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# Quantitative analysis of the use of virtual reality environments among higher education professors

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**Abstract**

Virtual Reality (VR) is a computer-generated environment with noteworthy didactic applications in different educational levels and areas of knowledge. The study of the perceptions of the agents involved about the use of VR in lectures is a fruitful line of research because it has implications in terms of the measures to be taken to improve the training and competence of professors in its use. In this paper, a quantitative, descriptive, and correlational research is carried out on the assessments of a sample of 1638 Latin American university professors on both (i) the didactic use of VR and (ii) the influence of the professors' area of knowledge on these assessments. For this purpose, a validated questionnaire was used, the responses to which were subjected to statistical analysis. As a result, it was found that the ratings of VR are very high, but professors believe that their digital skills for its use are insufficient. In addition, the professors' area of knowledge significantly influences their ratings, being higher in the areas of knowledge in which professors have a better self-concept of their digital skills. Furthermore, gender gaps have also been identified in the answers given, which behave differently according to the area of knowledge. Finally, some conclusions, implications, and recommendations are drawn from the results obtained.

**Keywords:** Virtual reality, Digital learning environments, Educational technologies, Digital competence

## Introduction

Virtual reality (VR) is a set of computational technologies that enable the creation, through 3D graphic design techniques, of realistic environments with which the user can interact (Onyesolu & Eze, 2011). Therefore, the following are specific characteristics of VR technologies: (i) use of 3D designs to provide a realistic experience, which results in a more affective experience by users (Newman et al., 2022); and (ii) possibilities of human–computer interaction (Zhou et al., 2018). Also, the degree of immersion of the user's experience with virtual environments is variable and affects the realistic and interactive nature of VR (Kyriakou et al., 2017). It is possible to distinguish, according to the immersive character of VR, between immersive VR (IVR) and non-immersive VR (NIVR). Thus, the NIVR experience itself is the sensory and interactive experience with the simulated environment, but without the user evading the real environment in which he/she finds him/herself. In contrast, the IVR experience is one of total disconnection from the real environment and immersion in the simulated environment.

Other classifications of VR based on its immersive nature conceive immersiveness as a continuum of the integration of the user experience from the real environment to the virtual environment (Milgram & Kishino, 1994). However, classifications of VR based on immersiveness vary depending on the application of these technologies. Specifically, in the use of VR for educational purposes, four types of VR are distinguished (Zhou et al., 2018): (i) desktop semi-immersive VR; (ii) mobile semi-immersive VR; (iii) fully immersive VR room; and (iv) fully immersive headset supported VR. The first two scenarios generate weakly immersive experiences and are differentiated by the way of entering the virtual environments: desktop computers or pads, in desktop semi-immersive VR, or mobile phones or pads in mobile semi-immersive VR. This type of environments has been employed in several areas of knowledge to address situations in which spatial vision and three-dimensional geometric problem solving play an essential role (Hwang & Hu, 2013). Fully immersive VR rooms and headset supported VR, on the other hand, provide a strong immersive experience. VR rooms allow the environment to be projected on walls and floor, so that immersion is achieved because that projection covers 360°. VR headset, on the other hand, provides room-scale VR with 360° coverage immersion (Dalgarno & Lee, 2010)

VR is a particularly versatile teaching resource in higher education, where it can be applied in the most diverse areas of knowledge (Radianti, 2020). In technical areas, VR is applied to teaching content on issues involving complex spatial and geometric visualization (Kaufmann et al., 2000), or to experimentation through virtual laboratories (Potkonjak et al., 2016; Vergara et al., 2022a, 2022b). Meanwhile, in health science education, there are experiences of VR application in the representation of anatomical structures (Duarte et al., 2020), the simulation of surgical actions (Rogers et al., 2021), or the recreation of certain situations applied to the care of mental health problems (Srivastata et al., 2014). Although higher education in technical and health areas are those that most frequently apply VR technologies, VR can be applied in other areas. Among them, higher humanistic and artistic education (González-Zamar & Abad-Segura, 2020; Hutson & Olsen, 2022) or history education (Zhang, 2019), among others.

The use of VR technologies in higher education links with the pedagogical line of introducing virtual learning environments of an immersive nature (López-Belmonte et al., 2023). Specifically, VR allows the simulation of very diverse environments that allow the student to acquire learning while having a realistic and immersive experience of it. In this way, through VR it is possible to provide the student with realistic interaction situations with machinery or architectural structures whose physical access is very difficult or expensive (Balamuralithara & Woods, 2009; Vergara et al., 2022a, 2022b), or with anatomical structures and medical and surgical processes, generating simulations that are at once realistic, immersive, and safe (Moro et al., 2017). This is, on the one hand, stimulating and motivating for the student, who is usually a digital native, and on the other hand, it allows costs to be reduced and facilitates guaranteed learning even in situations in which physical presence is compromised (distance teaching, health crisis situations, or access to higher education for students who reside in rural regions or with widely dispersed populations) (Kavanagh et al., 2017).

The literature has shown the educational effectiveness of using VR in higher education as a didactic resource (hereafter referred to as the didactic use of VR). Recent studies reveal that this type of technology helps students to increase their academic performance and that this increase is positively correlated with the user experience rating (Mäkinen et al., 2022). The literature presents a wide range of reasons that justify the didactic benefits of using VR in higher education. Among these reasons are the following: VR is more adaptable to the achievement of certain didactic and learning objectives than other traditional resources (Touloudi et al., 2022); it allows illustrating objects and concepts in realistic and sensorially perceptible environments, which makes meaningful learning easier (Bazarov et al., 2017; Kaminska et al., 2017); allows for interdisciplinary and multidisciplinary presentation of concepts (Singh et al., 2020); and facilitates student motivation and engagement toward learning (Natale et al., 2020).

However, the literature also reports some disadvantages of using VR in higher education. Among them, in some teachings, such as medicine (El-Miedany, 2019) or architecture (Checa & Bustillo, 2020), there is a need to complement training through virtual environments with authentic face-to-face training if complete learning is to be guaranteed. Furthermore, the strong digital gap that exists between students and between them and professors also conditions its use in higher education (Cabero-Almenara et al., 2021). Finally, some students state that the use of digital technologies such as VR have a distracting effect in terms of their participation in teaching–learning activities (Checa & Bustillo, 2020).

Likewise, the literature identifies difficulties and limitations for the integration of VR technologies in higher education. Among them, the lack of faculty training in digital skills development, in general (Antón-Sancho & Sánchez-Calvo, 2022), and for the use of VR, in particular (Antón-Sancho, Vergara et al., 2022a, 2022b). The difficulty of increasing faculty training in the use of digital teaching technologies lies, in part, in the age gap that exists in terms of the use of these technologies (Antón-Sancho, Cabero-Almenara et al., 2021; Vergara et al., 2022a, 2022b). However, it is also explained by the need to integrate, within digital training, the development of techno-pedagogical skills, which refer to the ability to mobilize digital resources for the achievement of specific didactic objectives (Noghabaei et al., 2020). Another limitation frequently pointed out by the literature is the economic cost involved in the implementation of VR technologies, linked to the need to dedicate specific spaces for the equipment, which is also subject to the effect of technological obsolescence (Chang et al., 2022).

Research on the reception of VR among the agents involved in higher education mainly follows two lines: the analysis of the work carried out presenting and assessing new virtual designs for teaching (Radianti et al., 2020), and the analysis of the evaluations made by professors and students regarding the use of VR (Lorenzo et al., 2019). The reception of VR is very good and growing in higher education, although unequal according to certain academic factors, such as the area of knowledge in which it is applied (Fernández-Arias et al., 2023); other geographical factors, such as the level of digitization of the country being studied (Antón-Sancho et al., 2023); and other sociological factors, such as the gender of the agents involved (Onele, 2023; Vergara et al., 2022a, 2022b). The general research objective of this work is to study the influence of the area of knowledge of a sample of Latin American university professors on their evaluations of the didactic use of VR. Specifically, it seeks to achieve the following specific objectives: (i) to study the perceptions that the sample of Latin American university professors has of the use of VR in higher education; (ii) to carry out a correlational study on the influence of the participants' area of knowledge on their evaluations of VR; and (iii) to study the gender gaps in the perceptions analyzed among the participants in each area of knowledge.

## Literature review

The specialized literature has shown that, in general, the area of knowledge of university professors influences their digital skills (Blayone et al., 2018; Cabero-Almenara et al., 2021). Specifically, professors from scientific-technical areas, in principle with better training in the use of digital technologies, manifest better digital skills, which results in a more frequent use of digital technologies in lectures (Antón-Sancho & Sánchez-Calvo, 2022). Even engineering professors report insufficient digital skills and a strong lack of training in the use of VR (Cabero-Almenara et al., 2021; Vergara et al., 2022a, 2022b). In this sense, Fernández-Arias et al. (2023) show that there are no significant differences between the self-concept of digital skills for the use of VR of engineering and health sciences professors. However, the literature manifests uneven results in this regard when the focus is placed on faculty in specific countries. For example, a study conducted in Colombia concludes that professors from humanities and social sciences areas are those who express having better digital skills (Antón-Sancho, Vergara et al., 2022a, 2022b). However, Guillén-Gámez et al. (2022) found that there are no significant differences between the digital skills of Spanish university professors from different areas of knowledge. Underlying this disparity of results is a divergence in the digital training of professors according to their area of knowledge (Núñez-Canal et al., 2022). This significant difference in the frequency of use of digital technologies means that professors who use them less are more optimistic when it comes to assessing their skills (Antón-Sancho & Sánchez-Calvo, 2022). There is also a geographical factor that affects the use of digital technologies, probably linked to the level of digital development of different countries (Antón-Sancho et al., 2023; Zhao et al., 2021).

University professors' ratings of VR technologies have been found to be very good (Rasimah et al., 2011; Wells & Miller, 2020), particularly in terms of the development of logical thinking and problem solving, student engagement and motivation (Hamilton et al., 2021), and student acceptance (Rocha-Estrada et al., 2022). This is consistent with the good formative outcomes that VR has been shown to have (Merchant et al., 2014). In science and technology education, in particular, professors highlight that the use of VR allows overcoming the apathy that students, in general, feel towards the study of concepts that are sometimes complex (Fragkaki et al., 2020). In contrast, when VR is applied to the teaching of humanities and art, professors emphasize more the development of cross-cutting skills, such as communicative and teamwork skills, that the use of VR raises (Lu, 2011). In any case, professors do not fail to point out that there are difficulties that limit the implementation of VR in higher education institutions, mainly due to the costs involved and the training needs of professors (Alqahtani & AlNajdi, 2023; Hamilton et al., 2021). Studies conducted in Mexico and Colombia show that professors who express better digital skills –engineering professors in Mexico and humanities professors in Colombia– are those who best value VR, both in its technical dimensions of interaction, realism, and interactivity, and in its aspects of didactic effectiveness (Antón-Sancho, Vergara et al., 2022a, 2022b). However, as far as we have been able to explore, this correlation has not been corroborated. In the broader geographic region of Latin America and the Caribbean, it has been found that engineering professors rate the technical and usability aspects of VR higher than health sciences professors, but there are no significant differences between professors in the two areas with respect to the rating of the didactic effectiveness of VR (Fernández-Arias et al., 2023).

As far as it has been possible to explore, there are no studies that systematically analyze the differences by area of knowledge in the assessments of VR in a broad geographic region, such as Latin America and the Caribbean, which constitutes an original contribution of the present work. There are studies that make an indirect analysis of the influence of the area of knowledge on VR ratings. For example, Antón-Sancho et al., (2022a, 2022b) show that the digital generation of professors (digital natives or immigrants) conditions their ratings, in line with Kuleto et al. (2021), but that the way in which this influence occurs is different depending on whether the professor is a specialist in scientific-technical or humanistic-social areas. Specifically, the generation gap is greater in humanistic-social areas than in scientific-technical areas (Antón-Sancho et al., 2022a, 2022b).

Cabero-Almenara et al. (2021) explains that there is no broad consensus in the literature when it comes to identifying gender gaps in the use and appreciation of digital technologies among higher education professors. Thus, in some works it is explained that males make more frequent use of digital technologies and value them better than females (Cai et al., 2017). But other studies point out the opposite thesis (Krumsvik et al., 2016), while others do not find gender gaps in this regard (Guillén-Gámez et al., 2021). There is also no consensus on the identification of factors that can influence these gender gaps, but one of them could be the level of digitalization of each geographic region. In the Latin American and Caribbean region, there is a strong gender gap that affects the access and use of digital technologies, to the detriment of females (Ancheta-Arrabal et al., 2021; Basantes-Andrade et al., 2023). Some studies show that males are more interested than females in the use of VR applications in the classroom (Moreira et al., 2017). In other studies, it is found that this gender gap extends to the evaluations that professors give of VR, this being lower, in general, among females than among males (Antón-Sancho, Vergara et al., 2022a, 2022b). However, in this respect there are uneven results in the literature. Indeed, Vergara et al., (2022a, 2022b) showed that the gender gaps cited in the VR ratings of engineering professors depend on the tenure, private or public, of the university where the professor teaches. On the other hand, Antón-Sancho et al. (2023) did not identify significant gender gaps in a study that did not distinguish between areas of knowledge. This result contradicts those obtained by Vergara et al., (2022a, 2022b) in a population of engineering professors. All this proves that there must be academic factors, such as area of knowledge or university tenure, or other types of factors that condition the way in which the above-mentioned gender gaps behave.

## Materials and methods

### Research variables

Two explanatory variables are considered in the study. The main explanatory variable is the participants' area of knowledge. It is a polytomous categorical variable, whose possible values are: Arts and Humanities (hearafter, Humanities; includes arts, history, philology, literature, and philosophy); Pure and Experimental Sciences (hearafter, Sciences; includes mathematics, physics, chemistry, and natural sciences); Health Sciences (hearafter, Health Sciences; includes medicine, nursering, veterinary, and dentistry); Social and Legal Sciences (hearafter, Social Sciences; includes psychology, pedagogy, sociology, law, political science, economics, geography, and communication); and Engineering and Architecture (hearafter, Engineering; includes technical education, engineering, design, and architecture). These knowledge areas have been extracted from the International Standard Classification of Education (ISCED), which is the classification established by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2011), integrating the area of Education within the area of Social and Legal Sciences. As a secondary explanatory variable, gender is considered, which is a dichotomous categorical variable with possible values female and male.

Likewise, five explained variables are analyzed: (i) self-concept of university professors' digital competence for the use of VR; (ii) assessment of VR usability (in terms of interaction, user experience, immersion, realism, 3D graphic design, ease of use, and didactic usefulness); (iii) level of disadvantages of VR (costs, requirement of space and human and technical capital, lack of faculty training, and technological obsolescence of equipment); (iv) perspective of future implementation of VR technologies in higher education; and (v) perceived didactic effectiveness of the use of VR in higher education (student acceptance, induced motivation, impact on academic performance and lecture development). All the variables explained are quantitative and are measured on a Likert-type scale from 1 to 5, where 1 corresponds to a very low rating and 5 corresponds to a very high rating.

### Participants and data collection

The target population is a set of 1638 Latin American university professors registered as attendees in a training session on the didactic use of VR in higher education given by the authors every fifteen days between January and June 2023. This training session, developed in the form of a lecture, aimed at the theoretical presentation of the following contents: (i) notion and types of VR technologies (immersive, IVR and NIVR); (ii) technical characteristics of VR; and (iii) examples of didactic application of VR in higher education. After the training session, the attendees received by e-mail the questionnaire that served as the research instrument. The criteria for inclusion in the study were the following: (i) being an active university professor at a university in a Latin American and Caribbean country; and (ii) having attended the training session on VR given by the authors.

A total of 1,320 professors participated in the study. Participants lacked practical experience using VR technologies in higher education, beyond that provided in the training session they attended. All of them were informed of the research purposes of their participation and expressed their express consent to do so. Participation was voluntary, free, and anonymous, and no data were collected that could be used to identify participants. It can be assumed that, at the time of answering the questionnaire, the participants had a homogeneous and sufficient knowledge of the didactic use of VR technologies, even if they had no experience in their use, due to their attendance to the training session.

The areas of knowledge with the largest representation are Social Sciences (31.7%) and Engineering (24.9%). The minority areas are Sciences (16.2%), Humanities (14.8%), and Health Sciences (12.4%). In all the areas of knowledge analyzed, the frequency of females is higher than that of males, except in Engineering, where there are more males than females (Fig. 1).

In addition to the questions asked to the participants to assess the explanatory variables of the study, they were also asked about the country in which they teach, to complete their sociodemographic profile. The origin of the professors is diverse and not homogeneous within the Latin American and Caribbean region (Fig. 2), resulting in a strong bias by country of origin.

## Research instrument

In this research, a 22-question questionnaire has been used to assess different aspects or dimensions of VR on a scale of 1 to 5, where 1 means the lowest rating and 5 means the highest rating (Appendix A). The questionnaire has been validated in terms of its construct (Vergara et al., 2022a, 2022b) by means of an Exploratory Factor Analysis that allows identifying five families of questions that explain 54.1% of the variance: (i) digital skills for the use of VR (questions 1–4); (ii) usability of VR (questions 5–11); (iii) level of disadvantages for the didactic use of VR in higher education (questions 12–16); (iv) future projection for the use of VR in higher education (questions 17 and 18); and (v) aspects of didactic effectiveness of VR (questions 19–22). The validation was completed by analyzing the Cronbach's alpha parameters and the reliability through the composite reliability parameters, all of them greater than 0.70. Likewise, it was also measured that the average variance extracted was greater than 0.50

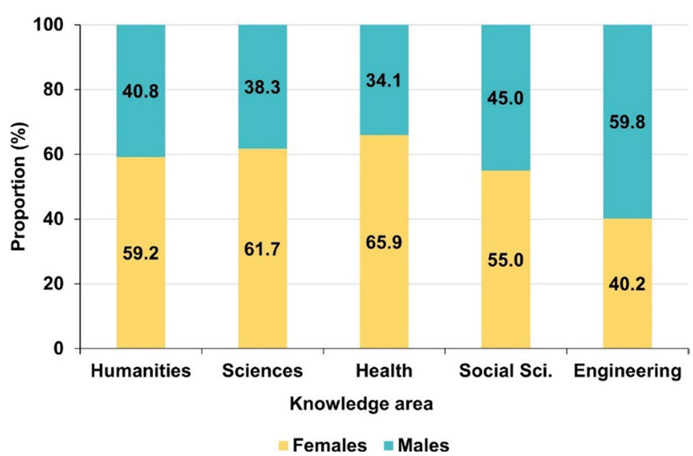


**Fig. 1** Distribution of the participants (%) by knowledge area and gender


**Fig. 2** Distribution of the participants by country

in all the identified families of questions. Finally, it was verified, through Pearson's correlation coefficients, that the different families of questions identified have low or moderate correlations between them, but high correlations with respect to the total questionnaire (Vergara et al., 2022a, 2022b).

The theoretical model of five families of questions described by Vergara et al., (2022a, 2022b) to explain the instrument is consistent with the results of the confirmatory factor analysis carried out with the responses obtained in the present research (chi-square = 1960, $p$-value < 0.0001). The incremental fit indices (adjusted goodness-of-fit index = 0.8504; NFI = 0.8384; TLI = 0.8233; CFI = 0.8516; IFI = 0.8521) and the absolute fit indices are good (GFI = 0.8853; SRMR = 0.0821; AIC = 2078.001; chi-square/df = 10.1031), but they are not optimal, since AGFI, NFI, TLI, CFI, IFI, GFI are not above 0.90, although all of them are above 0.83. Internal reliability parameters are optimal (Table 1).

**Table 1** Cronbach's alphas of the different families of responses

| Family of responses | Cronbach's Alpha |
|---|---|
| Competence | 0.7580 |
| Usability | 0.8473 |
| Disadvantages | 0.8033 |
| Future projection | 0.8107 |
| Didactic aspects | 0.7615 |

### Statistical analysis

The responses to the questionnaire have been analyzed quantitatively. To this end, the main descriptive statistics were obtained, and it was verified by means of the Shapiro–Wilk normality test that it is not possible to assume that the responses are normally distributed. Consequently, the Kruskal–Wallis nonparametric test was used to analyze the influence of the area of knowledge on the mean responses given, and the Wilcoxon nonparametric test was used to compare the mean responses for each pair of areas of knowledge, to identify which paired differences were significant. Finally, the Wilcoxon test was used again, within each knowledge area, to identify gender gaps in the responses.

## Results

The average digital skills expressed by the participating professors are low (below 3 out of 5). However, the ratings of VR are high (above 4 out of 5) both in its didactic and usability dimensions (Table 2). The greatest dispersion is found in the responses on digital competencies and assessment of the disadvantages of VR, with the responses on digital skills showing the greatest variation (Table 2).

The Kolmogorov–Smirnov normality test carried out on the responses of each of the families considered reveals that it is not possible to assume that the responses are normally distributed. Therefore, nonparametric hypothesis testing was chosen. From the Kruskal–Wallis test statistics, it follows that there is a gap by knowledge area in the responses of all the families of questions analyzed (Table 3). From this observation and from the p-values provided by the Wilcoxon tests for two samples performed, in each family of responses analyzed, comparing the mean responses of each pair of knowledge areas (Appendix B), the following is shown: (i) Health Sciences professors are those who express lower digital skills, with no significant differences between them and Sciences

**Table 2** Descriptive statistics of the responses

| Family | Mean (out of 5) | Standard Deviation (out of 5) | Coefficient of Variation (%) |
|---|---|---|---|
| Competence | 2.76 | 1.19 | 43.18 |
| Usability | 4.01 | 0.95 | 23.73 |
| Disadvantages | 3.61 | 1.22 | 33.73 |
| Future projection | 3.79 | 1.01 | 26.67 |
| Didactic aspects | 4.07 | 1.01 | 24.92 |

**Table 3** Mean responses (out of 5) differentiating by the area of knowledge of the participants and statistics of the Kruskal–Wallis test

| Family | Humanities | Sciences | Health | Social Sci | Engineering | KW chi-square | *p*-value |
|---|---|---|---|---|---|---|---|
| Competence | 2.77 | 2.71 | 2.60 | 2.82 | 2.77 | 13.93 | 0.0075** |
| Usability | 3.86 | 4.02 | 3.95 | 4.02 | 4.11 | 28.57 | 0.0000*** |
| Disadvantages | 3.60 | 3.53 | 3.64 | 3.67 | 3.59 | 10.56 | 0.0320* |
| Future projection | 3.72 | 3.67 | 3.94 | 3.78 | 3.85 | 13.22 | 0.0103* |
| Didactic aspects | 4.02 | 4.04 | 4.10 | 4.04 | 4.13 | 13.36 | 0.0097** |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

professors (Table 4); (ii) professors of Engineering give higher ratings to the technical aspects of VR than professors of the other areas (Table 5); (iii) the lowest level of disadvantages of VR is expressed by professors of Sciences, without significant differences with those of Humanities and Engineering (Table 6); (iv) the professors of Health Sciences are those who give the greatest future projection to VR, with no differences with the professors of Engineering (Table 7); and (v) the professors of Engineering are those who give the best evaluations to the didactic aspects of VR, with no significant differences with the professors of Health Sciences (Table 8).

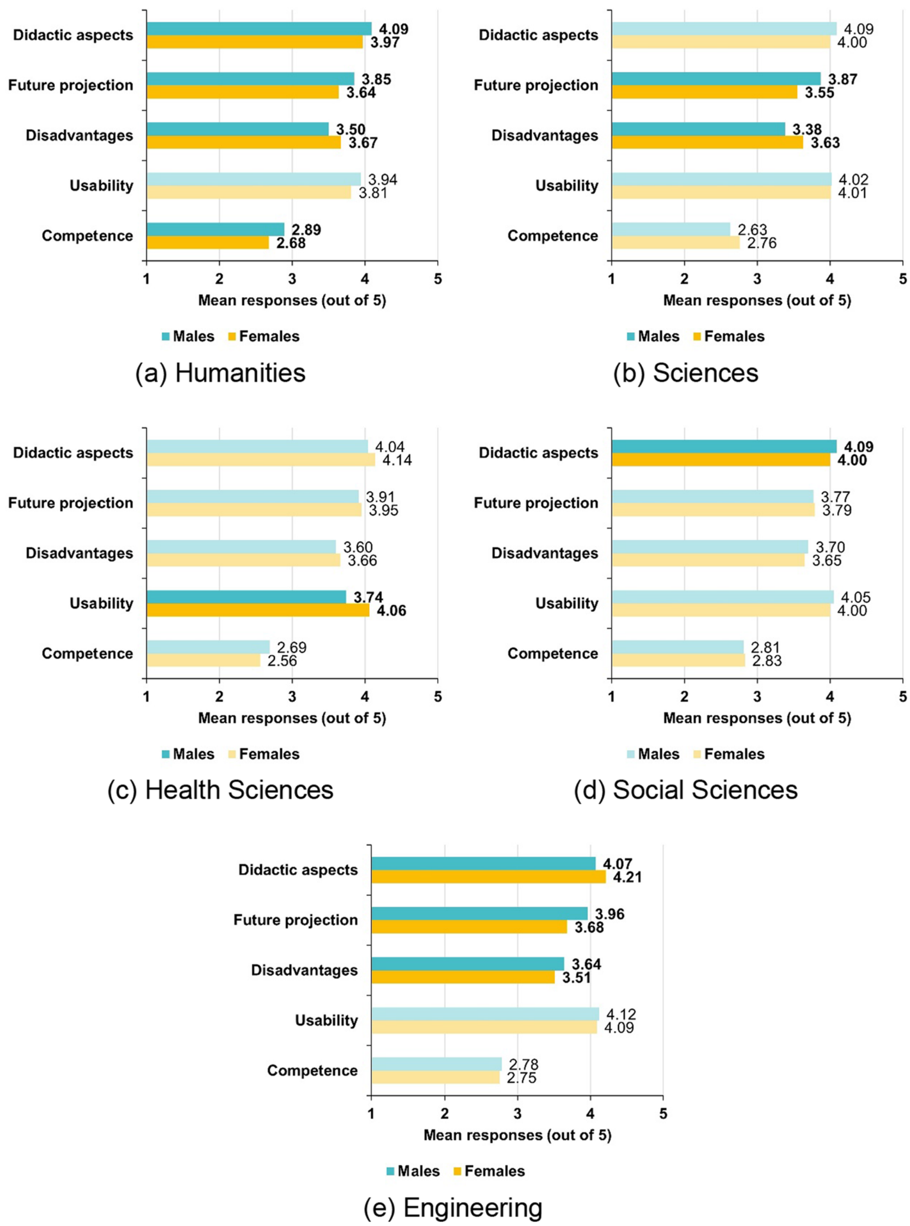


**Fig. 3** Mean responses (out of 5) of females and males to each of the families of questions considered within the different areas of knowledge: **a** Humanities; **b** Sciences; **c** Health Sciences; **d** Social Sciences; and **e** Engineering (mean responses where differences between females and males are significant are indicated in bold and bright colors)

There are gender gaps in the participants' responses, which behave differently according to the area of knowledge in question. In Table 9, 10, 11, 12, 13 (Appendix C) the Wilcoxon test statistics for the comparison of mean responses between females and males for each family of responses, within each of the knowledge areas studied, are shown. The largest number of families of responses in which significant gender gaps appear is in Humanities, followed by Engineering (Appendix C).

Within the Humanities area, males express having better digital skills, give higher ratings to the didactic aspects and future projection of VR, and lower ratings to the level of disadvantages of VR than females (Fig. 3a). All these gaps are statistically significant (Table 9). In Engineering, on the other hand, females give higher ratings of the didactic aspects of VR and lower ratings of its disadvantages than males, although they also give lower ratings of the future projection of VR than males (Fig. 3e; Table 13). In Sciences, females report more disadvantages and lower future projection for VR than males (Fig. 3b, Table 10). In Health Sciences, females rate technical aspects more highly than males (Fig. 3c, Table 11). Finally, in Social Sciences, males gave higher ratings to the didactic aspects of VR than females (Fig. 3d, Table 12).

## Discussion

The mean ratings of VR given by university professors are very high (above 4 out of 5) (Table 2). This is in line with the results of previous work carried out in populations of university professors in general (Rasimah et al., 2011; Wells & Miller, 2020), professors from specific countries in the region, such as Mexico and Colombia (Antón-Sancho, Vergara et al., 2022a, 2022b), engineering professors (Vergara et al., 2022a, 2022b), or health sciences professors (Fernández-Arias et al., 2023). However, the digital skills for the use of VR expressed by the participants are moderate (below 4 out of 5). This is consistent with the lack of digital training of university faculty reported in the literature (Antón-Sancho & Sánchez-Calvo, 2022) and with the need to train faculty in the development of techno-pedagogical skills (Noghabaei et al., 2020). The results presented here show that the participating professors perceive that VR has great didactic potential, but they do not feel sufficiently trained to use these technologies sufficiently in their lectures. The high dispersion of the ratings of digital competence (Table 2) also shows that there are strong differences in the self-concept of these digital skills. This poses an additional difficulty for the design of faculty training plans in digital skills. The results show, therefore, that there is a strong gap between the assessment given to VR and the digital skills expressed by professors. In the authors' opinion, given that the participants had no previous experience in the use of VR, this gap suggests that VR exerts a certain fascination among professors when they see it, because they can intuit the great potentialities and didactic uses that they would give to these technologies in their respective classrooms. However, they perceive, at the same time, an urgent need for specific training to be able to begin using it.

The results obtained reveal that the area of knowledge of the participating professors significantly influences their assessments in all the variables studied (Table 3). Professors of Sciences and Health Sciences are those who express lower digital skills. This contrasts with the results of other studies that find no significant differences between the self-concepts of the digital skills of professors of Engineering and Health Sciences

(Fernández-Arias et al., 2023). This discrepancy shows that, although the area of knowledge is an influential variable, it is probably necessary to further refine the distinction between areas of knowledge or to consider other academic variables that may also be influencing the self-concepts analyzed.

Professors of Engineering and Health Sciences are those who report the best assessments of VR (Table 3). Coincidentally, these are the areas where VR is most frequently applied in higher education and where more papers are published (Fernández-Arias et al., 2023). This suggests that greater experience in the use of VR leads to a better assessment of the didactic use of these tools, but this should be contrasted in a specific correlational study. Therefore, it may be advisable that the training of professors in the use of VR incorporate a practical module. Likewise, the superiority of the ratings of the Engineering professors with respect to the usability and didactic aspects of VR may be due to the, in principle, better technological training of these professors, although this aspect should also be contrasted. In fact, in the authors' opinion, there could be a certain predisposition of professors, different depending on their area of knowledge, towards the use of digital technologies that conditions the assessments expressed. This would explain why Humanities or Social Sciences professors do not stand out for their high ratings of VR, but Engineering professors (in principle more open, due to their training, to digital technologies) do. This is despite the existence, confirmed in the literature, of notable applications of VR to the teaching of the Humanities (Hutson & Olsen, 2022).

As a novelty in the specialized literature, this research has shown that the different areas of knowledge present different gender gaps in the assessments studied. Indeed, there is a strong gender gap in Humanities, in the sense that males give better assessments of VR than females and claim to have a better digital competence for its use (Fig. 3a). In the case of the Engineering professors, a gender gap is also observed, but in the opposite direction, i.e., it is the females who offer better evaluations of the VR, mainly of the didactic aspects (Fig. 3e). The results obtained with Humanities professors are in line with the results of previous studies (Antón-Sancho, Vergara et al., 2022a, 2022b), but the results on Engineering professors contradict them. This shows that the area of knowledge strongly conditions the gender gap observed here, which had already been identified in the previous literature. Probably, the greater training and updating in digital training that Engineering professors are expected to have acts as a corrector of the gender gap that persists in other professors, such as those in Humanities. However, it would be useful to go deeper into this aspect by conducting a qualitative study within each area of knowledge.

There is much divergence in the literature regarding gender gaps in the digital training of university professors (Cabero-Almenara et al., 2021). There are works that do not identify gender gaps (Guillén-Gámez et al., 2021), others express that males have better digital skills than females (Cai et al., 2017) and others state that females are the best trained (Krumsvik et al., 2016). This suggests that there are explanatory factors for gender gaps that the literature has not clearly identified. Given that the results presented here show that gender gaps behave divergently depending on the area of knowledge, this suggests that the area of knowledge could be one of those explanatory factors. If so, it could be concluded that the process of integrating digital technologies in higher education is guaranteeing equal integration between males and females in some areas of knowledge and not in others. This could be because stronger gender stereotypes persist in certain areas of knowledge.

## Limitations

The strong lack of homogeneity in the distribution of participants by country has prevented a comparative analysis of the different countries that would yield significant results. Likewise, it would be useful to carry out an analysis like the one conducted here, but with a more homogeneous distribution by areas of knowledge and gender, to contrast the results obtained. On the other hand, it should be noted that the participating professors have had no practical experience prior to answering the questionnaire, which may condition their responses. Furthermore, it is necessary to indicate that the acquisition of practical experience in the use of VR by the participants could alter their perceptions of it acquired from the training session in which they participated. Finally, the fact that the parameters of the confirmatory factorial analysis of the instrument used are close to, but do not reach, the optimal values, suggests that biases could appear in the results and expresses the convenience of designing new, finer instruments to measure the perceptions of the higher education professors of any area of knowledge about VR.

## Conclusions

The participating professors express very high evaluations of VR, both in its usability dimensions as well as in its didactic aspects and in the projection of future use in higher education. However, their self-perceived digital skills for the use of VR are low. The professors' area of expertise significantly influences their ratings of VR. Specifically, Engineering professors rate the didactic dimensions of VR up to 2.7% higher than the rest of the professors, and up to 6.5% higher for the usability aspects. Likewise, the participants' evaluations of VR suffer from gender gaps, which behave differently according to the area of knowledge. Thus, the most pronounced gender gaps occur in the areas of Humanities and Engineering. In Humanities, females give worse evaluations of the VR than males, while in Engineering it is the males who give worse evaluations of the VR. This implies that the behavior of gender inequalities in the valuation of digital technologies, particularly VR, among higher education professors is significantly diverse according to the area of knowledge in question. This suggests the need to implement corrective measures in this regard to ensure that digital integration, at least in terms of VR technologies, is gender-equal. In addition, it is recommended that universities should increase the training of professors in digital training, focusing this training on the knowledge of VR technologies, and that this training should include a practical block. In this way, the development of techno-pedagogical skills of professors will be favored, as a necessary complement to a solid technical training.

## Appendix A: Questions of the survey

The questions are 1 to 5 Likert-type, where 1 means very low, 2 means low, 3 means intermediate, 4 means high, and 5 means very high (Vergara et al., 2022a, 2022b):

1. Self-concept of your digital skills to program or design new ICT-based educational tools.
2. Level of knowledge about virtual reality.
3. Do you feel that you have received sufficient training at your university on the possible applications of VR in education?
4. Level of importance you give to the didactic usefulness of virtual reality when designing didactic actions.
5. Importance of interaction when designing an educational experience with virtual reality.
6. Importance of user experience when designing an educational experience with virtual reality.
7. Importance of employability when designing a virtual reality educational experience.
8. Level of importance of the following usability aspect of virtual reality when designing a virtual reality educational experience: 3D Design.
9. Level of importance of the following usability aspect of virtual reality when designing a virtual reality educational experience: Immersion.
10. Level of importance of the following usability aspect of virtual reality when designing a virtual reality educational experience: Realism.
11. Possibility of your university implementing virtual reality in its teaching activities.
12. Level of inconvenience of the following aspects of virtual reality: Costs.
13. Level of inconvenience of the following aspects of virtual reality: Spatial limitations.
14. Level of inconvenience of the following aspects of virtual reality: Demand for technical and human resources.
15. Level of inconvenience of the following aspects of virtual reality: Requirement of specific knowledge on the part of teachers and technicians.
16. Level of inconvenience of the following aspects of virtual reality: Technological obsolescence of equipment.
17. Level of acceptance of virtual reality as a teaching resource that you think your students have (or would have).
18. Do you believe that the use of virtual reality in educational environments increases (or would increase) the academic performance of your students?
19. Do you believe that the use of virtual reality in educational environments increases (or would increase) your students' motivation to learn?
20. Do you consider that the application of virtual reality in educational environments helps (or would help) to improve the progress of your subject?
21. Degree to which you think that the implementation of immersive virtual reality will increase in the future at your university.
22. Degree to which you think that the implementation of non-immersive virtual reality will increase in the future at your university.

## Appendix B: Statistics of the comparisons by paired areas of knowledge of the mean responses to each of the families considered

See Tables 4, 5, 6, 7, 8.

**Table 4** Paired *p*-values from two-sample Wilcoxon test for comparison of means between each pair of knowledge areas for responses to the family of digital skills self-concept questions

| | Humanities | Sciences | Health Sci | Social Sci | Engineering |
|---|---|---|---|---|---|
| Humanities | | 0.3167 | 0.0185* | 0.3669 | 0.9772 |
| Sciences | | | 0.1269 | 0.0300* | 0.3039 |
| Health Sci | | | | 0.0004*** | 0.0138* |
| Social Sci | | | | | 0.3027 |
| Engineering | | | | | |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 5** Paired *p*-values from two-sample Wilcoxon test for comparison of means between each pair of knowledge areas for responses to the family of questions on assessment of usability of VR

| | Humanities | Sciences | Health Sci | Social Sci | Engineering |
|---|---|---|---|---|---|
| Humanities | | 0.02336* | 0.1981 | 0.0015** | < 0.0001*** |
| Sciences | | | 0.4236 | 0.4819 | 0.0055** |
| Health Sci | | | | 0.1425 | 0.0011** |
| Social Sci | | | | | 0.0115* |
| Engineering | | | | | |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 6** Paired *p*-values from two-sample Wilcoxon test for comparison of means between each pair of knowledge areas for responses to the family of questions on assessment of disadvantages of VR

| | Humanities | Sciences | Health Sci | Social Sci | Engineering |
|---|---|---|---|---|---|
| Humanities | | 0.1468 | 0.4803 | 0.2526 | 0.5689 |
| Sciences | | | 0.0382* | 0.0028*** | 0.2494 |
| Health Sci | | | | 0.7615 | 0.1995 |
| Social Sci | | | | | 0.0419* |
| Engineering | | | | | |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 7** Paired p-values from two-sample Wilcoxon test for comparison of means between each pair of knowledge areas for responses to the family of questions on assessment of future projection of VR

| | Humanities | Sciences | Health Sci | Social Sci | Engineering |
|---|---|---|---|---|---|
| Humanities | | 0.4098 | 0.0163* | 0.4512 | 0.1281 |
| Sciences | | | 0.0008*** | 0.0737 | 0.0103* |
| Health Sci | | | | 0.0445* | 0.2396 |
| Social Sci | | | | | 0.3252 |
| Engineering | | | | | |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 8** Paired p-values from two-sample Wilcoxon test for comparison of means between each pair of knowledge areas for responses to the family of questions on assessment of didactic aspects of VR

| | Humanities | Sciences | Health Sci | Social Sci | Engineering |
|---|---|---|---|---|---|
| Humanities | | 0.5539 | 0.0446* | 0.3091 | 0.0021** |
| Sciences | | | 0.1208 | 0.7147 | 0.0116* |
| Health Sci | | | | 0.1725 | 0.5635 |
| Social Sci | | | | | 0.0113* |
| Engineering | | | | | |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

## Appendix C: Mean responses of females and males, within each area of knowledge, to each of the families of questions considered

See Tables 9, 10, 11, 12, 13.

**Table 9** Mean responses (out of 5) of females and males, within the Humanities professors, to each of the families of questions considered, and Wilcoxon test statistics for two samples

| Family of responses | Females | Males | Wilcoxon W | *p*-value |
|---|---|---|---|---|
| Competence | 2.68 | 2.89 | 36,820 | 0.0189* |
| Usability | 3.81 | 3.94 | 38,294 | 0.0731 |
| Disadvantages | 3.67 | 3.50 | 125,804 | 0.0200* |
| Future projection | 3.64 | 3.85 | 16,048 | 0.0176* |
| Didactic aspects | 3.97 | 4.09 | 154,362 | 0.0192* |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 10** Mean responses (out of 5) of females and males, within the Sciences professors, to each of the families of questions considered, and Wilcoxon test statistics for two samples

| Family of responses | Females | Males | Wilcoxon W | *p*-value |
|---|---|---|---|---|
| Competence | 2.76 | 2.63 | 52,534 | 0.0836 |
| Usability | 4.01 | 4.02 | 46,982 | 0.4238 |
| Disadvantages | 3.63 | 3.38 | 150,044 | 0.0020** |
| Future projection | 3.55 | 3.87 | 17,452 | 0.0004*** |
| Didactic aspects | 4.00 | 4.09 | 183,634 | 0.0656 |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 11** Mean responses (out of 5) of females and males, within the Health Sciences professors, to each of the families of questions considered, and Wilcoxon test statistics for two samples

| Family of responses | Females | Males | Wilcoxon W | *p*-value |
|---|---|---|---|---|
| Competence | 2.56 | 2.69 | 25,306 | 0.2273 |
| Usability | 4.06 | 3.74 | 32,796 | < 0.0001*** |
| Disadvantages | 3.66 | 3.60 | 76,460 | 0.7821 |
| Future projection | 3.95 | 3.91 | 12,488 | 0.6102 |
| Didactic aspects | 4.14 | 4.04 | 116,230 | 0.0631 |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 12** Mean responses (out of 5) of females and males, within the Social Sciences professors, to each of the families of questions considered, and Wilcoxon test statistics for two samples

| Family of responses | Females | Males | Wilcoxon W | *p*-value |
|---|---|---|---|---|
| Competence | 2.83 | 2.81 | 196,926 | 0.7049 |
| Usability | 4.00 | 4.05 | 185,548 | 0.1325 |
| Disadvantages | 3.65 | 3.70 | 532,032 | 0.5227 |
| Future projection | 3.79 | 3.77 | 86,562 | 0.9805 |
| Didactic aspects | 4.00 | 4.09 | 735,408 | 0.0116* |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Table 13** Mean responses (out of 5) of females and males, within the Engineering professors, to each of the families of questions considered, and Wilcoxon test statistics for two samples

| Family of responses | Females | Males | Wilcoxon W | *p*-value |
|---|---|---|---|---|
| Competence | 2.75 | 2.78 | 114,476 | 0.6474 |
| Usability | 4.09 | 4.12 | 113,762 | 0.5153 |
| Disadvantages | 3.51 | 3.64 | 302,902 | 0.0242* |
| Future projection | 3.68 | 3.96 | 43,932 | 0.0006*** |
| Didactic aspects | 4.21 | 4.07 | 503,562 | 0.0010** |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

**Abbreviations**

VR Virtual reality
IVR Immersive virtual reality
NIVR Non-immersive virtual reality

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