50; those with over 20 years of experience rated themselves higher than those with 11-15 years; faculty in health sciences rated themselves lower than those in arts and humanities, sciences, and engineering and architecture; and faculty in social and legal sciences rated themselves lower than those in engineering and architecture.

In the case of pedagogical skills, significant differences were found among the following groups: men rated themselves higher than women; those aged 31-40 rated themselves lower than those aged 41-50 and 51-60; those with over 20 years of experience rated themselves higher than those with 11-15 years; and faculty in health sciences rated themselves lower than faculty in all four other fields of knowledge.

## CONCLUSIONS, DISCUSSION, LIMITATIONS, AND FUTURE RESEARCH

First, it should be noted that while the participant selection process was not random and a filtering method such as the expert competence coefficient was not applied (Cabero-Almenara et al., 2020), the number of responses received and the established selection criteria (i.e., having published a scientific article or presented at the Edutec24 conference) ensure the quality of the findings. Furthermore, the high reliability indices, for both the overall instrument and its various dimensions, underscore the quality of the obtained scores.

The research has revealed that participants perceive the integration of AR, VR, and XR technologies as a process that involves overcoming a series of challenges, with economic ($M = 8.04$) and pedagogical ($M = 7.40$) barriers being the most prominent. Importantly, all five dimensions received M scores of seven or above on the ten-point scale, indicating that no barrier category is perceived as negligible. Interpreted through the TAM/UTAUT2 framework, the prominence of pedagogical and economic barriers suggests that facilitating conditions and faculty preparedness are particularly relevant to the integration of immersive technologies. These findings converge with the barriers documented in **Table 1** and with the meta-analytic evidence reviewed.

No significant differences were found in the overall perception of challenges based on gender, consistent with prior research on technology adoption where gender has not emerged as a significant moderator (Colomo-Magaña et al., 2023; Hidalgo-Cajo & Gisbert-Cervera, 2021). From a UTAUT2 perspective, this suggests that the core constructs of performance expectancy, effort expectancy, and facilitating conditions are experienced similarly by male and female faculty in this context. However, the significant gender difference found specifically on the Social Inequality dimension—with female faculty rating these barriers higher ($p < .01$, $d = 0.211$)—merits interpretation. Drawing on the gender and technology literature, women in academic settings may be more sensitized to digital equity and accessibility issues because their own experiences of structural disadvantage in academic hierarchies make them more attuned to how technology can reproduce or amplify existing inequalities among students (González-Medina et al., 2024; Vergara et al., 2021). While the small effect size indicates a modest difference, this finding warrants further investigation, particularly with respect to whether it is mediated by field of knowledge or institutional type.

Conversely, significant differences were found in the perception of challenges based on the university's location (Spanish or Ibero-American). Faculty at Ibero-American universities rated the identified challenges more highly, with significant differences found across all dimensions compared to their counterparts at Spanish universities. This is understandable given the existing disparities between most Spanish and Ibero-American universities, as highlighted in official reports on the impact of the digital divide in Ibero-American universities concerning digital technologies (Banco Interamericano de Desarrollo, 2021; Cantor & Morocho, 2023; González, 2024; Rivoir & Morales, 2019). However, it is important to acknowledge that these between-group M comparisons presuppose measurement invariance across the Spanish and Ibero-American sub-samples—an assumption that has not been empirically verified. As detailed in the Limitations section, multi-group confirmatory factor analysis to test configural, metric, and scalar invariance is required before strong comparative conclusions can be drawn. Differences were also found according to field of knowledge. Significant global differences emerged for the total instrument score and for technical, pedagogical, economic, and resistance-to-change difficulties, whereas no significant differences were found for ethical, social, and psychological difficulties. However, no Dunn-Bonferroni pairwise comparison remained significant for resistance to change. Overall, the corresponding effect sizes were small, indicating that the disciplinary differences should be interpreted as modest and dimension-specific.

Differences in the perception of challenges were also found based on participants' age and years of teaching experience, with the oldest and most experienced groups generally reporting higher difficulty scores, although the pattern was not strictly linear across all age and experience categories. However, the specific types of challenges differed between these two variables. Regarding age, differences were observed in pedagogical, economic, and resistance-to-change difficulties. In contrast, for teaching experience, differences were found in technical, pedagogical, and institutional-resistance-to-change difficulties. No significant differences were found for either variable in the "ethical, social, and psychological difficulties" dimension.

The age-related findings reveal a non-monotonic pattern that deserves theoretical interpretation rather than simple description. The 31-40 and 41-50 age groups reported the lowest difficulty scores—a finding that initially appears counterintuitive, since older faculty are not necessarily the youngest adopters. This pattern is consistent, however, with a cohort-effect explanation: mid-career faculty completed their doctoral training during the period of initial AR/VR educational experimentation (approximately 2010-2020) and may have developed greater technological familiarity while simultaneously having sufficient institutional seniority to access resources. In UTAUT2 terms, these groups may have higher self-efficacy and more positive facilitating-condition perceptions. By contrast, the oldest cohort (over 61) reported the highest difficulties, particularly in resistance to change—a pattern consistent with diffusion-of-innovation theory (Rogers, 2003) and empirical evidence that digital competence declines with age in the absence of ongoing institutional training (González-Medina et al., 2024; Vergara et al., 2021). The evidence from our study could be explained, as noted in other research that has also considered faculty age (Baldoni et al., 2023; González-Medina et al., 2024; Vergara et al., 2021; Wang & Chuang, 2023), by the fact that these faculty members often exhibit resistance to change in general and to the adoption of technology in particular. It is significant that these experienced faculty members point to the institution itself as a source of the difficulty, citing its resistance to transforming teaching methodologies and technologies.

Regarding the study’s limitations, several aspects must be carefully acknowledged. First, the sample was recruited through purposive criteria (publication record, conference attendance, and known research-group affiliation), which introduces selection bias and limits generalization: participants have already engaged with AR/VR/XR research, and their perceptions of barriers may differ systematically from those of faculty with no prior exposure to these technologies. Second, all data are self-reported and collected at a single time point, making the study susceptible to common-method bias. Perceptions of barriers may be influenced by social desirability (faculty aware that their institution promotes these technologies may under-report difficulties) or by recency effects (faculty who recently encountered problems may over-report them). Longitudinal designs or multi-method approaches combining survey data with objective usage logs and semi-structured interviews would strengthen validity. Third, and critically, no measure of actual AR/VR/XR adoption behavior was included. The instrument measures perceived barriers, which are not guaranteed to predict adoption decisions; TAM and UTAUT2 research consistently documents intention-behavior gaps in educational technology contexts. Fourth, although statistically significant differences were found between Spanish and Ibero-American sub-samples on all five dimensions, measurement invariance across these groups has not been established. Without multi-group confirmatory factor analysis testing configural, metric, and scalar invariance, it is not possible to determine whether observed mean differences reflect true between-group differences in barrier perceptions or are partially attributable to scale non-equivalence (differential item functioning). This represents a critical limitation that should be addressed before strong comparative conclusions are drawn. Fifth, threats to external validity arise from the disciplinary and gender composition of the sample, which may not be proportionally representative of all academic fields or institutional types in Spain and Ibero-America. Replication with probability samples and inclusion of additional Spanish-speaking regions would improve generalizability.

The identified challenges suggest several avenues for future research, moving in the following directions: replicating the study with faculty from universities in different geographical regions; using the expert competence coefficient strategy to refine the final sample selection; and implementing a second round of feedback with participants to allow them to review the findings and rate their final agreement.

Based directly on the empirical findings of this study, several evidence-grounded measures can be proposed for educational institutions and academic leaders seeking to facilitate the integration of AR, VR, and XR into higher education.

1. First, establishing training plans that equip faculty to use these technologies effectively in their teaching practices. However, it is not enough merely to create these plans; they should be oriented more toward the pedagogical dimension than toward simple instrumental use. At the same time, if, as various authors point out, pedagogical practices supported by these technologies are often mobilized under constructivist, generative, and experiential learning perspectives (Kavanagh et al., 2017; Marougkas et al., 2024; Mulders et al., 2020), this training should also be planned considering these frameworks.

2. It is necessary to establish financial strategies in institutional strategic plans that do not focus exclusively on hardware acquisition but also on the maintenance and updating of acquired equipment. This investment should also necessarily contribute to improving the quality of existing Wi-Fi technology in the institutions, prioritizing cross-platform solutions like WebXR and Wi-Fi 6.
3. Due to the high cost of production, it is necessary to create institutions or hubs dedicated to producing learning objects with these technologies, which can then be included in open-access institutional repositories. Creating high-quality educational materials would also require collaboration between educators and developers.
4. The lack of references and theoretical frameworks for the use of these technologies requires establishing research plans that prioritize the search for design principles and the analysis of effective educational methodologies for their use. In this context, it could be beneficial to establish policies for transferring best practices within educational institutions and to design implementation guides.
5. And finally, fostering a culture of educational innovation within the institutions.

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**Ethics declaration:** The authors declared that, in accordance with the institutional regulations of the University of Seville and applicable Spanish national legislation, formal approval from an Ethics Committee or Institutional Review Board is not required for this type of study. The research involved adult university faculty members participating in their professional capacity; participation was entirely voluntary; no sensitive personal data, as defined in Article 9 of Regulation (EU) 2016/679, were collected; and the study involved no medical or clinical intervention. All procedures performed in this study were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki (World Medical Association, 2025) and with Regulation (EU) 2016/679 (General Data Protection Regulation) and Spanish Organic Law 3/2018 on the Protection of Personal Data and Guarantee of Digital Rights. Prior to participation, all participants were fully informed about the purpose and procedures of the study, the voluntary nature of their participation, the anonymous treatment of their responses, and their right to withdraw at any time without consequence, and all provided informed electronic consent before accessing the questionnaire. No incentives were offered.

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