Virtual reality as a didactic resource from the perspective of engineering teachers

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Abstract
This paper analyzes the assessment of engineering professors of different nationalities and universities regarding the use of virtual reality (VR) technologies in the classroom. In particular, the existence of gaps in these evaluations by ownership (private or public) of the university where each professor teaches is analyzed, both within the complete sample of participants and within the subsets formed when they are differentiated by gender, age, and time of teaching experience. For this purpose, a questionnaire has been designed and validated with 22 inquiries that have been dispersed in six scales, corresponding to six different dimensions that affect the didactic use of VR. The questionnaire has been distributed to a set of 279 university professors from different Engineering schools and countries. The results, which have been analyzed quantitatively, both descriptive and inferential, indicate that engineering teachers give high evaluations to VR as a didactic tool, but show a certain lack of knowledge and specific training regarding its use. Furthermore, there is a gap between private and public universities, where private university professors express overall higher evaluations of VR than public university professors.

KEYWORDS
higher education, quantitative analysis, questionnaire, university ownership, virtual reality

1 INTRODUCTION
The term virtual reality (VR) is the current name for a certain collection of technological resources [74] whose origin dates to the 1960s and which has previously been known as synthetic environments, cyberspace, or artificial reality [42]. This technology can be described as a set of multimedia computerized environments, which combines hardware and software, aimed at generating in the user the sensory perception of being in a certain world that, in reality, it does not exist in a real way [33], but with which it is possible to interact [41]. VR allows, therefore, to create simulated environments in which the user can visualize, listen, and interact in the three spatial dimensions, the experience of that environment in real-time, and interact with it [67]. In this way, VR creates the three-dimensional (3D), interactive, and multisensory sensation of being in the real world [26].

Depending on the level of feeling of immersion in the virtual environment, one can distinguish immersive VR (IVR) and nonimmersive VR (NIVR). On one hand, NIVR provides a VR experience in which the user does not evade their real environment but remains sensory connected to it while developing the experience in a simulated...
environment through a screen, audio, and output devices, such as keyboard, mouse, or command, or through specific devices [65]. On the other hand, IVR involves the introduction of additional elements, such as VR glasses or head mount display or virtual caves [67], for the user to fully immerse himself in the virtual environment and to interact with it, completely disconnecting from his/her real environment [23,45]. Although immersivity is a continuum that varies widely from less immersive experiences to those that are more immersive, depending on the continuity of sensory stimuli increases, freedom of movement, and the user’s capacity for interaction [38], these two are usually distinguished VR classes according to the degree of immersion.

VR has been used in multiple areas of knowledge. However, its employability in certain areas stands out mainly, such as in medicine [34,47,57], engineering [16,17,75], and architecture [16,73]. These three fields have in common that many of their objects of study are linked to complex geometric models, or experimentation with them requires laboratories or certain specific environments of construction, manufacturing, electricity, and so forth. VR has proven to be an effective tool for generating environments that efficiently simulate the above concepts.

The specialized literature collects abundant experiences of applying VR as a learning resource in different areas and educational levels, particularly in higher education [4,5,22,43,71]. It is surprising that, even though VR is a technology widely used in research and development in engineering, its use as a didactic resource in this field is scarce [30]. VR technologies have proven to be an efficient didactic resource for the teaching of engineering [7,35,43,44,48,64]. Numerous works support the efficacy and effectiveness of VR as a didactic resource in very different fields of engineering: mechanical engineering [28,31], chemistry [24], electricity and electronics [6,31,52,76], civil engineering [49], biomedical engineering [51], materials engineering [66,68,69], or manufacturing [28].

Previous work recognizes that using VR as a didactic resource in engineering is more effective than traditional methodologies in different aspects. Specifically, it facilitates the establishment of relationships between theoretical and practical knowledge [8,19,55], it enables the concepts under study to be illustrated from a unitary and integrative vision [8,19,51], it provides a multidisciplinary and interdisciplinary perspective to teaching [51], and contextualizes the learning process in an immersive and tangible environment [6,24,31]. All these traits indicate that VR can make learning more meaningful [13], an aspect that has been intensively sought and in which the design of VR apps is particularly important [61]. Likewise, VR has proven to be useful for working on specific technical competencies of engineering education, such as understanding certain complex concepts [6,19,31,76], problem-solving [27,51], acquisition of the geometric models underlying the different technical developments [39,49], developing 3D spatial vision [6,10,11,21,27,39,49,66] or in 4D (with the temporal dimension) [8] or the skills inherent to the design of projects of different types [27]. The most recent works on the didactic use of VR explore this technology as a learning tool by carrying out concrete experiences of application in combination with different learning methodologies [59,70] or analyzing the impact they have on students’ learning anxiety [58].

In addition to those benefits to learning, the application of VR results in the strengthening of numerous transversal competencies in engineering teaching. Among them, it allows increasing communication skills [27,51] because it is possible to design cooperative didactic actions [51], it increases the motivation of students [6,20,27,30,76], their creativity [21,27] and independence that students demonstrate in terms of learning [6]. Experts perceive that the use of VR would allow engineering students to achieve more lasting learning than the traditional methodology, but this point has yet to be confirmed [14]. Aside from this, the recreation of learning environments through VR supposes reducing the costs in the training of engineers [1,27,29,53] and facilitates the learning process for students who present some difficulty in accessing physical structures or laboratories (e.g., the distance from their respective homes) [53].

Similarly, the digitization of practical classes through virtual laboratories is a current and growing trend in Engineering education and has been the object of study in various conferences and publications [64]. The health crisis caused by COVID-19 has favored the incorporation of this type of technology in university classrooms as a way of adapting to the confinements they have suffered in the last 2 years. Engineering degrees are especially sensitive to this phenomenon because practical classes take on special importance. In this sense, it is of interest to know the training that university engineering professors have received on the didactic uses of VR, their assessment, and their degree of satisfaction in this regard, to help engineering schools to face the situation of digital transformation that is currently being experienced in higher education.

The studies that deal with analyzing the satisfaction of the affected individuals on the didactic use of VR in engineering teachings are notably scarce and focus, for the most part, on the assessment of students, for which instruments have been designed specifically [25,54]. Thus, VR is perceived by engineering students as an intuitive and easy-to-use resource [18,55] that helps them...
acquire a more realistic knowledge of objects [18], increases motivation [37], and facilitates transmission knowledge, active participation, and independence in its acquisition [55]. Some studies show that students specifically value the significance of the mathematical models that can be made through VR [32]. In short, students see VR as an effective learning instrument with an important future projection [36]. Engineering students also point out the existence of limitations for the didactic use of VR, such as the need to have the background that VR by itself does not provide [12] or the need that students perceive for the presence of a teacher to accompany them in their learning process [64]. Furthermore, according to recent investigations [63], technological obsolescence affects these types of applications in such a way that they must be updated every 6–7 years. Some studies identify gender gaps in certain aspects of the evaluation of VR as a didactic resource [15,54]. The most notable refers to the user experience, which is significantly higher among women than men [15].

There are much fewer studies that deal with describing the assessment that university professors of engineering teachings make of VR and none of them identify gaps between them for sociodemographic or academic reasons. In general terms, the evaluation that engineering professors make of VR is very positive and they recommend its use [72]. They especially appreciate the interest that VR provokes in students and the increase it generates in their knowledge and motivation towards learning [77]. In some studies, the opinion of engineering professors from private universities [9] or public universities [46] has been analyzed. All these previous studies coincide in pointing out the benefits of VR as a didactic resource in engineering, but none of them compares the opinion of professors from private and public universities. However, it is reasonable to think that the ownership of the university could influence the degree of incorporation of digital teaching materials, such as VR, and the design of teacher training plans in this regard. Faced with this scenario, the present study focuses on analyzing the assessment of university engineering professors on VR to try to answer this question.

Specifically, this study analyzes the assessment of VR as a didactic resource by a group of 279 university engineering professors from universities in 15 South American countries, to identify the existence of a gap in the character, private or public, from the university where these professors carry out their teaching activities. For this purpose, a robust questionnaire has been designed and distributed to those professors, classifying the questions into different groups which, hereafter, will be referred to as subscales of the survey. The responses have been analyzed, differentiating by university ownership. Such a variable has been studied in relation to other variables such as professors’ gender, age, and teaching experience.

## Methodology

### Participants

The sample of participants is 279 professors of higher education in engineering who teach at universities in 15 different South American countries (Figure 1). The participants were chosen by a nonprobabilistic convenience sampling procedure so that all the contacted teachers responded to the questionnaire and did so voluntarily and anonymously. The gender breakdown of these participants is 61.29% men and 38.71% women. By age, most of the participants are intermediate (26.88% are between 34 and 44 years old and 34.41% are between 45 and 54 years old), while the extreme ages are a minority (12.90% are between 25 and 34 years old, 17.20% are between 55 and 64 years old and 8.60% are 65 or over). However, if the sample of participants is distributed by teaching experience in ranges of 5 years (from 0 to 25 years and more than 25 years), the professors are distributed approximately homogeneously ($\chi^2 = 1.3871, p = .9257$). Regarding the ownership of the university where the teaching activity takes place, 34.41% work in private universities, and the rest do so in public universities. The participants attended a training lesson on VR and its didactic use in higher education classrooms that took place during several sessions held throughout the months of May, June, and July 2021. Therefore, it can be assumed that all of them had a homogeneous conceptual background on VR, so it can be also assumed that geographic location does not interfere with the analysis.

### Variables and objectives

This study considers four independent variables (Figure 2), two of which are sociological (gender and age range) and the other two are academic (years of teaching and university tenure). The main independent variable is university tenure, so the rest of the independent variables considered (gender, age, and teaching experience) will be studied in a subordinate manner to the main one. The variables gender and university degree are dichotomous. The age is polytomous and will take five possible values, which correspond to ranges of 10 years of age from 25 to 65 years, with the last value that includes participants aged 65 years or more. Teaching experience is also polytomous, but, in this case, it reaches six values, corresponding to the
five ranges of 5 years from 0 to 25 years and a final value for those with more than 25 years of experience. Likewise, Table 1 shows the different dependent variables of the study, which have been initially classified according to the families of variables indicated.

The general objective of this study is to analyze the assessment that engineering teachers have about the use of VR as a teaching resource in the classroom and to compare the responses of teachers from private and public universities (Figure 2). Therefore, the main research question to be addressed in this paper is whether the university tenure of Latin American engineering professors significantly influences their perception of VR technologies as a teaching resource. As specific objectives, the following are pursued: (i) analyze the mean evaluations of engineering professors about the didactic use of VR and the corresponding dispersions; (ii) identify gaps in the evaluations expressed because of ownership, private or public, of the university; and (iii) study whether there are significant differences by gender, age or teaching experience in VR assessments between engineering professors from private and public universities.

2.3 | Instrument

A robust questionnaire has been used that consists of 22 inquiries (Appendix A), each of which corresponds to each of the dependent variables described in Table 1. In the survey, participants are asked to assess their self-concept in terms of digital skills, knowledge about VR, the training received about VR, and the possibility that their university implants VR technologies for teaching purposes (Inquiries 1–4). They are then asked to assess the

![Figure 1](South American countries participating in this study)
importance of certain experiential, technical, or didactic aspects of VR, such as interaction, user experience, ease of use, 3D design, degree of immersion, realism, and usefulness for didactic purposes (Inquiries 5–11). They are also asked about the level of the inconvenience of certain factors such as costs, scarcity of spaces, technical and human resources, lack of teacher training, and technological obsolescence (Inquiries 12–16). They are subsequently asked to assess the level of acceptance that VR could have among students, to give their opinion about the increase that its use could cause in academic performance, in motivation, and in the development of the classes they teach (Inquiries 17–20). Finally, they are asked to assess the future projection of the didactic use of IVR and NIVR (Inquiries 21 and 22). All inquiries are Likert-type with values from 1 to 5, where 1 means totally disagree and 5 means totally agree.

### 2.4 | Procedure

After collecting the responses to the questionnaires, an exploratory factor analysis (EFA) has been applied to identify the explanatory subscales of the survey, which have been established from the main indices of the confirmatory factor analysis. The validation of the instrument has been completed with the Cronbach’s \( \alpha \) parameter and composite reliability (CR) of each of the defined subscales, which has served to measure the internal consistency of the survey, the study of the convergent validity through the average variance extracted (AVE), and with an analysis of the Pearson correlations of the different subscales with each other and concerning to the global questionnaire.

The responses have been analyzed from their global descriptive statistics (means and standard deviations). Likewise, the identification of gaps by university ownership has been carried out through students’ \( t \)-tests for comparison of means and Levene’s tests for comparison of deviations, whose statistics have been computed for each of the subscales. Finally, after crossing the answers differentiating by a university degree and for each of the other independent variables (gender, age, and experience), the parametric multifactor analysis of variance (MANOVA) tests for comparison of means and the Bartlett test of comparison of deviations to compare the responses. All the tests have been carried out with a significance level of 0.05.

### 3 | RESULTS

The EFA identifies a minimum number of six latent variables of the variables measured by the survey (Table 2). Only the highest EFA parameters are indicated for each inquiry. Indeed, the \( \chi^2 \) statistic reaches
a value of 170.42 with 165 degrees of freedom, which allows us to conclude that the six identified factors are sufficient \( (p = .37) \), and with them, a total of 54.10% of the variance is explained (Table 3). The latent variables corresponding to these factors determine the following subscales: (i) competence over the use of VR (Inquiries 1–3); (ii) use by the user (Inquiries 5–7); (iii) technical aspects of VR (Inquiries 8–10); (iv) drawbacks (Inquiries 12–16); (v) future projection of IVR and NIVR (Inquiries 21 and 22); (vi) didactic employability (Inquiries 4, 11, and 17–20). The confirmatory factor Analysis indices support the theoretical model that emerged from the EFA \( (\chi^2 = 867.4915 \text{ with a } p = .0000) \). The incremental fit indices are adequate (adjusted goodness-of-fit index = 0.8158; normed fit index = 0.7861; Tucker–Lewis index = 0.9576; comparative fit index = 0.8766; incremental fit index = 0.8820) and the absolute fit indices also indicate that the model is acceptable (goodness-of-fit index = 0.8726; root mean square error of approximation = 0.0370; Akaike information criterion = 897.4915; \( \chi^2/df = 3.3365 \)).

Cronbach’s \( \alpha \) parameters and CR (Table 4) allow us to conclude that the instrument used has high levels of internal consistency, as all values are greater than 0.70. Also, all the factors presented adequate values of convergent validity, since the AVE is greater than 0.50 for every factor except for the disadvantage factor, which has an AVE slightly below 0.50. Likewise, Pearson’s correlation coefficients (Table 5) indicate that there are moderate or slight correlations between the different subscales but, the correlations between the subscales and the global survey are moderate or high.

The overall descriptive statistics collected in Table 6 indicate that the aspects of VR most valued by the participants are its usability, its technical characteristics, and its didactic employability. In these subscales, the deviations are the smallest of the entire survey, which indicates that the participants are more confident and
unanimous when answering than in the rest of the subscales. The worst value is the subscale on competence in the use of VR, which implies that teachers show little knowledge and training in this regard.

When differentiated by university ownership (Table 7), the t-test finds significant gaps in the subscales of usability, drawbacks, and didactic employability. Professors from public universities are more skeptical than those from private universities regarding the characteristics of VR use and its didactic benefits, although they also perceive its drawbacks to a lesser extent (with a very small difference). Regarding the use and didactic employability, private university professors claim to have

<table>
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Table 2: Results of the exploratory factor analysis

Table 3: Percentages of the variance explained by the identified factors

Table 4: Composite reliability (CR), average variance extracted (AVE), and Cronbach’s \( \alpha \) parameters of the different subscales of the survey

<table>
<thead>
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<th>Subscale</th>
<th>Cronbach’s ( \alpha )</th>
<th>CR</th>
<th>AVE</th>
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<td>.51</td>
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<td>.50</td>
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<td>.53</td>
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<td>.70</td>
<td>.48</td>
</tr>
<tr>
<td>Future</td>
<td>.8386</td>
<td>.81</td>
<td>.63</td>
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<tr>
<td>Didactic use</td>
<td>.7905</td>
<td>.79</td>
<td>.54</td>
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</table>

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more solidly formed concepts, because they present significantly lower deviations than public university professors.

When differentiating by gender, the MANOVA test (Table 8) identifies gaps in the mean assessments of the competency, usability, and technical aspects subscales. Among men, it is private university professors who express the highest ratings on these subscales, but within women, public university professors are the ones that offer the highest scores. Regarding the formation of the concepts, the Bartlett test (Table 9) shows that, of the aforementioned subscales, only in the usability one do the deviations differ significantly. Both within men and women, it is private university professors who have a more solid concept in this subscale.

When differentiated by age, the subscales of competence in the use of VR and assessment of its future projection show gaps in their mean scores (Table 10). Professors from private universities between 45 and 64 years of age show a lower knowledge about VR than professors from public universities of the same age ranges. In the rest of the age ranges, it is private university professors who score higher on this subscale. This age gap occurs in a situation of homoscedasticity (Table 11). Regarding the subscale of future projection of VR, among the youngest teachers and those between 55 and 64 years old, the most pessimistic ones are the private university professors, but in the rest of the age groups, the professors at public universities are the ones that give the lowest scores. In this case, the statistics in Table 11 indicate that the deviations differ significantly. Specifically, professors from public universities between the ages of 25 and 34 or between 55 and 64 provide more homogeneous answers, while in the rest of the age ranges it is the professors from private universities who give the most homogeneous answers.

The variable that gives rise to the most pronounced gaps on average VR ratings is teaching experience. Specifically, there are significant gaps due to teaching experience in the subscales of competence, technical aspects, inconveniences, and future projection (Table 12). The greatest competence in the use of VR is presented by public university professors in all ranges of teaching experience, except among the least experienced and among those who have between 21 and 25 years of experience. In the subscale of evaluation of technical aspects, the opposite trend occurs: The highest evaluation is provided by private university professors, except in the ranges of less than 5 years and between 21 and 25 years of experience. It is also the professors at private universities who find more disadvantages in VR, except in the ranges of 11–15 years and 21–25 years of experience. The greatest future projection among professors with more than 20 years of experience and among those with less than 5 is expressed by professors from public universities; in the rest of the bands, the most optimistic ones are the professors at private universities. In all these subscales, except for the competence, there are significant differences between the dispersions (Table 13). The most remarkable result in this regard is that, within the participants with an experience of between 16 and 20 years, all the participants from private universities have given the same answers in the three subscales, with which the dispersion is 0 in these cases.

### Table 5

<table>
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<tr>
<th></th>
<th>Competence</th>
<th>Use</th>
<th>Technical</th>
<th>Disadv.</th>
<th>Future</th>
<th>Didactic</th>
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*p < .05.

### Table 6

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<td>Didactic use</td>
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Abbreviation: St.D., standard deviation.
TABLE 7  Statistics of the student’s and Levene’s t-tests when differentiated by university ownership

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Mean</th>
<th>Std.D.</th>
<th>Levene F</th>
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<td>−0.3602</td>
<td>.7191</td>
</tr>
<tr>
<td>Use</td>
<td>4.43</td>
<td>4.07</td>
<td>3.3657</td>
<td>.0009*</td>
</tr>
<tr>
<td>Technical</td>
<td>4.18</td>
<td>4.16</td>
<td>0.1674</td>
<td>.8673</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>3.71</td>
<td>3.49</td>
<td>2.8777</td>
<td>.0214*</td>
</tr>
<tr>
<td>Future</td>
<td>3.86</td>
<td>3.93</td>
<td>−0.7045</td>
<td>.4816</td>
</tr>
<tr>
<td>Didactic use</td>
<td>4.21</td>
<td>4.11</td>
<td>2.1604</td>
<td>.0465*</td>
</tr>
</tbody>
</table>

Abbreviation: St.D., standard deviation.
*p < .05.

TABLE 8  Statistics of the MANOVA test when differentiated by university ownership and gender

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Males</th>
<th>Females</th>
<th>MANOVA</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Private</td>
<td>Public</td>
<td>Private</td>
<td>Public</td>
</tr>
<tr>
<td>Competence</td>
<td>2.87</td>
<td>2.74</td>
<td>2.52</td>
<td>2.83</td>
</tr>
<tr>
<td>Use</td>
<td>4.59</td>
<td>3.91</td>
<td>4.21</td>
<td>4.36</td>
</tr>
<tr>
<td>Technical aspects</td>
<td>4.22</td>
<td>4.07</td>
<td>4.12</td>
<td>4.32</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>3.70</td>
<td>3.58</td>
<td>3.73</td>
<td>3.32</td>
</tr>
<tr>
<td>Future</td>
<td>3.98</td>
<td>4.04</td>
<td>3.71</td>
<td>3.75</td>
</tr>
<tr>
<td>Didactic</td>
<td>4.11</td>
<td>4.05</td>
<td>4.33</td>
<td>4.22</td>
</tr>
</tbody>
</table>

Abbreviation: MANOVA, multifactor analysis of variance.
*p < .05.

TABLE 9  Statistics of the Bartlett test when differentiated by university tenure and gender

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Males</th>
<th>Females</th>
<th>K²</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Private</td>
<td>Public</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competence</td>
<td>1.15</td>
<td>1.16</td>
<td>3.5412</td>
<td>.3155</td>
</tr>
<tr>
<td>Use</td>
<td>0.69</td>
<td>0.96</td>
<td>8.1572</td>
<td>.0429*</td>
</tr>
<tr>
<td>Technical aspects</td>
<td>0.96</td>
<td>0.88</td>
<td>2.4268</td>
<td>.4887</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>1.20</td>
<td>1.23</td>
<td>1.5502</td>
<td>.6707</td>
</tr>
<tr>
<td>Future</td>
<td>1.03</td>
<td>0.97</td>
<td>9.8325</td>
<td>.0280*</td>
</tr>
<tr>
<td>Didactic</td>
<td>0.98</td>
<td>1.00</td>
<td>9.5823</td>
<td>.0225*</td>
</tr>
</tbody>
</table>

*p < .05.

TABLE 10  Statistics from the MANOVA test when differentiated by university ownership and age

<table>
<thead>
<tr>
<th>Subscale</th>
<th>25–34 years old</th>
<th>35–44 years old</th>
<th>45–54 years old</th>
<th>55–64 years old</th>
<th>≥65 years old</th>
<th>MANOVA</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence</td>
<td>2.87</td>
<td>2.76</td>
<td>3.27</td>
<td>3.27</td>
<td>2.71</td>
<td>2.71</td>
<td>2.82</td>
</tr>
<tr>
<td>Use</td>
<td>4.53</td>
<td>4.48</td>
<td>4.37</td>
<td>4.32</td>
<td>4.44</td>
<td>4.44</td>
<td>4.46</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>3.48</td>
<td>3.54</td>
<td>3.70</td>
<td>3.60</td>
<td>3.74</td>
<td>3.44</td>
<td>4.00</td>
</tr>
<tr>
<td>Future</td>
<td>3.48</td>
<td>4.40</td>
<td>3.98</td>
<td>3.75</td>
<td>3.95</td>
<td>3.83</td>
<td>3.67</td>
</tr>
<tr>
<td>Didactic</td>
<td>4.30</td>
<td>4.31</td>
<td>4.10</td>
<td>3.92</td>
<td>4.35</td>
<td>4.22</td>
<td>4.06</td>
</tr>
</tbody>
</table>

Abbreviations: MANOVA, multifactor analysis of variance; Pr., private; Pub., public.
*p < .05.
In all the above subscales, except for the competence, there are significant differences between the dispersions (Table 13). The most remarkable result in this regard is that, within the participants with an experience between 16 and 20 years, all the participants from private universities have given the same answers in the three subscales, with which the dispersion is 0 in these cases.

There is an essential difference between the results that have just been presented and those corresponding to the age variable, because the dependency relationship between the distributions of the two variables, measured

### Table 11: Statistics of the Bartlett test when differentiated by university tenure and age

<table>
<thead>
<tr>
<th>Subscale</th>
<th>≤5 years of experience</th>
<th>6–10 years of experience</th>
<th>11–15 years of experience</th>
<th>16–20 years of experience</th>
<th>21–25 years of experience</th>
<th>&gt;25 years of experience</th>
<th>K²</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr.</td>
<td>1.19</td>
<td>1.24</td>
<td>1.16</td>
<td>1.13</td>
<td>1.17</td>
<td>1.11</td>
<td>0.58</td>
<td>1.15</td>
</tr>
<tr>
<td>Pub.</td>
<td>1.48</td>
<td>1.36</td>
<td>1.24</td>
<td>1.16</td>
<td>1.30</td>
<td>1.11</td>
<td>0.58</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Abbreviations: Pr., private; Pub., public.

### Table 12: Statistics of the MANOVA test when differentiated by university ownership and years of teaching experience

<table>
<thead>
<tr>
<th>Subscale</th>
<th>≤5 years of experience</th>
<th>6–10 years of experience</th>
<th>11–15 years of experience</th>
<th>16–20 years of experience</th>
<th>21–25 years of experience</th>
<th>&gt;25 years of experience</th>
<th>MANOVA</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr.</td>
<td>2.93</td>
<td>2.62</td>
<td>2.54</td>
<td>2.60</td>
<td>2.61</td>
<td>3.17</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Pub.</td>
<td>2.67</td>
<td>3.18</td>
<td>3.08</td>
<td>2.41</td>
<td>2.22</td>
<td>2.62</td>
<td>3.18</td>
<td>2.22</td>
</tr>
</tbody>
</table>

Abbreviations: MANOVA, multifactor analysis of variance; Pr., private; Pub., public.

### Table 13: Statistics from the Bartlett test when differentiated by university tenure and years of teaching experience

<table>
<thead>
<tr>
<th>Subscale</th>
<th>≤5 years of experience</th>
<th>6–10 years of experience</th>
<th>11–15 years of experience</th>
<th>16–20 years of experience</th>
<th>21–25 years of experience</th>
<th>&gt;25 years of experience</th>
<th>K²</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr.</td>
<td>1.31</td>
<td>1.50</td>
<td>1.25</td>
<td>1.16</td>
<td>1.50</td>
<td>1.31</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Pub.</td>
<td>0.76</td>
<td>0.93</td>
<td>0.64</td>
<td>0.80</td>
<td>0.97</td>
<td>1.20</td>
<td>0.00</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Abbreviations: Pr., private; Pub., public.

*p < .05.
with Cramer’s $V$ parameter, is moderate, although significant ($V = 0.6689$, $p = .0000$).

### 4 | DISCUSSION

The results obtained confirmed that Engineering professors have a high or very high concept of VR, in terms of both its technical aspects and its use, and its didactic utility. This fact is consistent with the results of previous investigations that were carried out on an analogous target population [9,46,62,72,77]. The results are also consistent with the conclusions of studies [56,61] on the benefits that VR brings to learning, self-confidence, and academic performance of Engineering students and with other studies, such as [36], which point to the future projection of VR as a didactic resource. Likewise, the studies that expose the opinion of Engineering students on the use of VR in the classroom indicate that there is also a consonance between the perception of the teaching staff and that of the students in this regard [65,66,69].

Considering the prior literature, it does not seem that an opinion as positive as the one obtained here is specific to engineering professors because the results are like those of other studies that do not specify an area of knowledge [40,50]. Furthermore, in a study [60] it is explained that there are no significant differences between the VR assessments made by Engineering teachers and Health Sciences teachers, except in the technical aspects of the subscales, which seems reasonable given the specific technical training of engineering professors.

On the other hand, the participating teachers have deficiencies in terms of their knowledge and skills in the use of VR. Again, this result is consistent with those of previous studies carried out on populations of professors of scientific-technical education or a broader spectrum of university professors [2,3,14]. This consistency in the results is surprising because it could be expected that teachers of higher technical education show a higher training on the use of VR, as it is a set of technological resources. However, the results suggest that engineering teachers need to receive specific training on VR that allows them to perform, in the long term, the future projection that they attribute to the use of this technology as a didactic resource.

Regarding the different discriminating variables of the responses, the specialized literature does not abundantly address the assessment of VR among university professors of technical teachings, differentiating by these variables. However, the most explored variable in this regard is gender. In an article focused on the opinion of students from a private university in Saudi Arabia [15], it is shown that female engineering students say they are more satisfied than men in terms of their knowledge and skills about VR. In this study, it has been verified that this trend is repeated among professors, but only in private universities. In the public ones, it is men who value their competence in the use of VR more positively. The results, therefore, suggest that the distinction between public and private universities regarding the assessment of VR might not depend on geographic location (although, to conclude this point, the opinions of Saudi professors would have to be studied on engineering of public universities and extend the analysis to other geographic areas).

The literature does not collect studies that analyze the assessment of engineering professors, specifically differentiating by ownership, public or private, of the university. Although the area of knowledge is expanded, the specialized literature does not collect studies in this regard, as far as it has been possible to verify. The most closely related studies contextualize their target population in students or professors from private universities (such as article [15]) or public universities (such as [46]), but they do not relate some universities to others. Specifically, in Rasimah et al. [46] the assessment of VR technologies in students from a public university in Malaysia is studied. The most outstanding result is the high valuation of the user experience of the VR. This fact agrees with the results obtained in this study (considering that here VR is valued and that the population is made of university professors), although the valuation is higher among professors from private universities than public universities for the experience of the user, in general. In addition, it is in women that the highest valuation is achieved in public universities. However, to better understand if there is a true convergence between the results of Rasimah et al. [46] and those presented here, the case of private university professors in the geographic context of Rasimah et al. [46] should be explored.

In summary, the approach to distinguish between private and public universities in this study is new in the literature and has provided interesting results. Specifically, significant gaps have been identified by university ownership within men and women, of different age ranges and experiences. In simple terms, it can be said that the highest evaluations are found among private university professors, except among women and those with 55–64 years of age or between 21 and 25 years of teaching experience. These facts reveal that, in general, professors from private universities in the field of engineering give better evaluations to VR as a technology for educational purposes. This may be because private universities are making a more determined bet to introduce digital means of teaching. The results also reveal
that there are real differences, regarding the valuation of VR, between genders and ages in Engineering teaching staff according to the type of university in which they teach. Consequently, there are real differences of a sociological nature, and not only academic, between the teaching staff of both types of universities. Identifying the reasons for these differences exceeds the objectives of this study and constitutes an interesting line of research.

5 | CONCLUSIONS

This study has evaluated the assessment made by engineering teachers regarding VR as a didactic resource through a designed questionnaire. Moreover, gaps in these opinions have been identified when differentiated by the nature (private or public) of the university, gender, age, and the teaching experience of the professors. Specifically, male private university professors make a better assessment of VR than those in public universities, while among women, public university professors make a higher assessment. In general, the best evaluations are given by private university professors, except in two cases: (i) professors between 55 and 64 years of age and (ii) professors with 21–25 years of experience.

The subscale that measures knowledge and skills in the use of VR is the least valued, regardless of university, ownership, gender, age, and experience. The technical training of the participants influences their assessment of the technical aspects of VR but does not imply that they feel trained in its use. This fact shows that it is necessary to introduce specific training plans on the didactic use of VR in higher technical education, both in private and public universities, especially aimed at those over 55 years of age and the youngest (because they are the ones who feel less skilled).

The fact that there are gaps between private and public universities by gender, age, and teaching experience means that there are latent variables that differentiate both types of universities, at least regarding the use of VR. To suggest additional measures to be taken by universities to correct such differences, it would be convenient to identify these latent variables, which exceeds the aims of the present work but constitutes an interesting line of future research.

REFERENCES


AUTHOR BIOGRAPHIES

Diego Vergara-Rodríguez is an Associate Professor in the Department of Mechanical Engineering at the Catholic University of Avila (Spain). He completed his Ph.D. studies at the University of Salamanca, where he also obtained degrees in both Civil Engineering and Materials Engineering. He has participated as coauthor in more than 200 papers published in recognized international conferences and journals, as well as in several research projects. It is worth mentioning his activity as a reviewer of prestigious journals.

Álvaro Antón-Sancho is a Researcher and Teacher at the Department of Mathematics of the School of Education Fray Luis de Leon and at the Catholic University of Avila (Spain). He completed his Ph.D. in Mathematics at the Spanish National Research Council and at the Complutense University of Madrid. He has published numerous research articles in recognized journals on algebraic geometry and didactics of mathematics. In addition, he has been a visitor in several foreign universities, participated in different research projects, and organized some events on geometry.

Lilian P. Davila is currently an Assistant Professional Researcher in the Department of Materials Science and Engineering at the University of California, Merced. Dr. Davila’s research interests include nanostructures, biomaterials, porous materials, and “materials by design” using experiments and simulations. Dr. Davila established major research areas that focus on the effects of structure and size of materials on properties at various scales via integrative approaches. Dr. Davila has a strong record of both research projects and publications, with 35 articles published in different engineering fields (materials science and engineering, drug delivery, sustainable materials), experience in teaching and academic service, and participated in various committees and as a speaker at national and international conferences.

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 Ph.D. degree from the University of Salamanca, in the Ph.D. 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).


APPENDIX A: QUESTIONS OF THE SURVEY

The questions of the survey were the following (all questions are Likert-type from 1 to 5 where 1 means the lowest valuation and 5 means the highest valuation):

1. Rate from 1 to 5 your self-perception of your digital skills to program or design new information and communication technologies-based educational tools.
2. Rate from 1 to 5 your level of knowledge about virtual reality (VR).
3. Do you feel that you have received sufficient training at your university on the possible applications of VR in education?
4. Rate from 1 to 5 the level of importance you give to the didactic usefulness of VR when designing an educational experience.

5. Value the importance of interaction when designing an educational experience with VR.

6. Assess the importance of user experience when designing an educational experience with VR.

7. Assess the importance of employability when designing a VR educational experience.

8. Please rate the level of importance of the following technical aspect of VR when designing a VR educational experience: Three-dimensional design.

9. Please rate the level of importance of the following technical aspect of VR when designing a VR educational experience: Immersiveness.

10. Please rate the level of importance of the following technical aspect of VR when designing a VR educational experience: Realism.

11. Rate from 1 to 5 your opinion about the possibility of your educational institution implementing virtual reality in its teaching activities.

12. Rate the level of inconvenience of the following aspects of RV: Costs.

13. Rate the level of inconvenience of the following aspects of RV: Spatial limitations.

14. Rate the level of inconvenience of the following aspects of RV: Demand for technical and human resources.

15. Rate the level of inconvenience of the following aspects of RV: Requirement of specific knowledge of the part of teachers and technicians.

16. Rate the level of inconvenience of the following aspects of RV: Technological obsolescence.

17. Rate from 1 to 5 the possible level of acceptance of VR as a teaching resource that you think your students have (or would have).

18. Do you believe that the use of VR in educational environments increases (or would increase) the academic performance of your students?

19. Do you believe that the use of VR in educational environments increases (or would increase) your students' motivation to learn?

20. Do you consider that the application of VR in educational environments helps (or would help) to improve the progress of your subject?

21. Rate from 1 to 5 the degree to which you think that the implementation of IVR will increase in the future at your university.

22. Rate from 1 to 5 the degree to which you think that the implementation of NIVR will increase in the future at your university.