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Impact of the Digitalization Level on the Assessment of Virtual Reality in Higher Education

Álvaro Antón-Sancho, Catholic University of Ávila, Spain
https://orcid.org/0000-0002-1901-3878

Diego Vergara, Catholic University of Ávila, Spain*
https://orcid.org/0000-0003-3710-4818

Pablo Fernández-Arias, Catholic University of Ávila, Spain
https://orcid.org/0000-0002-0502-5800

ABSTRACT

This paper conducts quantitative research on the assessment made by university professors of the didactic use of virtual reality technologies according to the level of technological development and digitization of their country. For this purpose, a survey was used, the responses to which were statistically analyzed, and the level of digitalization was differentiated through the country's global innovation index. The results show that the valuations of virtual reality as a teaching tool are high, but the competence for its use of university professors is intermediate. On the other hand, it was found that the higher the country's level of digital development, the more pronounced the gender gap in this study. Similarly, the higher the country's level of digital development, the smaller the age gap.

KEYWORDS

Digital Development, Digital Learning Environments, Digital Resources, Extended Reality, Higher Education, Innovation, Online Learning, Reality-Virtuality

INTRODUCTION

The outbreak of the COVID-19 pandemic in 2020 forced governments and administrations around the world to adopt restrictions on physical contact and mobility that particularly affected the education sector and, specifically, higher education (Sabu, 2020). Thus, a significant proportion of university students had to give up participation in face-to-face training activities and their professors had to look for methodological strategies and resources suited to a non-face-to-face teaching scenario (Vital-López, 2022).

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*Corresponding Author

In this situation, professors had to suddenly strengthen the presence of digital learning environments and technologies that would allow students to develop the appropriate competences and keep alive the motivation and involvement of students with learning activities (Tejedor et al., 2020). In this sense, virtual reality (VR) technologies are among the tools that have proven to provide the best results (Nesenbergs, 2021). Indeed, these technologies allow immersion in simulated but realistic environments that help to visualize possibly complex three-dimensional objects –such as those presented, for example, in medical (Barteit et al., 2021), art, or architecture classrooms (Özgen et al., 2021)– and interact with them, thus virtually simulating laboratory activities –which is of great interest in science and engineering education (Vergara, Fernández-Arias et al., 2021).

VR technologies have proven to be well adapted to the academic requirements of different areas of knowledge and to the demands of non-face-to-face education (Lamb et al., 2019). However, they pose important limitations, such as technological infrastructure needs (Luo et al., 2021; Marks & Thomas, 2022), digital competence and faculty training (Cabero-Almenara et al., 2021), or the adaptation of professors to this type of environment (Antón-Sancho, Vergara, & Fernández-Arias, 2022). These limitations give rise to numerous gaps in the use and perception of VR technologies for various reasons, including cultural, gender or age (Vergara, Antón-Sancho et al., 2021). Due to the growing trend for the virtualization of educational environments and, in general, for the educational metaverse (Antón-Sancho & Sánchez-Calvo, 2022; Vergara-Rodríguez et al., 2022), the literature reflects the current interest in exploring the opinions of professors and students about the didactic use of these technologies –identifying the factors influencing these opinions –, because this can provide keys to improve faculty training in this regard (Vergara, Fernández-Arias et al., 2021; Vergara, Fernández-Arias et al., 2022).

Given the interest of this line of work, this study focuses on the perceptions about the didactic use of VR technologies of university professors, analyzing for this purpose a sample of 1234 professors from the Latin American and Caribbean region. Specifically, the influence of the level of technological and digital development of the country on the perceptions expressed is analyzed quantitatively. This level of development has been measured through the Global Innovation Index (WIPO, 2021). Specifically, conclusions are drawn about the behavior of gender and age gaps in perceptions of VR as a function of the level of digital development and some recommendations and lines of research are suggested based on the results.

LITERATURE REVIEW

VR Technologies in Higher Education

VR consists of a set of computational technologies that allow the user to immerse in a three-dimensional virtual environment in a realistic way and interact with it (Ospina-Bohórquez et al., 2022). Consequently, there are some characteristics that specifically define VR technologies and differentiate them from other computerized technologies (Slater, 2009; Sundar et al., 2010): (i) immersive character –i.e., the ability to generate the stimuli of the simulated environment–; (ii) 3D design –i.e., the sensation of three-dimensionality of that environment–; (iii) ability to generate sensory experiences; (iv) realism; and (v) interactivity –i.e., allowing the user to interact with the simulated environment–. Because of the above characteristics, VR has been abundantly applied to very different areas of knowledge in which three-dimensional representation and the ability to interact with those representations is crucial, including construction industry (Safikhani et al., 2022); arts (Kim & Lee, 2022); architecture (Gao & Li, 2022); history (Allal-Chérif, 2022); or medicine (Bruno et al., 2022).

The application of VR technologies in higher education, hereinafter referred to as the didactic use of VR, not only requires the professor to have sufficient technical knowledge and adequate access to the necessary equipment, but also the development of a series of specific digital competencies, of a techno-pedagogical nature, aimed at the professor being able to integrate the technological resource of VR in an adequate manner in the didactic situations he/she designs in order to achieve the desired didactic objectives (Antón-Sancho & Sánchez-Calvo, 2022). The literature shows that this didactic use of VR, as of any other computer application, requires a didactic perspective that puts the needs and interests of the students at the center and a faculty training that is specifically aimed at designing didactic situations that employ VR as a didactic tool within the specific area of knowledge in which it is being used (Antón-Sancho, Vergara, Fernández-Arias et al., 2022; Vergara, Antón-Sancho et al., 2022).

VR has been used as a didactic tool in different areas of knowledge and at all educational levels, especially in higher education (Radianti, 2020). In this sense, the literature recognizes the existence of three main taxonomies of reality-virtuality technologies when applied to education (Motejlek & Alpay, 2021). The most classical one, that of Migram & Kishino (1994), classifies the different VR technologies on an increasing continuum of virtuality experience from real phenomenon experience to fully virtual experience depending on the type of imaging device used. The most modern classification, by Vergara et al. (2017), has as its main distinguishing criterion the immersive nature of VR technologies, so that non-immersive VR –which generate a sense of virtuality from conventional peripherals or special devices– corresponds to the lowest degree of immersion, and immersive VR –which employ head-mountain display (HMD) technologies or room-scale CAVE, i.e., projectors which display synchronised images on the walls of a room– corresponds to the highest degree of immersion. The degree of immersion of the different VR technologies is a criterion of distinction frequently used by authors (Kyriakou et al., 2017).

VR allows the design of three-dimensional simulations that have proven to be effective in the training of different types of professionals, due to the immersive nature of the experiences that can be generated (Antón-Sancho, Vergara, Fernández-Arias et al., 2022). It follows that the use of VR in higher education increases the academic performance of students, in general, even when compared to the use of other types of computational applications (Mäkinen et al., 2022). The greatest strengths of VR from a didactic point of view lie in its technical and usability characteristics in lectures: (i) the realism of the simulations that can be designed, which allows a better adaptation to the didactic objectives than traditional methodologies (Touloudi et al., 2022); (ii) the immersion (Touloudi et al., 2022) and interaction (Vergara et al., 2017) characteristics of these technologies; and (iii) the user experience, which acts as a source of motivation towards learning (Mäkinen et al., 2022).

The literature also finds limitations in the didactic use of VR. Specifically, there are two limitations that are frequently reported in the literature (i) the technical and techno-pedagogical training needs of professors, which entails a strong development of their digital skills (Noghabaei et al., 2020); and (ii) the economic costs involved in incorporating the necessary equipment for the integration of VR technologies (Antón-Sancho, Vergara, Fernández-Arias et al., 2022). The lack of appropriate digital skills for the use of VR is indicated by professors as a persistent limitation of VR, regardless of the area of knowledge, being so that the intensification of faculty training in digital matters is a common suggestion in the specialized literature (Antón-Sancho, Vergara, Fernández-Arias et al., 2022; Vergara, Antón-Sancho et al., 2022). In terms of costs, the main limitation refers to the initial outlay required to install the appropriate equipment, because, once this is done, the didactic use of VR technologies has proven to be economically effective, due to the savings in costs, especially about the use of laboratories and the development of other content of a practical nature (Chang et al., 2022; Vergara, Fernández-Arias et al., 2022).

The specialized literature reveals that the number of scientific publications regarding the didactic use of VR is growing every year, at least, in the last twenty years (Vergara et al., 2017; Vergara, Antón-Sancho et al., 2021), which demonstrates the interest of these technologies in the design of training tools for use in learning environments, both digital and face-to-face. In this sense, the applications of VR in higher education presented in the literature are usually based on describing experiences with certain application domains and learning content, and the presentation of new design elements (Vergara et al., 2019; Radianti et al., 2020).

Factors Influencing VR Assessment

The literature identifies three types of variables that can influence the assessment that professors and students make of the didactic use of VR in higher education (Vergara, Antón-Sancho et al., 2021; Antón-Sancho, Vergara, Fernández-Arias et al., 2022): (i) sociological, such as gender or age; (ii) academic, such as area of knowledge, teaching experience, or digital competence; and (iii) geographic, such as country of origin.

The geographic region where the university is located influences the possibilities of access to digital technologies, the training of professors in digital competence (Vergara, Antón-Sancho et al., 2021) and the pace of local development in digitization, which decisively affects university teaching activity (Murphy & Farley, 2017). For that reason, it also influences professors' perceptions of VR technologies. This causes the literature to present diverse results regarding the influence of different sociological and academic variables on the valuation of VR according to the geographical area in which they are measured (Durão et al., 2019). However, no work is found in the literature that identifies the underlying sociodemographic or technological development factors that explain this dependence on geographic origin.

In the Latin American and Caribbean region, which is the area of interest in this study, the literature recognizes the existence of a marked gender gap in favor of males in terms of access, training and use of digital learning technologies (Gray et al., 2017; Ancheta-Arrabal, 2021). This gender gap translates into a gap in terms of VR assessments in some countries such as Colombia, where, in general, female university professors in any area of knowledge express higher assessments than males, despite acknowledging that they have less training in digital skills. This result is analogous to what the literature presents contextualized, for example, in Saudi Arabia (Dayarathna et al., 2020). However, if the study area is extended to a broader region of South America, studies are found in which the gender gap behaves similarly (Vergara, Antón-Sancho et al., 2022) and others in which no significant gender gaps are found in areas such as Health Sciences and Engineering (Vergara, Antón-Sancho et al., 2021). Therefore, the gender gap is influenced by other academic or sociodemographic variables that the literature has not yet studied in depth.

The digital competence of professors and the training received in digital skills are recognized by the literature as determinants of the use and assessment of any digital learning technology and, in turn, is conditioned by geographic origin (Zhao, Pinto-Llorente et al., 2021). In general, professors' digital competence is intermediate or low, with a certain dependence on other variables, mainly age, area of knowledge and training received in digital skills (Cabero-Almenara et al., 2021). Usually, professors' digital competence and, consequently, their ability to implement new digital technologies, is diminished with age (Portillo et al., 2020; Zhao, Sánchez-Gómez et al., 2021), which also increases the dispersion of these levels of digital competence (Guillén-Gámez et al., 2021). In addition, the use of digital tools is strongly influenced by the training that professors have received on the pedagogical use of these technologies (Amhag et al., 2019) and contextual circumstances, such as the ease of access they have to different technologies (Spante et al., 2018) and the technological development in the local context (Amhag et al., 2019).

The Global Innovation Index

Among the objectives of this work is to study the influence of the level of technological and digital development of the area on the perceptions of university professors about the didactic use of VR. To quantify this level of development, the Global Innovation Index (GII), published annually by Cornell University, Institut Européen d'Administration des Affaires (INSEAD), and World Intellectual Property Organization (WIPO), has been used. This Index analyzes 131 countries around the world with respect to a large number of factors related to the innovative nature of their economies, with technological and digital development as the main criteria (WIPO, 2021). As a result of this analysis, a numerical index, between 0 and 100, is attributed to each country, indicating its level of technological development, innovation and digitalization. The GII has been used by the specialized literature as a discriminating variable for certain professional competencies of university teachers, including digital competence (Antón-Sancho et al., 2021; Antón-Sancho, Vergara, Fernández-Arias et al., 2022), and has been shown to condition teachers' perception of the use of digital technologies in the classroom (Lamas-Álvarez et al., 2021).

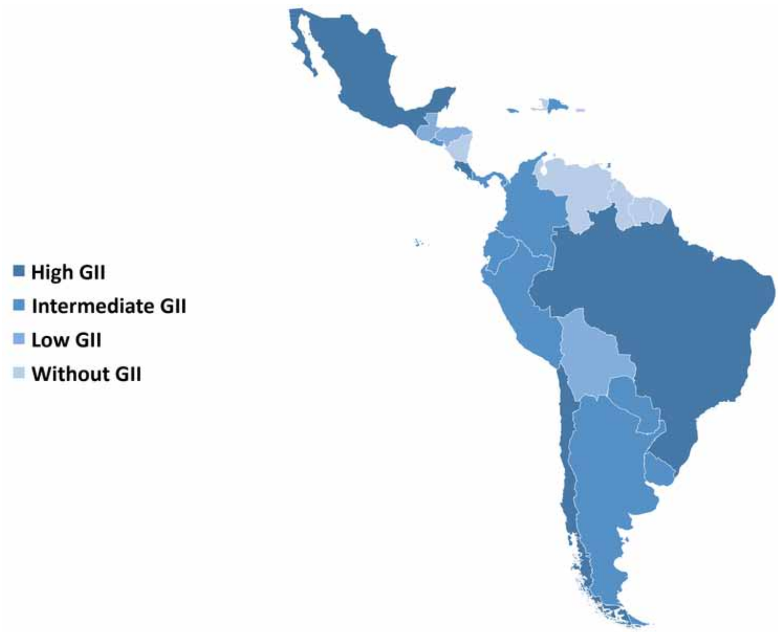
The GII groups the countries it analyzes into geographic regions that have an approximately homogeneous index. Thus, a total of seven regions are distinguished (WIPO, 2021), one of which is Latin America and the Caribbean. For the year 2021, Table 1 shows the indexes of the countries in this region that are analyzed by the GII.

The mean GII of the region is 28.8222, with a standard deviation of 4.3665. Based on these data, three different zones are defined within the Latin America and the Caribbean region, which will henceforth be referred to as digitization zones (Figure 1): (i) zone with low GII, which is formed by the countries whose GII is lower than the region's mean minus the standard deviation –Honduras, Bolivia, and Guatemala–; (ii) intermediate GII zone, composed of countries whose GII varies between the mean GII minus the deviation and the mean GII plus the deviation –Trinidad and Tobago, El Salvador, Dominican Republic, Ecuador, Paraguay, Panama, Jamaica, Argentina, Peru, Colombia, and Uruguay–; and (iii) high GII zone, composed of countries whose GII is greater than the mean GII plus the standard deviation –Brazil, Costa Rica, Mexico, and Chile.

Table 1. GII of the different countries in the Latin America and Caribbean region

Country	GII (2021)
Chile	36.1
Mexico	34.5
Costa Rica	34.5
Brazil	34.2
Uruguay	32.2
Colombia	31.7
Peru	31.2
Argentina	29.8
Jamaica	29.6
Panama	28.0
Paraguay	26.4
Ecuador	25.4
Dominican Republic	25.1
El Salvador	25.0
Trinidad and Tobago	24.8
Guatemala	24.1
Bolivia	23.4
Honduras	22.8

Figure 1. Countries belonging to each of the three digitization zones within the Latin America and Caribbean region



METHODOLOGY

Participants

The inclusion criteria for the study were to be an active university professor and to teach at a university in one of the countries analyzed by the GII in the Latin American and Caribbean region. Finally, 1234 university professors responded to the survey used as an instrument, who were contacted through a non-probabilistic convenience sampling process because they participated in one of the training talks on the use of teaching VR given every two weeks by the authors between January and June 2022. All participants responded voluntarily, freely, and anonymously and all responses obtained were validated. Participants came from all the countries in the Latin American and Caribbean region that are members of the GII, except Jamaica and Trinidad and Tobago. 11.99% of the participants come from the low digitization zone, 53.48% come from the intermediate digitization zone and 34.52% come from the high digitization zone. Although the distribution in digitization regions is not homogeneous (chi-square = 319.44, df = 2, p-value < 0.0001), the representation of each region is sufficiently significant.

Around 53.48% of the participants are females and 46.52% are males, so there is a weak but statistically significant majority of females (chi-square = 5.9935, df = 1, p-value = 0.0144). The zones with high or intermediate levels of digitization have the highest presence of females among the participants (Figure 2), so that the gender distribution depends significantly on the digitization zone (chi-square = 4.8615, df = 2, p-value = 0.0880). The least frequent age range is those over 65 years old (5.34%), followed by the youngest professors (12.00%) and those between 55 and 64 years old (18.48%). The most frequent are middle-aged participants (28.53% are between 35 and 44 years old, and 35.66% are between 45 and 54 years old). The goodness-of-fit test confirms that the age distribution is not homogeneous (chi-square = 995.4, df = 6, p-value < 0.0001). However, this distribution is independent of the digitization zone (Figure 3), as it can be observed from Pearson's test of independence statistics (chi-square = 23.004, df = 12, p-value = 0.0277).

Figure 2. Distribution of participants by gender, within each digitalization zone

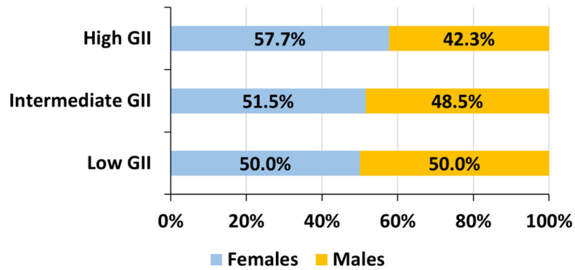
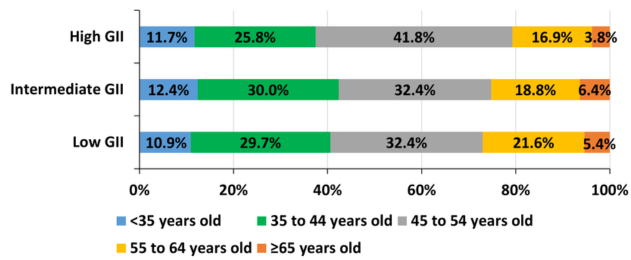


Figure 3. Distribution of participants by age, within each digitalization zone



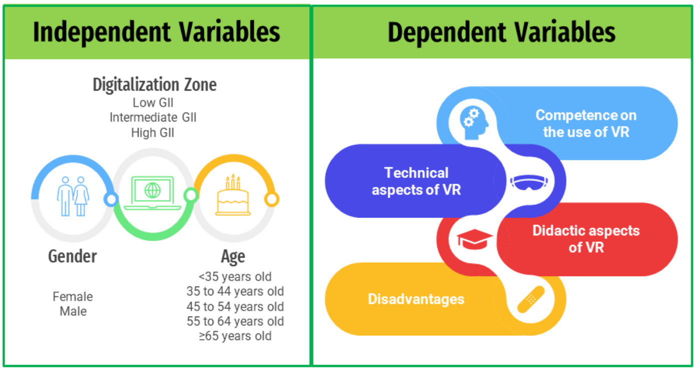
Objectives, Variables, and Hypothesis

The main objective of this research is to analyze the influence of the level of digitalization of the countries in the Latin American and Caribbean region on the perception of university professors about the didactic use of VR technologies. In particular, it seeks to satisfy the following objectives: (i) to study the competence for the use of VR of the participating professors and their assessment of the technical and didactic dimensions and disadvantages of the use of VR in the classroom; (ii) to identify whether there are significant differences in the above assessments according to the digitization zone; and (iii) to analyze whether there are gender or age gaps in each of the digitization zones described for the perceptions studied. In other words, this paper seeks to answer the following research questions: (i) what is the self-concept of university professors about their digital skills for the didactic use of VR?; (ii) do professors' perceptions about the didactic use of VR change according to the digitalization zone in which they are located?; and (iii) do gender and age influence the professors' assessments of the use of VR in their lectures?

The main independent variable of the study is the participants' digitization zone, and the secondary independent variables are their gender and age. The digitization zone is a trichotomous variable, whose values are the three regions –with high, intermediate, or low GII– that have been defined. Gender is a dichotomous variable and age is defined as a polytomous variable with 5 possible values, since the ages have been grouped in 10-year ranges, as specified in Figure 4. Four dependent variables are also considered: (i) digital competence for the didactic use of VR in higher education; (ii) technical aspects of VR; (iii) didactic aspects of VR; and (iv) disadvantages of VR. Las variables dependientes son cuantitativas ordinales y se han medido en una escala de 1 (mínima valoración) a 5 (máxima valoración).

The hypothesis tested throughout the research is that differences in the assessments of VR by gender and age depend on the digitization zone of the professors' country of origin.

Figure 4. Dependent and independent variables of the study



Instrument

A survey adapted by the authors for this research was used, based on analogous VR assessment instruments (Antón-Sancho, Vergara, Fernández-Arias et al., 2022; Vergara, Antón-Sancho et al., 2021; Vergara, Antón-Sancho et al., 2022). The survey consists of 18 questions that ask for a rating of the aspect of VR posed by each one, on a Likert-type scale from 1 to 5 (where 1 means very low rating and 5 means very high rating). The questions are distributed in four families (Table 2), which correspond to the four dependent variables defined. The first family (questions 1 and 2) measures

Table 2. Questions of the survey

Family	Number	Question
Competence on the use of VR	1	Digital skills for the use of VR
	2	VR knowledge
Technical aspects of VR	3	3D Design
	4	User experience
	5	Usability
	6	Immersion
	7	Interaction
	8	Realism
	9	Classroom employability
Didactic aspects of VR	10	Acceptance by the students
	11	Dynamization of the classess
	12	Motivation
	13	Academic performance
Disadvantages of the didactic use of VR	14	Costs
	15	Space required
	16	Faculty competence
	17	Obsolescence of equipment
	18	Technical resources required

the participants' perceived competence to use VR; the second family (questions 3 to 9) measures the assessment of the technical aspects of VR; the third family (questions 10 to 13) measures the assessment of the didactic benefits of VR; and the fourth family (questions 14 to 18) measures the assessment of the different disadvantages that VR may present. In this last family, a high rating means that the participant understands that the VR presents the corresponding disadvantage to a high degree.

From the factor weights resulting from the Exploratory Factor Analysis (EFA) carried out on the responses (Table 3), it can be deduced that the theoretical model that explains them results from distinguishing four latent factors within the survey, which correspond to the four families of questions defined and to the four dependent variables considered. This theoretical model explains 53% of the total variance (Table 4). The parameters of the Confirmatory Factor Analysis (CFA) confirm the theoretical model defined (Schmitt, 2011), since the incremental fit indices are optimal (AGFI = 0.8831; NFI = 0.8964; TLI = 0.9063; CFI = 0.9085; IFI = 0.9087) and the absolute fit indices are also good (GFI = 0.9118; RMSEA = 0.0434; chi-square/df = 7.6297). Finally, the instrument has a high level of internal consistency (Steiner, 2003), since all Cronbach alphas and composite reliability

Table 3. Factorial weights of the Exploratory Factor Analysis

	Factor 1 Competence	Factor 2 Technical	Factor 3 Didactic	Factor 4 Disadvantages
Digital skills	0.640			
VR knowledge	0.817			
3D Design		0.728		
User experience		0.618		
Usability		0.651		
Immersion		0.804		
Interaction		0.638		
Realism		0.730		
Classroom employability		0.596		
Acceptance by the students			0.461	
Dynamization of the classess			0.744	
Motivation			0.831	
Academic performance			0.802	
Costs				0.624
Space required				0.559
Faculty competence				0.689
Obsolescence of equipment				0.620
Technical resources required				0.814

Table 4. Cumulative proportions of the explained variance

	Competence	Technical	Didactic	Disadvantages
Proportion Variance	0.134	0.199	0.131	0.067
Cumulative Variance	0.134	0.333	0.464	0.530

(CR) parameters are above 0.70, and the convergent validation may be assumed, since average variance extracted (AVE) values are above 0.50 (Table 5).

Analysis of Responses

This article develops a descriptive quantitative research based on the answers obtained from the survey. Descriptive statistics have been obtained and it has been proved, by means of the Lilliefors normality test and Bartlett's test of variance comparison, that the answers of none of the four families of questions are normal, but all of them are homogeneously distributed when differentiated by the digitization area. Consequently, we have chosen to use nonparametric tests for hypothesis testing. Specifically, the Kruskal-Wallis test was used to test whether there are significant differences by digitization zone, or by age, within each area, and the Wilcoxon test for independent samples to test whether there are gender gaps in each digitization area. All tests were performed at the 0.05 significance level.

RESULTS

The participating professors expressed having an intermediate knowledge of VR technologies but gave high ratings to their technical and didactic dimensions, although they found an intermediate-high level of disadvantages for their use (Table 6). The valuations of the technical and didactic aspects are the least dispersed, and, therefore, those with the highest agreement. All the response distributions show moderate negative skewness, and the Lilliefors normality test statistics show that it is not possible to assume that they are normally distributed. However, the responses are distributed with homoscedasticity when differentiating by digitization zone, as follows from Bartlett's test (Table 6).

The level of training in the use of VR hardly changes with the level of digitization (Figure 5) and, in any case, these changes are not significant (chi-square = 0.0706, p-value = 0.9653). The ratings of the technical dimensions increase when the level of digitization of the area increases and those of the didactic dimensions decrease, but neither of these variations is statistically significant (chi-square = 2.9245, p-value = 0.2317 for the technical aspects; chi-square = 2.3585, p-value = 0.3075 for the didactic aspects). Participants in the area with low digitization find a slightly higher mean level of

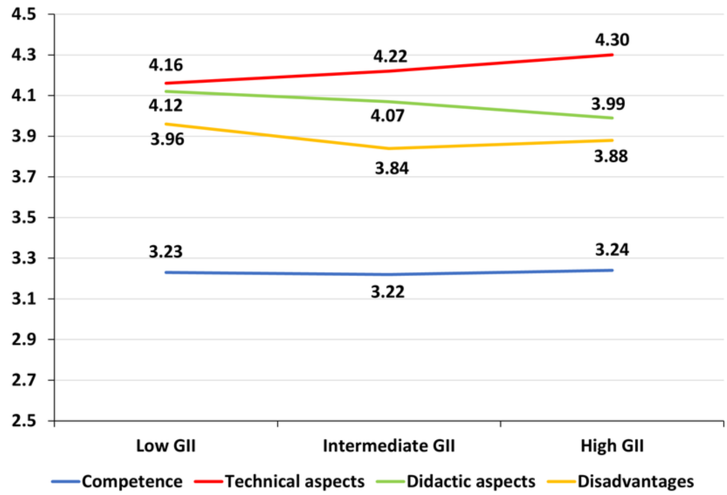
Table 5. Cronbach alphas, CR and AVE parameters

	Cronbach alpha	CR	AVE
Competence	0.7807	0.7765	0.6280
Technical	0.8829	0.8627	0.6851
Didactic	0.8273	0.8031	0.6524
Disadvantages	0.8028	0.7892	0.6368

Table 6. Descriptive statistics (SD means standard deviation), Lilliefors normality test (D) and Bartlett test of comparison of variances with 2 degrees of freedom (K-squared) of the different digitalization zones

	Mean	SD	Skew	D	p-value	K-sq.	p-value
Competence	3.22	1.07	–0.3050	0.1912	<0.0001	1.5338	0.4601
Technical	4.24	0.89	–1.1340	0.2819	<0.0001	1.4289	0.4895
Didactic	4.05	0.96	–1.0050	0.2423	<0.0001	1.5668	0.4569
Disadvantages	3.87	1.15	–0.7648	0.2230	<0.0001	4.7997	0.1230

Figure 5. Responses differentiated by the digitalization zone



inconvenience than those in the more digitized areas, but again this is a weak and non-significant difference (chi-square = 1.3270, p-value = 0.5151).

In the VR knowledge variable, females go from slightly outperforming males in the low digitization zone to being below them in the intermediate and high digitization zones (Figure 6). The gender gap identified in these zones is statistically significant (Table 7). Within these gender gaps, in the zone with intermediate level of digitization the gap is larger in the question on digital skills for handling VR (3.08 out of 5 for females and 3.36 out of 5 for males) than in the question on knowledge of VR (2.66 out of 5 for females and 2. 74 out of 5 for males), while, in the highly digitized area, the gap is higher in the knowledge question (2.48 out of 5 for females and 3.79 out of 5 for males) than in the digital skills question (3.14 out of 5 for females and 3.37 out of 5 for males).

The differences by gender are not statistically significant in the rest of the variables (Table 7), but there is a tendency for males to value technical aspects more than females and didactic aspects less as the country's level of digitalization increases (Figure 6). Males also perceive a higher level of disadvantages in the didactic use of VR than females in general, especially in the area with high GII (Figure 6).

The obtained results reveal that there is a strong age gap in the region with low digitization (Figure 7). In fact, both the level of knowledge about VR and the assessment of its technical aspects and disadvantages decreases with age, while the highest assessment of its didactic aspects corresponds to middle-aged professors (35 to 54 years old). These gaps are statistically significant (Table 8). The differences shown by age decrease in the regions with a higher level of digitization, except for the variable of knowledge about VR, to the point that in the area with a high level of digitization no significant differences are found by age in the evaluations of VR, only in terms of competence for its use (Table 8).

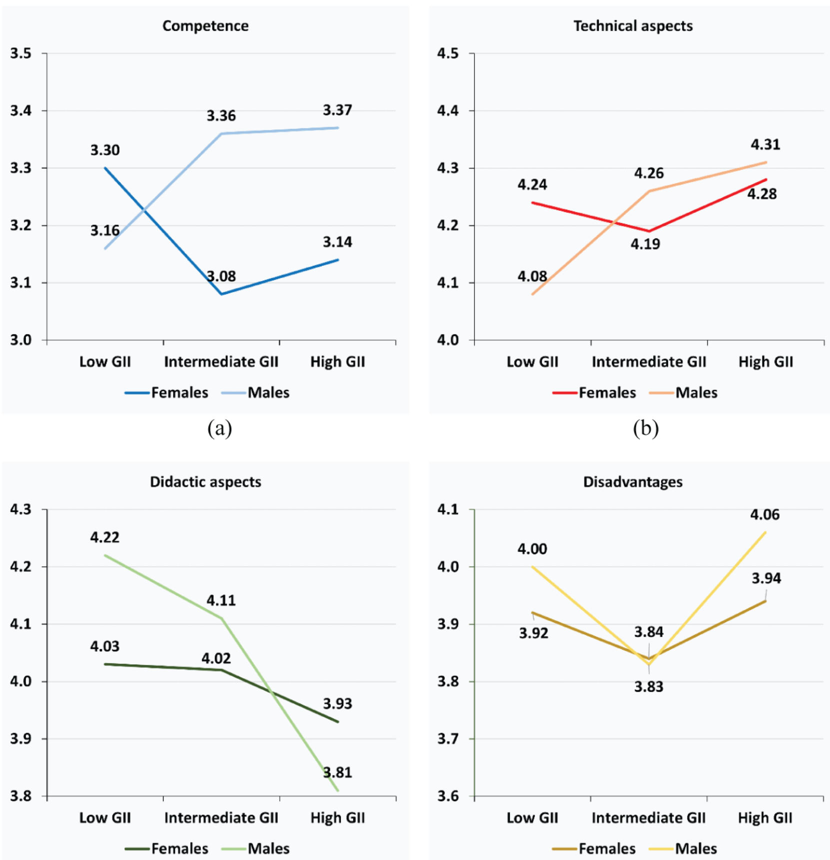
In the three digitization zones, the largest gap by age, within the variable of competence for the use of VR, is in the question on digital skills (with a difference of 0.73 out of 5 between the average responses of the youngest and oldest professors in the low digitization zone; of 0.43 out of 5 in the intermediate digitization zone and of 0.88 in the high digitization zone). In the assessment of technical aspects, in the low digitization zone, the greatest distance between young and old is in interaction (difference of 1.07 out of 5) and the smallest is in usability (distance of 0.42 out of 5), while, in the intermediate digitization zone, the greatest distance is in user experience (0.58 out of 5), followed by interaction (0.54 out of 5), and the smallest is in realism (0.16 out of 5) and 3D design (0.17 out of

Table 7. Wilcoxon test statistics (independent samples, bilateral contrast) for each variable within each digitalization zone when the participants are differentiated by their gender

	Low GII		Intermediate GII		High GII	
	W	p-value	W	p-value	W	p-value
Competence	2830	0.7126	46608	0.0015*	19546	0.0481*
Technical	2980	0.3195	50728	0.1046	21510	0.5825
Didactic	2468	0.2682	54870	0.8408	21320	0.4895
Disadvantages	2770	0.8986	50940	0.1321	23710	0.1905

*p<0.05

Figure 6. Mean scores (out of 5) for each of the variables within each digitization zone, differentiated by the gender of the participants



(a) (b) (c) (d)

5). As for the disadvantages, both in the low digitization region and in the intermediate digitization region, the greatest distance between young and old is in the valuation of space (1.25 out of 5 in low digitization region and 0.75 out of 5 in intermediate digitization region). Those that achieve the greatest consensus among participants of different ages are teacher training in the low digitization region (difference of 0.40 out of 5) and equipment obsolescence in the intermediate digitization region (distance of 0.21 out of 5).

Figure 7. Mean scores (out of 5) for each of the variables within each digitization zone, differentiated by the age of the participants

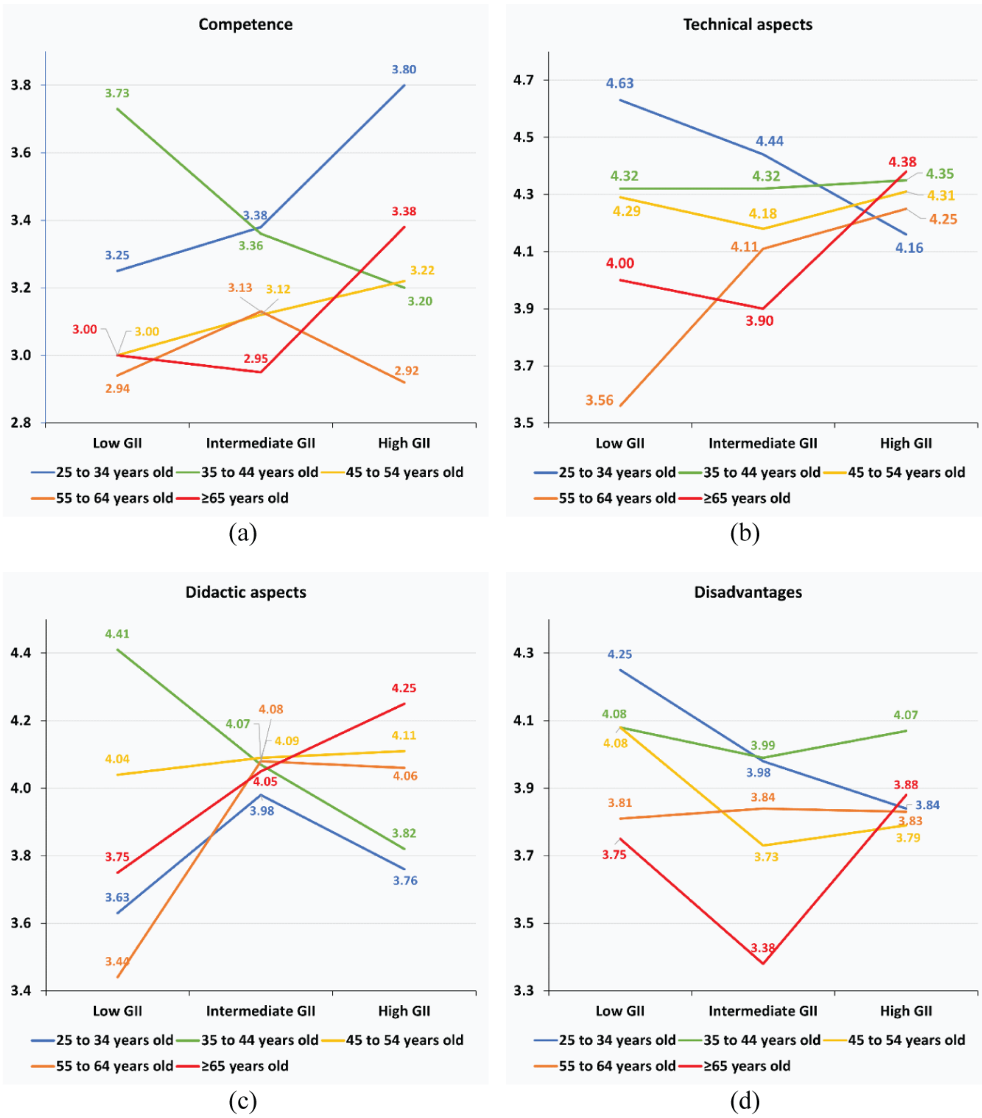


Table 8. Kruskal-Wallis test statistics (with 4 degrees of freedom) for each variable within each digitalization zone when the participants are differentiated by age

	Low GII		Intermediate GII		High GII	
	Chi-sq.	**p-value**	**Chi-sq.**	**p-value**	**Chi-sq.**	**p-value**
Competence	17.1640	0.0018*	9.5127	0.0495*	24.1390	0.0001*
Technical	19.9630	0.0005*	14.1340	0.0069*	2.7978	0.5922
Didactic	15.0030	0.0047*	1.7350	0.7844	8.3306	0.0802
Disadvantages	14.1540	0.0068*	11.1600	0.0248*	4.8605	0.3019

*p<0.05

DISCUSSION

Professors' Digital Skills

The participating professors express having an intermediate level of digital skills for the use of VR in the classroom. In this sense, they find more limitation in their digital competence than in the specific knowledge of VR, which shows that there is a problem of formation of professors' digital teaching skills. These results are in line with the levels of digital competence expressed by university professors in the area, as indicated by the specialized literature (Antón-Sancho et al., 2021; Vergara, Antón-Sancho et al., 2022). However, the valuations made of the VR technologies are, at the average level, very high, mainly in terms of didactic effectiveness aspects, which is also in line with the preceding literature (Antón-Sancho, Vergara, Fernández-Arias et al., 2022; Vergara, Antón-Sancho et al., 2022).

Influence of Digitalization Level of the Country on VR Assessment

The level of digitization did not prove to be a significantly discriminative variable of the mean VR ratings of the participating professors. However, this level, measured from the GII, significantly conditions the way in which gender and age differences occur in the ratings analyzed. Thus, it has been shown that the higher the level of digitalization of the country, the greater the gender gap in terms of knowledge and ability to use VR (Figure 6 and Table 7), to the detriment of female professors. This result deepens the findings of numerous previous studies that had found gender gaps in the access and use of digital technologies among university faculty (Gray et al., 2017; Ancheta-Arrabal, 2021; Vergara, Antón-Sancho et al., 2022), as it identifies that the level of technological development and digitization in the country is occurring unequally among faculty of the two genders. It is therefore suggested that universities encourage, mainly among their female faculty, the use of virtual learning tools, especially VR, through specific training sessions in this regard.

Likewise, the GII has a decisive influence on the age gap in the assessments analyzed. Specifically, the higher the country's level of digitalization, the smaller the age gap (Figure 7 and Table 8). This means that the technological development of the region helps to balance the digital divide affecting the elderly, at least among university faculty. These results provide a better understanding of how the age gap in the use of certain digital technologies develops (Portillo et al., 2020; Zhao, Sánchez-Gómez et al., 2021; Guillén-Gámez et al., 2021). In addition, it is suggested to continue working on the digitization of countries with lower GII, particularly in the financing, equipment, and infrastructure of universities, to technologically develop their economies (Katz & Callorda, 2018) and, thus, contribute to the dissolution of the digital age gaps.

Future Lines of Research

Based on these results, different lines of research are opened in the line of deepening the analysis carried out: (i) carry out an analogous quantitative analysis, but focused on other regions, so that the results can be compared and locate, if necessary, new socio-demographic discriminating factors of VR assessments; (ii) extend the study to other digital teaching tools and analyze whether the results obtained here are generalizable to other digital tools; and (iii) complement these results with a qualitative research, based on an appropriate instrument.

CONCLUSION

Throughout the research it has been found that there are gender and age gaps in the valuations of VR expressed by university professors. Specifically, there is a gender gap in terms of digital skills for the use of VR that penalizes female professors and an age gap that affects the valuation of all dimensions of VR and that penalizes older professors. The level of technological development and digitalization of the participants' country of origin significantly influences the way in which the above two gaps occur.

Thus, the gender gap widens as the digital level of the country increases, but the age gaps decrease as this level of digitalization increases. In any case, the ability to use VR technologies is intermediate, but professors give very high ratings to VR, both in its technical aspects linked to the achievement of learning objectives and in its didactic aspects. They also recognize that the implementation of VR is limited, mainly due to the technological requirements it poses and the need for specific training for professors. It is suggested that universities increase training sessions on digital skills for professors and that these are specifically focused on developing techno-pedagogical skills, that is, the didactic application of specific computational resources such as VR. According to the results obtained in this article, it is expected that this increase in faculty training will help reduce the digital gender and age gaps and encourage the educational use of VR among professors.

CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

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Álvaro Antón-Sancho holds a degree in Mathematics from the University of Valladolid (Spain), specializing in algebra and geometry, a Master's degree in Mathematical Research and a PhD in Mathematical Sciences from the Complutense University of Madrid (Spain). He has held several predoctoral fellowships at the Institute of Mathematics and Fundamental Physics of the Spanish National Research Council and has been Visiting Professor at the TATA Institute of Fundamental Research (India) and the Universidad Técnica Particular de Loja (Ecuador). At present, he is Teacher and Researcher at the University School of Education Fray Luis de León (Valladolid, Spain) and the Catholic University of Avila (Avila, Spain). He is the author of several research articles, conference contributions and books in the fields of algebraic geometry, educational technologies and didactic methodologies.

Diego Vergara holds both a degree in Civil Engineering and a degree in Materials Engineering from the University of Salamanca, USAL (Spain). In addition, he completed his Ph.D. studies -related to Mechanical and Materials Engineering- at the USAL, where he worked as an assistant professor for almost a decade. He has held several postdoctoral fellowships at the Polytechnic Institute of Bragança (Portugal). At present, he is an Assistant Professor and a Researcher at the Catholic University of Avila (UCAV, Spain). He is the author of two hundred research papers, conference contributions and books in the fields of both materials engineering and engineering education.

Pablo Fernández-Arias holds a degree in Industrial Engineering from the University of Salamanca and Industrial Engineering from the University Alfonso X el Sabio. He later obtained his PhD degree from the University of Salamanca, in the PhD program in Social Studies of Science and Technology. He has more than 10 years of professional experience in the energy sector. He has had different professional profiles, including Nuclear Power Plant Operation Instructor, Technological Development and Innovation Manager and Technological Leader. Expert in new educational environments, disruptive technologies for training and active learning methodologies. Since 2019, he has been working as a Teacher and Researcher at the Catholic University of Avila (Spain).