Article

The Use of Virtual Reality in the Countries of the Central American Bank for Economic Integration (CABEI)

Álvaro Antón-Sancho [1], Pablo Fernández-Arias [1], Edwan Anderson Ariza [2] and Diego Vergara [1,*]

1   Technology, Instruction and Design in Engineering and Education Research Group (TiDEE.rg), Catholic University of Avila, C/Canteros s/n, 05005 Ávila, Spain; alvaro.anton@ucavila.es (Á.A.-S.); pablo.fernandezarias@ucavila.es (P.F.-A.)
2   Grupo de Nuevos Materiales, Facultad de Ingeniería, Universidad del Magdalena, Santa Marta 470004, Colombia; earizaec@unimagdalena.edu.co
*   Correspondence: diego.vergara@ucavila.es

Abstract: In recent years, virtual reality (VR) technologies have become one of the teaching tools with the greatest training potential in higher education. Thus, the study of factors that influence the adoption and valuation of VR by the educational agents involved is a fruitful line of research, because it can provide keys to promote its incorporation. This article compares the assessments of VR as a teaching technology in higher education given by professors from countries that are members of the Central American Bank for Economic Integration (CABEI) with those of professors from countries in the Latin American region that are not members of CABEI. For this purpose, a validated questionnaire on the perception of VR use was administered to a sample of 1246 professors from the entire Latin American region, and their responses were statistically analyzed. As a result, it was found that professors from CABEI countries give better ratings to the usability dimensions of VR and report a lower number of disadvantages in its use than professors from countries outside CABEI. However, the increase in the digital competence of professors in CABEI countries is more than twice as high as the increase in the valuation of VR. It follows that there is still much room for the integration of VR in higher education in CABEI countries. Furthermore, in CABEI countries there is a more pronounced gap between professors from private and public universities with respect to the above-mentioned ratings than in non-CABEI countries. As a consequence, some implications and suggestions derived from the results are reported.

Keywords: virtual reality; virtual learning environments; information and communication technologies; university tenure; developing countries

1. Introduction

The term Virtual Reality (VR) refers to computer technologies that create environments, objects, and scenes with the appearance of reality and with which the user can have an interactive experience [1]. Thus, certain technical characteristics are inherent to VR, such as the three-dimensional design of virtual environments [2], which should give as realistic a feeling as possible [3], and interactivity [4], since the user experience should be able to allow interaction with that environment. In addition, a certain degree of immersiveness is required from VR, i.e., the user is sensorially immersed in the environment, inhibiting users from experiencing their real environment. This degree of immersion can be greater or lesser depending on the VR technological application in question; it is a continuum that allows distinguishing, in extreme situations, between immersive VR and non-immersive VR [5]. All these technical characteristics allow VR technologies (together with augmented or mixed reality technologies) to have a multitude of applications in the most diverse fields of technology [6–10].

Within the educational world, VR is one Information and Communication Technology (ICT) that has shown great potential to develop the knowledge of students at all educational

stages [11]. This potential arises from the ability of VR technologies to recreate diverse and dynamic learning situations such that users have all their senses focused on the environment and are able to interact with it in a realistic way. In this way, the virtual environment does not lose the practicality of the real environment but gains in amenities over other non-immersive technological resources. Therefore, in general terms, VR brings unquestionably numerous advantages for use in the classroom, including the following: (i) it allows the recreation of environments in a realistic way that could likely not be recreated with that same realism through other technological resources, which is of special interest in fields such as medicine [12], architecture [13], engineering [14], or art [15]; (ii) the three-dimensional, immersive, and realistic nature facilitates the achievement of learning objectives, which often leads to an increase in academic performance [16]; and (iii) the interactive nature of the environments and the strong underlying technological foundation is motivating for most students, who generally increase their involvement in learning activities [17].

It is also necessary to point out that the implementation of VR technologies in education has some limitations. These include the costs involved in implementation [18] and the digital and techno-pedagogical skills that educators must develop to effectively incorporate these technologies into their teaching activities [19]. Certainly, the initial expense involved in implementing VR technologies is high. Nonetheless, research indicates that over time, their adoption leads to considerable cost savings across various domains, including expenditure on consumables or laboratory equipment [20]. Consequently, the incorporation of VR technologies by educational institutions represents a sustainable initiative [21]. Conversely, the accessibility of VR is hindered by limitations in teacher training, particularly in regions experiencing technological advancement, where the integration of ICT into educational practices is less robust [22].

Digital transformation in Central America faces significant obstacles, which impact regional development and competitiveness. A considerable digital divide and limitations in technological infrastructure, coupled with a lack of advanced digital skills and cybersecurity challenges, hinder the transition to a more digital and connected economy. In response to these challenges, the Central American Bank for Economic Integration (CABEI) has played a crucial role in financing projects that seek to overcome these barriers. For example, CABEI financed in 2023 the construction and improvement of educational infrastructure in Guatemala, benefiting more than 107,000 students [23], provided a USD 80 million loan in 2019 to the Republic of Honduras for the "Program for the Integral Improvement of Educational Infrastructure and Training in Honduras" [24] to promote progress in improving the infrastructure of public education centers, and also supported, in 2022, the creation of an immersive virtual room in the National Art Museum of Guatemala to enrich the cultural experience of visitors through advanced technology [25]. These initiatives not only improve access to education and culture, but also lay the groundwork for integrating emerging technologies such as virtual reality into the educational environment.

In addition, the increase in infrastructure and digital capabilities thanks to CABEI's efforts has provided a special context for examining the reception of virtual reality (VR) in the region's universities. Another outstanding example of CABEI's promotion of advanced technologies in the Latin American and Caribbean region was the financing of the Agriculture and Technology (AgTec) 2022 event, organized by Zamorano University, with the sponsorship of CABEI's DYNAMIC II initiative [26]. This event brought together nearly 900 participants, including students, graduates, industry, and development institutions, to share innovations in processes, products, and services aimed at improving the resilience and equity of agri-food systems. This event discussed how the inclusion of technologies such as the Internet of Things and Artificial Intelligence offers a relevant framework for considering the expansion and acceptance of virtual reality in educational contexts, given its low adoption in the region, which does not exceed 2% among small-scale farmers [26]. Along the same lines, in 2020 CABEI held the forum "Science, Technology and Innovation for Development: the necessary normality" [27], in which the possibility of regional inte-

gration was proposed based on science and technology systems linked between countries and their productive systems. This forum also discussed possible solutions to the most urgent problems based on investment in research and development in Latin America, as the COVID-19 pandemic revealed the low scientific and technological capacity as well as the relative backwardness in the use of information technologies. Likewise, CABEI's initiative to support the development of the Artificial Intelligence Strategy in coordination with the Executive Directorate of the Innovation Cabinet of the Dominican Republic exemplifies the entity's commitment to the promotion and adoption of advanced technologies [28]. These supports, initiatives, and efforts provide a solid framework to drive research and development, which is crucial to understand the potential for integration of technologies such as virtual reality in higher education in the region.

Despite CABEI's firm commitment to the digitalization of its member countries, especially in higher education, there are no studies in the specialized literature that analyze the impact of CABEI's actions in this digital integration process. For this reason, the main purpose of this paper is to contribute to closing this gap. The general objective of this research is to analyze the reception of VR technologies by Latin American university professors, distinguishing between CABEI countries and non-CABEI countries. Specifically, it aims to achieve the following objectives: (i) to analyze the perceptions that Latin American professors have about the didactic use of VR and their self-concept of digital competence for its use; (ii) to identify gaps in the above perceptions between CABEI and non-CABEI countries; and (iii) to analyze whether the behavior of the differences in the perception of VR between private and public universities in CABEI countries is similar or different from those in non-CBEI countries. Therefore, we seek to answer the following research questions:

- RQ1: Are there significant differences in perceptions of the didactic use of VR between teachers in CABEI and non-CBEI countries within the Latin American region?
- RQ2: Are differences by university tenure in perceptions of VR in CABEI countries similar to or different from those of teachers in non-CABEI countries?

2. Related Works

The digital competence expressed by university professors in the Latin American region is low, both in general terms [29] and in relation to the use of VR [22]. In this sense, the area of specialty of the professors conditions their digital competence [30] which, in general, is higher among professors in scientific and technical areas [31]. As far as we have been able to explore, there are no studies that analyze differences in digital skills between private and public university teachers in general. However, there are contextualized studies on professors of Engineering [32] and Health Sciences [33] that claim that professors from private universities report having better digital competence than those from public universities. This disparity is attributed to several factors. Predominantly, private universities tend to have a larger contingent of distance learning students, necessitating substantial investments in digital infrastructure and resources [32]. Moreover, private institutions might also prioritize comprehensive training programs in digital skills for their faculty, which not only enhance technical abilities but also improve pedagogical and professional capacities to integrate these technologies effectively into their teaching practices. These strategies are integral to fostering an environment that supports digital competence, tailored to the evolving educational needs and modalities of the modern academic landscape.

However, the digital competence of faculty in the Latin American region also changes depending on the particular country studied. Specifically, it has been shown that the level of digitization of the country correlates positively with the level of digital competence expressed by university teachers [22]. In addition, it has also been shown that in certain Latin American countries there are gaps in the digital competence of university professors that do not exist in countries in more strongly digitized regions. For example, in Mexico, engineering professors express the best digital competence [34], while in Spain, no gaps in digital competence by knowledge area have been identified [35].

University professors give very good ratings to VR technologies as a teaching resource in higher education [36]. In this sense, the aspect most highlighted by the literature is the very high acceptance generated by these technologies among students [37], which leads to a significant increase in students' motivation and engagement with learning activities [38]. However, these high ratings are accompanied by the identification of a high number of limitations or disadvantages, mainly linked to the cost of implementation and the needs VR poses in terms of faculty training [39].

The specialized literature identifies numerous factors that condition the reception of digital technologies in general and VR in particular, in higher education. The factors most frequently present in the literature are sociological factors such as the gender and age of teachers. In the case of gender, the literature presents diverse results. There are works that report a better reception of digital technologies by men compared to women [29], works that report that women are the ones who show a better reception [40], and works that report no significant differences by gender [35]. As far as we have been able to explore, it has not been possible to describe the extraneous variables that explain these divergences. A similar phenomenon occurs with age. In fact, it has been found that the digital generation (digital natives or digital immigrants) affects professors' evaluations of digital technologies [41]. However, it has also been found that the field of expertise of a professor significantly influences how age affects their evaluation of virtual reality (VR). Specifically, the area of knowledge acts as a critical variable that could explain the variance in VR ratings across different age groups [42]. This suggests not only that age impacts technological adoption but that this effect is moderated by the specific disciplinary contexts in which the technology is used. Thus, the interaction between the age of a professor and their field of knowledge provides a detailed understanding of their perception and valuation of VR technology, highlighting the importance of considering both individual and contextual factors in studies of technology adoption in educational settings.

It has also been found that the teacher's area of knowledge conditions the way in which age influences his or her evaluations of VR [42]. Thus, knowledge area appears as a possible explanatory extraneous variable for age gaps in VR ratings.

University tenure has been shown to be an explanatory variable for faculty perceptions of VR within specific subject areas, such as Health Sciences [31] and Engineering [32]. In both knowledge areas, faculty from private universities value VR more than those from public universities [31,32]. However, the gap between the two is wider in Health Sciences [31]. This shows that university tenure is not only an explanatory variable for VR ratings but also an extraneous variable that explains, secondarily, the influence of other factors on the above-mentioned ratings.

3. Materials and Methods

3.1. Participants

The target population for this research was university professors in the Latin American and Caribbean region. Specifically, the authors designed and taught a master class on the didactic use of VR in higher education focused on Latin American university professors, which was accessed through free registration in the course, and which was repeated every two weeks between January and June 2023. This session had the following objectives: (i) to present VR technologies as didactic tools and elucidate their technical characteristics of realism, three-dimensionality, interactivity, and immersion; (ii) to discuss the logistical, equipment, and training needs necessary for the implementation of VR technologies in university classrooms; and (iii) to present different examples of practical applications of the use of VR technologies in the various areas of knowledge in higher education. The criteria for inclusion were the following: (i) being a professor at a Latin American university and (ii) being a registered attendee at a training session on the use of VR in higher education given by the authors. Attendance at the above-mentioned training session allows assuming that the participants had, at the time of their participation in the study, similar and homogeneous knowledge about the didactic use of VR, even though they

were professors with no previous experience in the use of VR. After each training session, the attendees were asked to respond telematically to the questionnaire used as a research instrument, which was sent to them by means of a GoogleForms® (v1, Mountain View, CA, USA) questionnaire. Participation was informed and consented to in writing, as well as free and anonymous. At no point in the process were participant data recorded that could lead to identification. A total of 1559 professors attended the training session, of whom 1246 responded to the questionnaire. All the responses received were considered valid by the authors, in the sense that they were complete.

3.2. Research Variables and Instrument

In this study, the main explanatory variable considered is whether or not the country of origin of the participating professors belongs to CABEI. This is a dichotomous nominal variable. The secondary explanatory variable is the tenure, private or public, of the university where the professors teach. This is also a dichotomous variable.

The following explained variables are also considered: (i) self-concept of the participants' digital competence in the use of VR technologies; (ii) assessment of the didactic aspects of VR; (iii) assessment of the usability of VR by professors and students; (iv) level of perceived disadvantages of VR use in higher education; (v) perceived future use for VR in the universities of the region; and (vi) assessment of the didactic and formative effectiveness of VR use. All the explained variables were measured on Likert-type scales from 1 to 5, where the lowest rating corresponds to value 1 and the highest to value 5.

For measuring these explained variables, a validated questionnaire [32] oriented to university professors about the perception of the use of VR technologies in higher education was used (Appendix A). The questionnaire consists of 22 questions, each of which requests a rating of an aspect related to the didactic use of VR on a scale of 1 to 5, where 1 means a very low rating and 5 means a very high rating. The validation of the instrument refers to the construct, which consisted of an exploratory factor analysis that allowed the identification of six families of questions that explain the construct [32] (Table 1): (i) self-concept of participants' digital competence in using VR (questions 1 to 3); (ii) rating of technical aspects of VR, including realism, immersion, and three-dimensional design (questions 4 to 7); (iii) rating of usability aspects of VR, including user experience, employability of VR in lessons, and perceived possibility at the participant's university implementing VR technologies (questions 8 to 10); (iv) disadvantages of VR, including costs, space required, human and technical resources used, training required by technicians and professors, and technological obsolescence of equipment (questions 11 to 15); (v) assessment of the future projection of the use of VR in higher education, including both immersive and non-immersive VR (questions 16 and 17); and (vi) assessment of the didactic and formative aspects of VR, including student acceptance of VR, its impact on academic performance, induced student motivation, impact on the development of lessons, university capacity to implement VR technologies, and didactic employability (questions 18 to 22). This distribution of the questions into six families, which correspond to the explained variables of the present study, allows explaining 54.1% of the variance [32]. Likewise, the instrument was validated in terms of its internal consistency (notice that the Cronbach's alpha parameters of the different families mentioned vary between 0.70 and 0.84 [32]).

Table 1. Explained variables and questions of the instrument (Appendix A).

Variable	Questions
Digital competence	1 to 3
Technical aspects	4 to 7
Usability	8 to 10
Disadvantages	11 to 15
Future projection	16 to 17
Didactic aspects	18 to 22

3.3. Research Methodology

In this work, descriptive quantitative research was carried out on the assessments made by a sample of Latin American university professors of the didactic use of VR technologies. The core of the research consists of the statistical analysis of the comparison of the mean ratings of professors from CABEI countries with respect to professors from non-CABEI countries, and of private universities with respect to public universities. The research process was as follows (Figure 1): The authors provided a training session on the didactic use of VR as part of the data collection phase. After the session, the participants answered a questionnaire, which was used as a research instrument. After validation of the responses obtained (in the sense of checking for completeness), the data collection phase was concluded. These data were subjected to statistical analysis, which were finally discussed and conclusions were drawn.
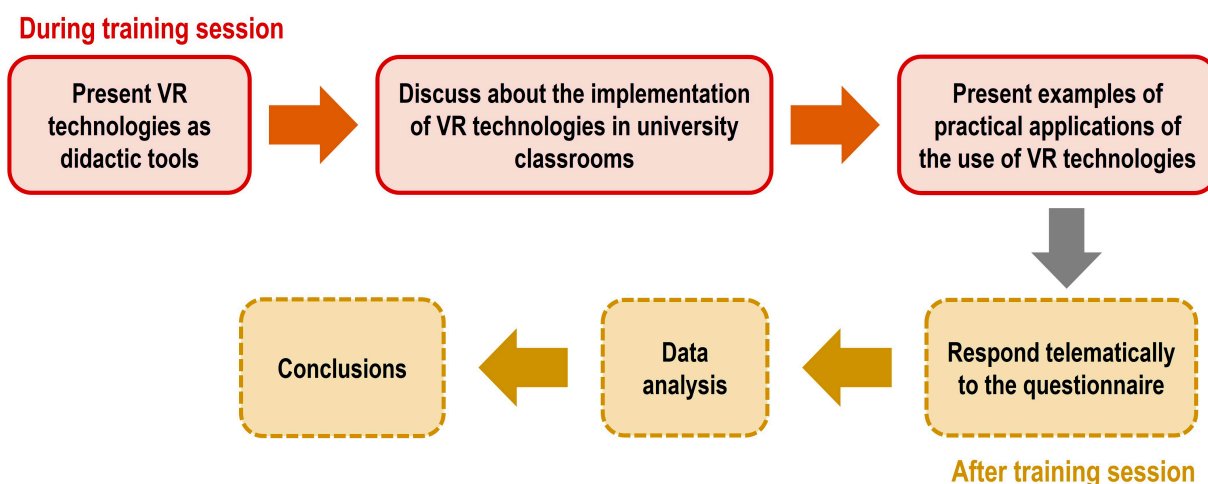

Figure 1. Research phases.

3.4. Data Analysis

This work is of a descriptive quantitative nature and is based on the statistical analysis of the responses obtained to the questionnaire used as a research instrument. For this purpose, it was confirmed, by means of a confirmatory factor analysis and the computation of internal reliability statistics, that the theoretical model of six families of questions that was presented explains the responses obtained. Descriptive statistics were then obtained for the responses, grouped by families of questions according to the model derived from the factor analysis. To answer the research questions, we obtained the statistics of the bilateral *t*-test, comparing the mean responses between CABEI countries and non-CABEI countries, with Welch's correction, without assuming equality of variances. Likewise, to contrast whether the gaps by university tenure in the responses are similar or different in CABEI countries and non-CABEI countries, the multifactor analysis of variance (MANOVA) test was used, again with Welch's correction, without assuming equality of variances.

4. Results

4.1. Distribution of Participants

A total of 1246 professors participated in the study, of which 746 come from nine CABEI countries (59.87% of the total) and 500 come from nine countries in the Latin American and Caribbean region that do not belong to CABEI (40.13% of the total). Of the participants from CABEI countries, 37.50% teach in private universities and 62.50% teach in public universities, so there is a slight majority of professors from public universities. Among participants from non-CABEI countries, 46.00% work in private universities and 54.00% work in public universities, so the majority are again in public universities, although the difference is smaller than in the case of CABEI countries. The distribution of participants by country of origin is shown in Table 2.

Table 2. Distribution of the participants by their country of origin.

CABEI Countries	Proportion (%)	Non-CABEI Countries	Proportion (%)
Argentina	16.6	Bolivia	10.4
Colombia	29.5	Brazil	4.0
Costa Rica	1.1	Chile	4.8
El Salvador	1.9	Ecuador	22.4
Guatemala	3.2	Paraguay	3.2
Honduras	1.1	Peru	44.4
Mexico	37.8	Puerto Rico	1.6
Panama	1.6	Uruguay	2.4
Dominican Republic	2.9	Venezuela	6.8
TOTAL	100	TOTAL	100

4.2. Validation of the Instrument

The Cronbach's alpha and composite reliability (CR) parameters computed on the responses obtained (Table 3), all greater than 0.70, show that the instrument enjoys good internal consistency.

Table 3. Cronbach's alpha and composite reliability (CR) parameters.

| Family of Responses	Cronbach's Alpha	CR
Digital competence	0.7551	0.7421
Technical aspects	0.8491	0.8406
Usability	0.7814	0.7696
Disadvantages	0.8017	0.7933
Future projection	0.7941	0.7861
Didactic aspects	0.7640	0.7551

4.3. Responses

Participating professors express an intermediate average level of digital competence for VR use (between 3 and 4 out of 5) but higher ratings for technical and usability aspects (greater than or equal to 4 out of 5), according to the average responses shown in Table 4. On the other hand, the didactic aspects are rated lower than the technical and usability aspects (between 3 and 4 out of 5). Likewise, the level of disadvantage perceived by the professors is close to 4 out of 5. A bilateral *t*-test was performed to compare the mean ratings between teachers from CABEI countries and teachers from non-CABEI countries, the results of which are shown in Table 4 and Figure 2. Since the corresponding *p*-values are less than the significance level previously set (0.05) only for the usability and disadvantages variables, it can be concluded that there are significant differences between the mean ratings only for these variables. Specifically, professors from CABEI countries give better ratings of the usability of VR and identify a lower level of disadvantage in its use in lessons than professors from non-CABEI countries (Table 4).

The bilateral *t*-test performed for the comparison of means between private and public universities reveals significant differences (*p*-values lower than the 0.05 significance level) for the usability and didactic aspects variables. Therefore, professors from private universities give higher ratings to the usability and didactic aspects of VR than those from public universities (Table 5). However, no differences by university tenure were identified in the professors' self-concept of digital competence or in their ratings of the technical aspects of VR, its future projection or its disadvantages (Table 5 and Figure 3).

Table 4. Average responses distinguishing between CABEI countries and non-CABEI countries as well as statistics of the bilateral *t*-test for comparison of means, carried out with the Welch correction, without assuming equality of variances.

| Family	Mean CABEI Countries (Out of 5)	Mean Non-CABEI Countries (Out of 5)	t-Statistic	*p*-Value
Digital competence	3.26	3.23	0.58	0.56
Technical aspects	3.97	3.91	0.91	0.36
Usability	4.29	4.15	2.81	<0.05 *
Disadvantages	3.80	3.92	−1.96	0.04 *
Future projection	4.00	3.90	1.62	0.10
Didactic aspects	3.08	3.14	−0.87	0.38

* *p* < 0.05.
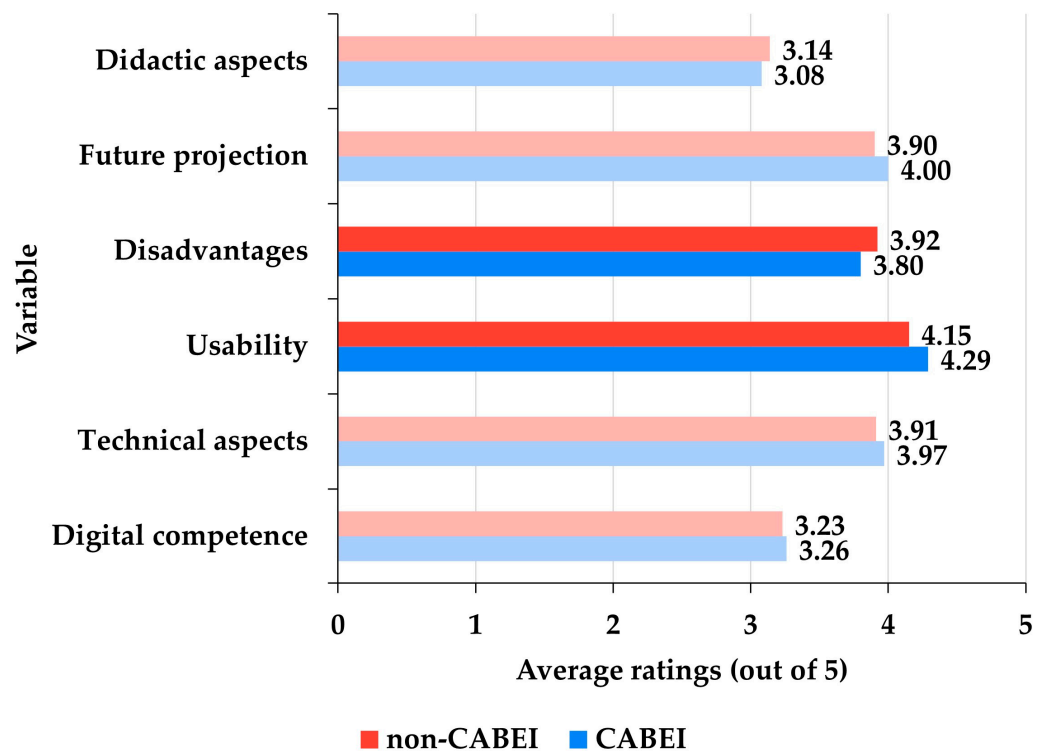
Figure 2. Average responses differentiated by geographic location (dark colors indicate significant differences between CABEI and non-CABEI countries).

Table 5. Average responses distinguishing between private and public universities as well as statistics of the bilateral *t*-test for comparison of means, carried out with the Welch correction, without assuming equality of variances.

| Family	Mean Private	Mean Public	t-Statistic	*p*-Value
Digital competence	3.31	3.20	1.75	0.08
Technical aspects	3.98	3.92	1.06	0.29
Usability	4.36	4.15	4.27	0.00 *
Disadvantages	3.91	3.81	1.49	0.14
Future projection	3.97	3.95	0.38	0.70
Didactic aspects	3.27	2.98	4.40	0.00 *

* *p* < 0.05.
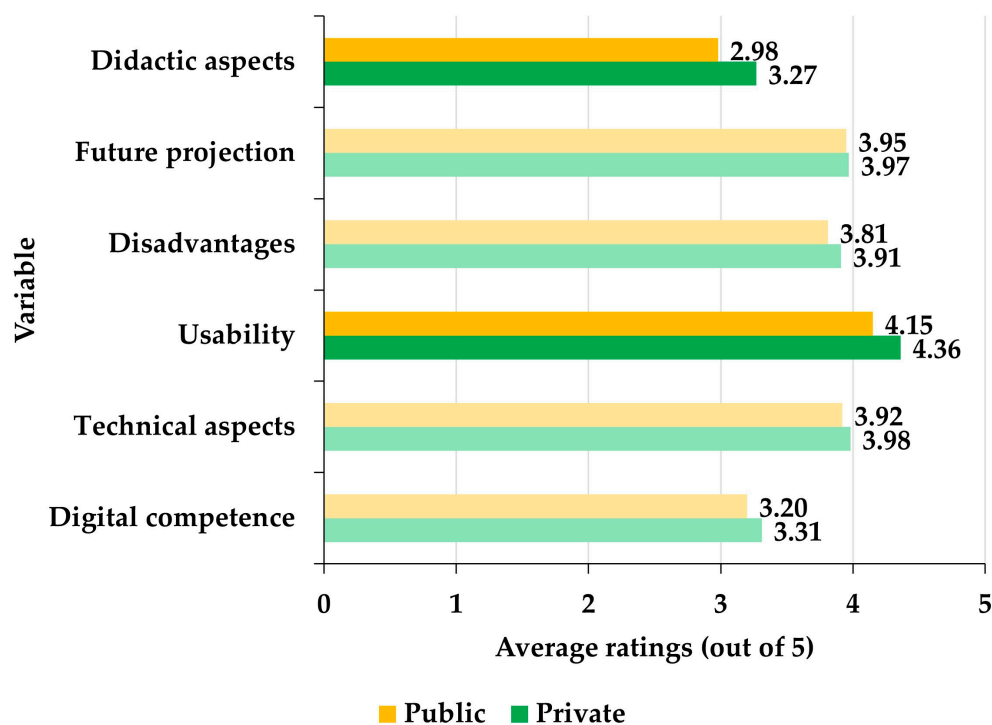
Figure 3. Average responses differentiated by university tenure (dark colors indicate significant differences between private and public universities).

The behavior of the gap between public and private universities depending on whether the professors are from CABEI or non-CABEI countries was studied using multifactor analysis of variance (MANOVA), the results of which are shown in Table 6 and Figure 4. Specifically, the behavior of the mean responses, distinguishing between private and public universities, is different for CABEI and non-CABEI countries in terms of self-concept of digital competence and assessment of the future projection of VR. Specifically, in the CABEI countries, professors in private universities report higher levels of digital competence and a better assessment of the future projection of VR than professors in public universities (Table 6). On the other hand, in countries outside CABEI, it is public university professors who show a slight superiority in their average self-concept of digital competence and also in their assessment of the future projection of VR compared to private university professors (Table 6).

Table 6. Average responses (out of 5) distinguished by university tenure within CABEI countries and non-CABEI countries as well as statistics from the multifactor analysis of variance (MANOVA) test with Welch's correction, without assuming equality of variances.

Family	CABEI Countries		Non-CABEI Countries		F-Statistic	*p*-Value
	Private	Public	Private	Public		
Digital competence	3.41	3.18	3.20	3.25	5.02	0.03 *
Technical aspects	3.99	3.95	3.97	3.86	0.47	0.49
Usability	4.45	4.20	4.25	4.06	0.28	0.60
Disadvantages	3.81	3.79	4.02	3.84	1.13	0.29
Future projection	4.08	3.95	3.84	3.96	4.36	0.04 *
Didactic aspects	3.26	2.97	3.29	3.01	0.02	0.89

* $p < 0.05$.
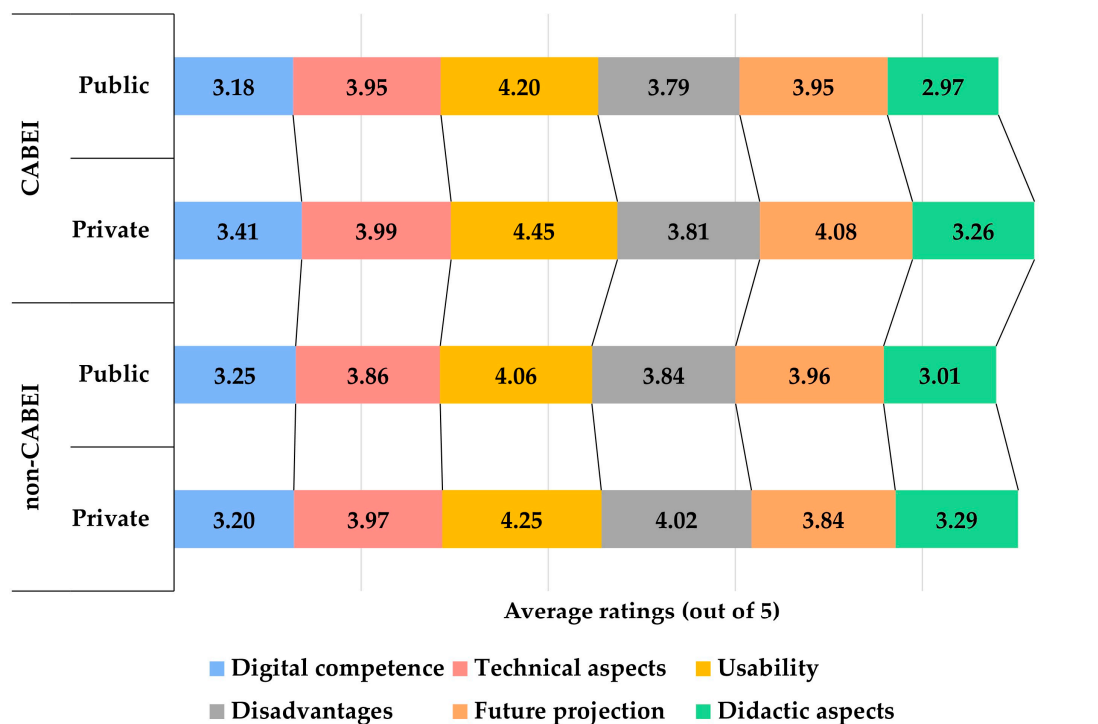
Figure 4. Average responses (out of 5) differentiated by geo-localization (CABEI and non-CABEI countries) and university tenure.

5. Discussion

The first novel contribution of the present research is to demonstrate that teachers from CABEI countries rate the usability and user experience dimensions of VR higher than teachers from non-CABEI countries (Table 4). In addition, the level of VR disadvantage perceived by CABEI members is lower than that of non-CABEI members (Table 4). This allows us to conclude, in response to RQ1, that belonging to the CABEI certainly influences professors' acceptance of VR, although not in all the dimensions analyzed. If there are no differences in the ratings of technical or didactic aspects, it is probably because these ratings are not so much conditioned by the digitization of the country or the experience of use, which seems to condition the rating of usability. This implies that professors in CABEI countries probably have greater knowledge and experience in the use of technologies such as VR.

In any case, the above results are in line with previous work that identifies the geographic variable as an influential factor in VR valuations [19,22,35]. Also, it is shown that CABEI policies regarding the egalitarian digital development of member states lead to higher acceptance of VR technologies by university professors. However, this higher acceptance, while significant, is still small (around 3.37% for usability aspects of VR and 3.16% for disadvantages; Table 4). In contrast, digital competence in CABEI countries is about 7% higher than in non-CBEI countries (Table 4). These two data together imply that membership in CABEI leads to an increase in the digital integration of its universities, but this increase has probably not yet sufficiently reached specific VR technologies.

University tenure has also been shown to be an explanatory variable for the evaluation of the didactic and usability aspects of VR (Table 5). Specifically, professors from private universities give higher ratings of these dimensions than professors from public universities. Again, these results are in line with previous work contextualized in specific areas of knowledge, such as Health Sciences [31] and Engineering [32]. Moreover, these results are extended here to a broader population of university faculty. This gap may be due to the greater experience and investment of private universities in the region in digital integration [32].

However, these university tenure gaps behave differently in CABEI and non-CABEI countries. Specifically, in CABEI countries, there is a larger gap in digital competence for VR use between private and public universities than in non-CABEI countries (Table 6). Indeed, the digital competence of professors at private universities is 7.23% higher than that of professors at public universities within CABEI countries. In contrast, the digital competence of professors at public universities is 1.6% higher than that of professors at private universities within countries outside the CABEI. This implies, in response to RQ2, that the gaps by university tenure are different depending on whether or not one belongs to the CABEI in terms of self-concept of digital competence, but not in the assessment of the different technical, didactic, or usability dimensions of VR. This probably means that CABEI countries are pursuing more determined university digitization policies than non-CABEI countries, but the impact of these policies is evident mostly in private universities. Again, the reality of the student body of these universities may explain this gap [32].

The implications of this study are as follows: (i) supranational alliances of an economic nature, such as CABEI, have a significant and positive impact on the digitization process in the region in which they are established; (ii) the previous digitization process carried out by CABEI countries has had very little impact on the use and acceptance of specific VR technologies in higher education; and (iii) the policies carried out by CABEI generate inequalities in terms of the digitization process between private and public universities, at least in terms of the digital training of faculty. Based on this second implication, it is suggested that CABEI member states take measures to ensure an increasing use of digital technologies in public universities, for example, by encouraging the design of protocols for their use in lessons.

Among the limitations of this study are the following: (i) the methodology employed is strongly quantitative, so that it is not possible to conduct an in-depth analysis of the reasons behind the gaps identified, which would be derived from a more qualitative or mixed approach; (ii) it is possible that there are extraneous variables influencing the perceptions analyzed, both sociological and academic, that have not been addressed in this research; and (iii) the geographic region analyzed, in the process of technological development, is specific and particular, so it is not possible to extend the results to other regions with higher levels of digitization. Thus, the following lines of future research are proposed: (i) to carry out a similar quantitative analysis, but with a sample of participants homogeneously distributed by country, so that the influence of the geographic variable can be studied in greater depth; (ii) to complete the study with a qualitative analysis that will make it possible to identify the exact reasons for the gaps identified; and (iii) to compare the results obtained with those of other geographic regions with different levels of digitization.

Central America faces significant challenges in its digital transformation, marked by a notable digital divide, limited technological infrastructure, and a lack of digital and innovation skills. These challenges, together with problems in cybersecurity and access to financing, hinder progress towards a digital economy. CABEI has responded to these challenges with significant initiatives, such as financing the expansion of educational infrastructure in Guatemala [23] and the development of an immersive virtual room at the National Museum of Art [25], in addition to supporting technological innovation projects in agriculture and education in other member countries [26]. In addition, CABEI has supported initiatives that promote technological innovation in various sectors, which could indirectly benefit education by improving the technological infrastructure available to educational institutions in the region. These efforts not only improve the access to and quality of education and culture but also foster greater integration with global value chains, paving the way for the incorporation of advanced technologies such as virtual reality. CABEI has thus played a fundamental role in the quest to mitigate these barriers through the financing of key projects.

CABEI's implementation of infrastructure and advanced technology offers a unique platform to explore the integration and perception of virtual reality in higher education in the region. The analysis of CABEI-supported projects, such as the creation of immersive

facilities and support for research and development in countries such as Guatemala and Honduras, influence professors' perceptions of the didactic use of VR. In addition, these analyses make it possible to compare the differential situation between private and public universities, in order to understand the differences in the reception and application of Virtual Reality depending on the type of institution and the technological support provided by regional initiatives such as the National Artificial Intelligence Strategy in the Dominican Republic and educational innovation in Honduras, thus reflecting the impact of digitalization policies promoted by CABEI.

The results of the present study show that, despite funding for infrastructure improvements in universities and other educational institutions by CABEI in the Latin American and Caribbean region, the integration of technologies such as virtual reality in higher education in CABEI countries is still in its early stages. Integrating VR more deeply into academic curricula could improve the perception of its didactic benefits, thus aligning digital competence with positive evaluations of its practical applicability. While teachers in CABEI countries rate the usability aspects of VR positively and perceive fewer disadvantages in its use compared to their counterparts in non-CABEI countries, the increase in digital competence is not fully reflected in a high valuation of VR. This suggests that, while CABEI investments in technology infrastructure and training are critical, a more targeted and specific approach to VR training is needed for these technologies to be fully leveraged in educational contexts. These infrastructure projects would have the potential to incorporate advanced technological components such as computer labs and digital media, which can be critical in supporting VR technologies.

6. Conclusions

The participating professors give high ratings to the technical and usability aspects of VR but express an intermediate self-concept of their digital competence to use VR, an intermediate–high level of disadvantages, and an intermediate rating of its didactic benefits. Professors from CABEI countries express 3.37% higher ratings of the usability aspects of VR and 3.16% lower ratings of its disadvantages than those from non-CABEI countries. Also, within the CABEI countries, the digital competence expressed by private university professors is 7.23% higher than that of public university professors. However, within countries outside the CABEI, the digital competence expressed by public university professors is 1.6% higher than that of private university professors. Consequently, it can be affirmed that CABEI activity in its member states leads to a notable increase in the digital competence of professors in its universities, which is clearly concentrated in private universities. This is probably because private universities may have both a greater awareness of the digital integration process and a greater capacity to carry it out. Thus, this may have led them to a more optimal capacity to channel the investment received in the digitization of higher education than public universities. In addition, CABEI membership also significantly increases the valuations of VR technologies. However, this increase of just 3% is low (less than half of the increase in digital competence shown by CABEI countries). This means that the CABEI countries have not taken sufficient action in relation to specific VR technologies. From the results obtained, it is recommended that CABEI countries promote the design of protocols for the use of digital technologies, specifically VR, within their public universities, to reduce the existing gap with private universities, and that efforts to digitize higher education in non-CABEI countries be increased. In conclusion, the main original contribution of the article consists of a mathematical verification of the influence of CABEI's technological development policies in higher education on university professors' reception of digital teaching technologies, specifically VR.

Although it has been shown that there are significant differences in the acceptance of VR technologies depending on whether a country belongs to the CABEI, the methodology used cannot ensure that membership in the CABEI is the cause (at least the only cause) of these differences. This is a methodological limitation of this work. Thus, given that only a small part of the investment in higher education in CABEI countries can be assumed to be

due to CABEI membership, it is possible that there are extraneous variables that cause the differences identified in this paper. Among these hidden causes could be, for example, the differences in socioeconomic levels that exist between CABEI and non-CABEI countries.

CABEI's commitment to improving digital infrastructure and training has facilitated a more receptive environment for VR in educational institutions in its member countries. This is inferred because the results obtained among participants from CABEI countries are better. However, despite CABEI funding for infrastructure improvements, the adoption of VR in higher education in CABEI countries is still in its nascent stages, because the superiority of the ratings to those of non-CABEI countries barely exceeds 3%. This implies that a more targeted approach to VR training is required to take full advantage of these technologies in educational contexts. Likewise, the results of the study indicate that, although there is a positive assessment of VR usability and recognition of its technical advantages, a concerted effort is still needed to build this improved infrastructure into an effective integration of VR into didactic processes, particularly in public universities, to close the gap with private institutions and maximize the educational potential of these advanced technologies. The difference in the reception of VR between private and public universities underscores the need for supportive policies that balance the distribution of technological resources and strengthen the capacity of all higher education institutions in the Latin American region.

Appendix A

The following are the questions of the survey used as the research instrument (all responses are measured on a Likert scale of 1 to 5, where 1 means a very low rating and 5 means a very high rating):

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 of the following usability aspect of virtual reality when designing a virtual reality educational experience: 3D Design.
5. Level of importance of the following usability aspect of virtual reality when designing a virtual reality educational experience: Immersion.
6. Level of importance of the following usability aspect of virtual reality when designing a virtual reality educational experience: Realism.
7. Importance of interaction when designing an educational experience with virtual reality.
8. Importance of user experience when designing an educational experience with virtual reality.
9. Importance of employability when designing a virtual reality educational experience.
10. Possibility of your university implementing virtual reality in its teaching activities.
11. Level of inconvenience of the following aspects of virtual reality: Costs.
12. Level of inconvenience of the following aspects of virtual reality: Spatial limitations.

13. Level of inconvenience of the following aspects of virtual reality: Demand for technical and human resources.
14. Level of inconvenience of the following aspects of virtual reality: Requirement of specific knowledge on the part of teachers and technicians.
15. Level of inconvenience of the following aspects of virtual reality: Technological obsolescence of equipment.
16. Degree to which you think that the implementation of immersive virtual reality will increase in the future at your university.
17. Degree to which you think that the implementation of non-immersive virtual reality will increase in the future at your university.
18. Level of importance you give to the didactic usefulness of virtual reality when designing didactic actions.
19. Level of acceptance of virtual reality as a teaching resource that you think your students have (or would have).
20. Do you believe that the use of virtual reality in educational environments increases (or would increase) the academic performance of your students?
21. Do you believe that the use of virtual reality in educational environments increases (or would increase) your students' motivation to learn?
22. Do you consider that the application of virtual reality in educational environments helps (or would help) to improve the progress of lessons?

References

1. Onyesolu, M.O.; Eze, U.F. Understanding virtual reality technology: Advances and applications. In *Advances in Computer Science and Engineering*; Schmidt, M., Ed.; InTech: Houston, TX, USA, 2011; pp. 53–70. [CrossRef]
2. Newman, M.; Gatersleben, B.; Wyles, K.J.; Ratcliffe, E. The use of virtual reality in environment experiences and the importance of realism. *J. Environ. Psychol.* **2022**, *79*, 101733. [CrossRef]
3. Kyriakou, M.; Pan, X.; Chrysanthou, Y. Interaction with virtual crowd in immersive and semi-immersive virtual reality systems. *Comput. Animat. Virtual Worlds* **2017**, *28*, e1729. [CrossRef]
4. Zhou, Y.; Ji, S.; Xu, T.; Wang, Z. Promoting knowledge construction: A model for using virtual reality interaction to enhance learning. *Procedia Comput. Sci.* **2018**, *130*, 239–246. [CrossRef]
5. Milgram, P.; Kishino, F. A taxonomy of mixed reality visual displays. *IEICE Trans. Inf. Syst.* **1994**, *77*, 1321–1329. Available online: https://cs.gmu.edu/~zduric/cs499/Readings/r76JBo-Milgram_IEICE_1994.pdf (accessed on 18 June 2023).
6. Pavilionis, P.; Adhanom, I.B.; Moran, R.; Taylor, M.R.; Murray, N.G. Virtual reality application for vestibular/ocular motor screening: Current clinical protocol versus a novel prototype. *Sports Health* **2024**, *16*, 407–413. [CrossRef] [PubMed]
7. Cheng, D.; Duan, J.; Chen, H.; Wang, H.; Li, D.; Wang, Q.; Hou, Q.; Yang, T.; Hou, W.; Wang, D.; et al. Freeform OST-HMD system with large exit pupil diameter and vision correction capability. *Photonics Res.* **2022**, *10*, 21–32. [CrossRef]
8. Shi, Y.; Wan, C.; Dai, C.; Wang, Z.; Wan, S.; Zheng, G.; Zhang, S.; Li, Z. Augmented reality enabled by on-chip meta-holography multiplexing. *Laser Photonics Rev.* **2022**, *16*, 2100638. [CrossRef]
9. Liu, C.; Zheng, Y.; Yuan, R.-Y.; Jiang, Z.; Xu, J.-B.; Zhao, Y.-R.; Wang, X.; Li, X.-W.; Xing, Y.; Wang, Q.-H. Tunable liquid lenses: Emerging technologies and future perspectives. *Photonics Res.* **2023**, *17*, 2300274. [CrossRef]
10. Solmaz, S.; Kester, L.; Van Gerven, T. An immersive virtual reality learning environment with CFD simulations: Unveiling the Virtual Garage concept. *Educ. Inf. Technol.* **2024**, *29*, 1455–1488. [CrossRef]
11. Johnston, E.; Olivas, G.; Steele, P.; Smith, C.; Bailey, L. Exploring pedagogical foundations of existing virtual reality educational applications: A content analysis study. *J. Educ. Technol. Syst.* **2018**, *46*, 414–439. [CrossRef]
12. Duarte, M.L.; Santos, L.R.; Guimarães, J.B.; Peccin, M.S. Learning anatomy by virtual reality and augmented reality. A scope review. *Morphologie* **2020**, *104*, 254–266. [CrossRef] [PubMed]
13. Balamuralithara, B.; Woods, P.C. Virtual laboratories in engineering education: The simulation lab and remote lab. *Comput. Appl. Eng. Educ.* **2009**, *17*, 108–118. [CrossRef]
14. Potkonjak, V.; Gardner, M.; Callaghan, V.; Mattila, P.; Guetl, C.; Petrović, V.M.; Jovanović, K. Virtual laboratories for education in science, technology, and engineering: A review. *Comput. Educ.* **2016**, *95*, 309–327. [CrossRef]
15. Hutson, J.; Olsen, T. Virtual reality and art history: A case study of digital humanities and immersive learning environments. *Fac. Scholarsh.* **2022**, *417*, 50–65. [CrossRef]
16. Mäkinen, H.; Haavisto, E.; Havola, S.; Koivisto, J.-M. User experiences of virtual reality technologies for healthcare in learning: An integrative review. *Behav. Inf. Technol.* **2022**, *41*, 1–17. [CrossRef]

17. Natale, A.F.D.; Repetto, C.; Riva, G.; Villani, D. Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research. *Br. J. Educ. Technol.* **2020**, *51*, 2006–2033. [CrossRef]

18. Chang, C.-Y.; Sung, H.-Y.; Guo, J.-L.; Chang, B.-Y.; Kuo, F.-R. Effects of spherical video-based virtual reality on nursing students' learning performance in childbirth education training. *Interact. Learn. Environ.* **2022**, *30*, 400–416. [CrossRef]

19. Antón-Sancho, Á.; Vergara, D.; Fernández-Arias, P.; Ariza-Echeverri, E.A. Didactic use of virtual reality in Colombian universities: Professors' perspective. *Multimodal Technol. Interact.* **2022**, *6*, 38. [CrossRef]

20. Alnagrat, A.J.; Ismail, R.C.; Idrus, S.Z. The opportunities and challenges in virtual reality for virtual laboratories. *Innov. Teach. Learn. J.* **2023**, *6*, 73–89. [CrossRef]

21. Ebinger, F.; Buttke, L.; Kreimeier, J. Augmented and virtual reality technologies in education for sustainable development: An expert-based technology assessment. *TATuP-Z. Für Tech. Theor. Und Prax./J. Technol. Assess. Theory Pract.* **2022**, *31*, 28–34.

22. Liu, D.; Bhagat, K.K.; Yuan, G.; Chang, T.W.; Huang, R. The potentials and trends of Virtual Reality in education. In *Virtual, Augmented and Mixed Realities in Education*; Springer: Berlin/Heidelberg, Germany, 2017.

23. More than 107,000 Guatemalan Students Have Quality Educational Infrastructure with the Support of CABEI. 2023. Available online: https://www.CABEI.org/en/news-and-media/news/article/more-than-107000-guatemalan-students-have-quality-educational-infrastructure-with-the-support-of-cabei (accessed on 7 April 2024).

24. Programa de Mejoramiento Integral de la Infraestructura y Formación Educativa en Honduras (MIFE). Available online: https://adquisiciones.CABEI.org/planes-de-adquisiciones/plan/5886 (accessed on 13 April 2024).

25. CABEI Approves Donation of US$130 Thousand to Provide the National Museum of Art of Guatemala with an Immersive Virtual Room. 2023. Available online: https://www.CABEI.org/novedades/noticias/articulo/CABEI-aprueba-donacion-por-us130-mil-para-dotar-al-museo-nacional-de-arte-de-guatemala-de-una-sala-virtual-inmersiva (accessed on 7 April 2024).

26. Agtec—Innovación e Investigación. 2022. Available online: https://agtec.zamorano.edu/ (accessed on 9 April 2024).

27. Foro Organizado Por el CABEI Destaca Fortalecimiento de la Integración Regional a Partir de Sistemas de Ciencia y Tecnología, 2020. Forum: Science, Technology and Innovation for Development: The Necessary Normality. Available online: https://www.CABEI.org/novedades/noticias/articulo/foro-organizado-por-el-CABEI-destaca-fortalecimiento-de-la-integracion-regional-a-partir-de-sistemas-de-ciencia-y-tecnologia (accessed on 9 April 2024).

28. CABEI Apoya a República Dominicana en la Elaboración de Estrategia Nacional de Inteligencia Artificial. 2023. Available online: https://www.CABEI.org/novedades/noticias/articulo/CABEI-apoya-a-republica-dominicana-en-la-elaboracion-de-estrategia-nacional-de-inteligencia-artificial (accessed on 9 April 2024).

29. Cabero-Almenara, J.; Guillén-Gámez, F.D.; Ruiz-Palmero, J.; Palacios-Rodríguez, A. Digital competence of higher education professor according to DigCompEdu. Statistical research methods with ANOVA between fields of knowledge in different age ranges. *Educ. Inf. Technol.* **2021**, *26*, 4691–4708. [CrossRef]

30. Blayone, T.J.B.; Mykhailenko, O.; vanOostveen, R.; Grebeshkov, O.; Hrebeshkova, O.; Vostryakov, O. Surveying digital competencies of university students and professors in Ukraine for fully online collaborative learning. *Technol. Pedagog. Educ.* **2018**, *27*, 279–296. [CrossRef]

31. Cabero-Almenara, J.; Barroso-Osuna, J.; Gutiérrez-Castillo, J.-J.; Palacios-Rodríguez, A. The Teaching Digital Competence of Health Sciences Teachers. A Study at Andalusian Universities (Spain). *Int. J. Environ. Res. Public Health* **2021**, *18*, 2552. [CrossRef] [PubMed]

32. Vergara, D.; Antón-Sancho, Á.; Dávila, L.P.; Fernández-Arias, P. Virtual reality as a didactic resource from the perspective of engineering teachers. *Comput. Appl. Eng. Educ.* **2022**, *30*, 1086–1101. [CrossRef]

33. Saltos-Rivas, R.; Novoa-Hernández, P.; Rodríguez, R.S. Understanding university teachers' digital competencies: A systematic mapping study. *Educ. Inf. Technol.* **2023**, *28*, 16771–16822. [CrossRef] [PubMed]

34. Antón-Sancho, Á.; Fernández-Arias, P.; Vergara, D. Perception of the use of virtual reality didactic tools among faculty in Mexico. *Future Internet* **2023**, *15*, 72. [CrossRef]

35. Guillén-Gámez, F.D.; Cabero-Almenara, J.; Llorente-Cejudo, C.; Palacios-Rodríguez, A. Differential analysis of the years of experience of higher education teachers, their digital competence and use of digital resources: Comparative research methods. *Technol. Knowl. Learn.* **2022**, *27*, 1193–1213. [CrossRef]

36. Wells, T.; Miller, G. Teachers' opinions about virtual reality technology in school-based agricultural education. *J. Agric. Educ.* **2020**, *61*, 92–109. [CrossRef]

37. Rocha-Estrada, F.J.; Ruiz-Ramírez, J.A.; George-Reyes, C.E.; Glasserman-Morales, L.D. Evaluation of a virtual campus adapted to web-based virtual reality spaces: Assessments of teachers and students. *Front. Educ.* **2022**, *7*, 918125. [CrossRef]

38. Hamilton, D.; McKechnie, J.; Edgerton, E.; Wilson, C. Implementing immersive virtual reality in higher education: A qualitative study of instructor attitudes and perspectives. *Innov. Pract. High. Educ.* **2021**, *4*, 206–238. Available online: http://journals.staffs.ac.uk/index.php/ipihe/article/view/210 (accessed on 18 January 2024).

39. Alqahtani, E.S.; AlNajdi, S.M. Potential obstacles to adopting augmented reality (AR) technologies as pedagogical tools to support students learning in higher education. *Interact. Learn. Environ.* **2024**. *In press*. [CrossRef]

40. Krumsvik, R.J.; Jones, L.Ø.; Øfstegaard, M.; Eikeland, O.J. Upper secondary school teachers' digital competence: Analysed by demographic, personal and professional characteristics. *Nord. J. Digit. Lit.* **2016**, *11*, 143–164. [CrossRef]

41. Kuleto, V.; P., M.I.; Stanescu, M.; Ranković, M.; Šević, N.P.; Păun, D.; Teodorescu, S. Extended reality in higher education, a responsible innovation approach for generation Y and generation Z. *Sustainability* **2021**, *13*, 11814. [CrossRef]
42. Breiki, M.A.; Abri, A.A.; Moosawi, A.M.; Alburaiki, A. Investigating science teachers' intention to adopt virtual reality through the integration of diffusion of innovation theory and theory of planned behaviour: The moderating role of perceived skills readiness. *Educ. Inf. Technol.* **2023**, *28*, 6165–6187. [CrossRef] [PubMed]