Perceptions of secondary school students towards virtual reality in STEM subjects. Effect of the gender variable

El estudiantado de secundaria ante la RV en materias STEM. Efecto de la variable de género

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Abstract

This paper aims to examine the perceptions and attitudes of students in the secondary educational cycle towards the use of VR in scientific and technological subjects, as well as to analyze possible gender biases in the valuation of this technology. This second objective is justified by the scarcity of research that combines the use of VR for STEM education with the gender variable. A quasi-experimental study was carried out (n = 510) based on the application in the classroom and use by students of four VR STEM lessons developed *ad hoc* for this research in three Spanish secondary schools located in different population environments and with different levels of experience in the use of this technology. The Instructional Material Motivational Survey (IMMS) test –validated in previous studies– was used for this purpose. The resulting data were analyzed using descriptive and inferential statistics based on a predictive factor analysis using ordinal logistic regression. The results show that the most highly rated aspects of VR are those related to the structure and design of the lessons, as well as their potential to facilitate attention to the content. A notable effect of the gender variable is detected. Women significantly perceive greater difficulty in the usability of the lessons and report that the VR experience helps them less to maintain attention. They claim to have learned less than their male peers. They also feel less confident in their learning while using these immersive technologies.

Keywords: virtual reality, STEM, secondary school, gender bias, quasi-experimental study.

Resumen

El presente estudio pretende medir las percepciones y actitudes del estudiantado de Secundaria hacia el uso de la realidad virtual (RV) en materias científicas y tecnológicas, así como analizar los posibles sesgos de género en la valoración de este recurso. Este segundo objetivo se justifica en la escasez de trabajos que aúnan el uso de la RV para la formación STEM con la variable de género. Se llevó a cabo un estudio cuasi-experimental (n = 510) basado en la aplicación en el aula y utilización por parte del estudiantado de cuatro lecciones de asignaturas STEM en RV elaboradas *ad hoc* para esta investigación en tres centros de Secundaria españoles de diferentes entornos poblacionales y con distintos niveles de experiencia de uso de esta tecnología. Se utilizó para ello el test Instructional Material Motivational Survey (IMMS) validado en anteriores estudios. Los datos resultantes fueron analizados mediante estadística descriptiva e inferencial. Nuestros resultados evidencian que los aspectos mejor valorados de la RV son los relativos a la estructura y diseño de las lecciones, así como su capacidad para facilitar la atención en el contenido. Se observa un notable efecto de la variable de género. Las mujeres perciben de forma significativa una mayor dificultad en la usabilidad de las lecciones y afirman que la experiencia con RV les ayuda menos a mantener la atención. Manifiestan haber aprendido menos que sus compañeros varones y se sienten menos confiadas en su aprendizaje durante el uso de estas tecnologías inmersivas.

Palabras clave: realidad virtual, STEM, educación secundaria, sesgo de género, estudio cuasi-experimental.

INTRODUCTION

Teaching in the STEM subjects (Science, Technology, Engineering and Mathematics) has proven to be essential in meeting the increasing demand for skills in these areas in the workplace. During a pupil's entire school life but particularly in the latter stage, STEM education is fundamental and can be considered a strategic investment for their own personal development and, beyond that, for society as a whole since it is during that stage that the basis is laid for the development of critical skills such as, logical thinking, complex problem resolution and innovation.

Academic research into this field and the integral study of these subjects have focused on: training and enabling teachers (Boel et al., 2023), the methods for assessing performance and competence (Aguilera et al., 2022), the application of innovative teaching methods (Fuentes & González Martínez, 2017) or the use of technology in the classroom (Marrero Galván & Hernández Padrón, 2022) without ignoring the analysis of equality (Archer et al., 2020; Martín Carrasquilla et al., 2022).

As well as the obligation to educate the youngest generation of pupils in these subjects there is also a need to pay more attention to female pupils. Scientific literature has shown that there is a gender gap in STEM subjects at all levels of education and, consequently, in the labour market. This imbalance can be detected from a very young age. Martín Carrasquilla et al. (2022) show that from 10 to 14, male pupils are more keen on science. Rather than narrowing, the gap tends to widen during the latter stages of Secondary Education. The causes for this bias are of a psychological nature (personal beliefs about one's own ability and self-confidence), a sociocultural nature (parental influence and upbringing, discrimination, stereotypes and gender roles) and even a biological nature, according to Morales Inga and Morales Tristán (2020).

To reduce this gap, public administrations use different programs in an attempt to include women in the field of science and technology. In line with these initiatives, technology has been incorporated into the teaching system as a way to increase interest and motivation for STEM subjects among pupils. The implementation of technology has led to the use of virtual reality (VR), augmented reality (AR), robotics and artificial intelligence in the classroom. Of all these emerging technologies in education, VR would appear to be the most widely used, followed by robotics "with these being the longest running and most used in terms of classroom presence" (Palacios Ortega et al. 2022, p.14).

It is possibly for those reasons that, in recent years, scientific literature into VR and education has grown prolifically. The research, which analyses in-class experience indicates that VR, combined with learning based on problems or in-depth thinking is very useful for teaching in STEM subjects. (Marrero Galván & Hernández Padrón, 2022). The element of motivation stands out in all experiences, whether or not the activity is related to science subjects. Most of the conclusions from the papers are, in general, positive and indicate significantly greater learning and an improvement of the efficiency of the teaching-learning experience (Cabero-Almenara et al., 2023; Bermejo et al., 2023) as well as an increase in motivation (Marrero Galván & Hernández Padrón, 2022). Most authors highlight cognitive successes (knowledge acquisition) and affective ones (stimulation, cooperation, etc.) with these technologies, all of which justifies the use of VR to motivate students.

Similarly, other positive aspects of VR are mentioned, such as, a greater commitment, access to new environments, an improvement in the understanding of complex concepts (Spiriev et al., 2022), the perfecting of distance learning or even the creation of empathy (Marrero Galván & Hernández Padrón, 2022). Along those lines, work, such as that of Giakoni-Ramírez et al. (2023) reveals that both VR and AR have promising benefits for supporting teaching. The works of Marín-Díaz and Sampedro-Requena (2023) reveal that, as far as teaching methods are concerned, VR promotes autonomy and student initiative in Secondary Education.

From the point of view of strategies for producing VR material for the classroom, research in different countries concludes that gamification in this technology helps students in their learning (Lucena-Antón et al., 2022; Castellano et al., 2023). Numerous studies show that groups which work with virtual laboratories and VR simulation programs obtained significantly better results than those which followed the traditional methods (Arce et al., 2022; Tatiana Cox et al., 2022; Pontes Pedrajas, 2022). These studies also highlight the fact that the use of these immersive virtual spaces boost student motivation and they are a tool which should be considered for in-class activity, thus confirming previous studies, such as that of Mercado et al. (2019).

Regarding the assessment of teachers, studies, such as that of Castaño-Calle et al. (2022) reveal a favorable attitude towards these technologies, although they also show the scarce knowledge which teachers have. Results confirm the relevance of training teachers and improving their skills, thus developing positive attitudes towards these instruments. Without the necessary training, many teachers may feel intimidated or unable to use the new technologies in their classrooms (De Moraes Rossetto et al., 2023).

In the Spanish context, few studies include both the use of VR for teaching STEM subjects and the variable of gender. In order to cover this deficit, this research seeks not only to measure Secondary School students' perception of the use of VR in science and technology subjects, but also to study in depth the possible gender bias in the assessment of this education resource. Specifically, our study focuses on four essential dimensions for the teaching-learning process: (1) attention, (2) relevance, (3) confidence (4) satisfaction of pupils who used the technology or methodology. The choice of these dimensions is based on the ARCS model (Attention, Relevance, Confidence, Satisfaction) as defined by Keller (1987, 2010), which bases the activation of motivation in the teaching process on a construct made up of these four elements. As regards attention, our team seeks to measure the tool's capacity to get students to focus exclusively on the tasks to be carried out in the environment of VR. Relevance is defined as the usefulness perceived in the learning process. Confidence is related to how sure the pupil feels about learning from their interaction with the material and it is closely related to past experience (Cózar Gutiérrez et al., 2019) and it is the most difficult dimension to improve because it requires more time and dedication (Huett et al., 2008). These three dimensions converge in the fourth - satisfaction, "resulting in the prediction of good results during the realization of the task" (Cózar Gutiérrez et al., 2019, p. 2005). According to Cabero et al. (2017), these four dimensions form a chain reaction such that attention is essential for relevance which, in turn, leads to confidence in learning and, as we said before, the three dimensions together determine satisfaction.

Two specific dimensions from VR technology must be added to the four defined above: (1) the design, gamification and interactive nature of the tool and (2) its ease of use.

Objectives and hypothesis

Bearing in mind the above, the aims of our research were the following:

O1. To measure the perception and attitude of Secondary School pupils towards the application of VR in STEM subjects, with the following dimensions being used as a reference: (1) design and interactive nature, (2) ease of use, (3) attention, (4) relevance, (5) confidence and (6) student satisfaction with this technology.

O2. To examine the possible gender differences in terms of perception and attitude towards this technology and its application in the teaching of STEM subjects. This objective is subdivided into a sub-objective (O2a) which is conditioned by the existence of statistically significant gender differences in terms of perception and attitudes. Here, the gender variable is measured as a factor which influences the dimensions set out in O1.

The opening hypothesis states that there should not be statistically significant gender biases in any of the six dimensions of the study. Although many existing studies do show that female teaching staff have a more positive attitude and greater tendency towards the use of VR and other advanced technologies for education than their male counterparts, (Ateş & Kölemen, 2024), the studies carried out specifically with students do not reveal any gender differences in terms of the perception of VR in education, either at a Secondary (Cózar Gutiérrez et al., 2019) or University (Alsalleeh et al., 2024) level. Along this line, recent studies carried out with Secondary School pupils rule out the influence of gender when it comes to the acceptance of state-of-the-art technologies for teaching (An et al., 2024).

METHODOLOGY

Research design

A quasi-experimental study was carried out based on the application in the classroom and use by pupils of four VR lessons or learning pills for STEM subjects with curricular Secondary School content for the subjects of Physics, Chemistry, Mathematics and Biology. The fieldwork took place at three centres with different profiles in the province of Toledo and two cities in the Madrid region. The centre in Toledo is a rural environment (Centro Rural, CR) with a small population (10,000 inhabitants) and low average income. One of the centres in Madrid is in an urban municipality (72,500 high per capita income) and does not specialise in VR (Centro Urbano No Especializado, CUNE) and the rest are located in an urban environment (171,700 medium per capita income inhabitants and they do specialise in this technology (Centro Urbano Especializado).

One of the main strengths of the fieldwork lies in the fact that the four learning pills were created *ad hoc* and specifically for this study (no existing VR educational material was used). The information about these lessons can be accessed at: https://bit.ly/3Ye9AUg.

The four stages of the study were as follows:

- Phase 1: Choice of content of the learning pills. The research team and the company specializing in VR were advised by STEM teachers from the three participating centres. They were the ones who chose the specific content for each of the four learning pills. The content chosen was: (1) geometry and the visualization of space (Mathematics), (2) the structure and function of cells (Biology), (3) the Periodic Table and its elements (Chemistry) and (4) concepts of electricity and magnetism (Physics).
- Phase 2: Design and development of learning pills by the company in charge of VR educational software design together with the research team (Figure 1).

Figure 1
VR lesson in Mathematics class

- Phase 3: Teacher training in the three centres participating in the use of VR. Once the four VR lessons had been developed, several teachers from the three participating Secondary Education centres attended a week-long training workshop (Figure 2) organized by the university of the research team. The purpose was to familiarize themselves with the equipment and learn how to use it in experiments with pupils (safe distance between students, IT requirements in the classroom, incompatibility of the technology with certain health issues, etc.).

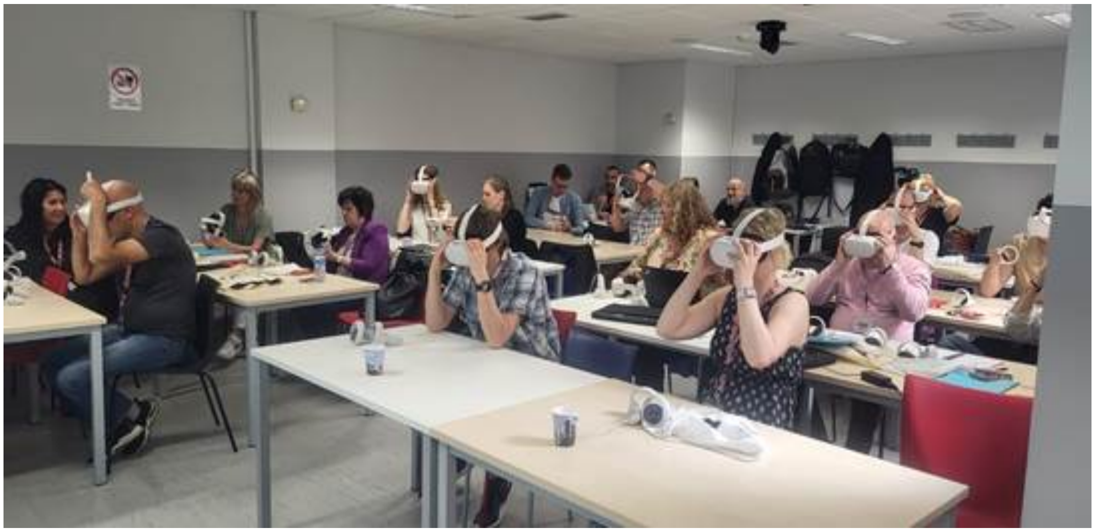

Figure 2
VR workshop for participating teachers

- Phase 4. Application of VR teaching software. Each centre had equipment for carrying out the tests over a 2-week period (Figure 3). Before pupils used the equipment, the research team - with the help of the teachers - explained the activities for each lesson, as well as how the equipment worked to eliminate the gap between those pupils who had prior experience of using the devices and those who had none. The equipment used was Meta Quest 2 goggles - one of the best selling VR devices on the market. The choice of this device was based on how safe it is for use by teenagers. It is adjustable and, therefore, does not squeeze the head or face. It can be adapted to accommodate people who wear glasses. It is harmless to the user's eyesight, runs on a rechargeable battery (like a smartphone) and is not connected to an electrical source - thus making it classroom-friendly.

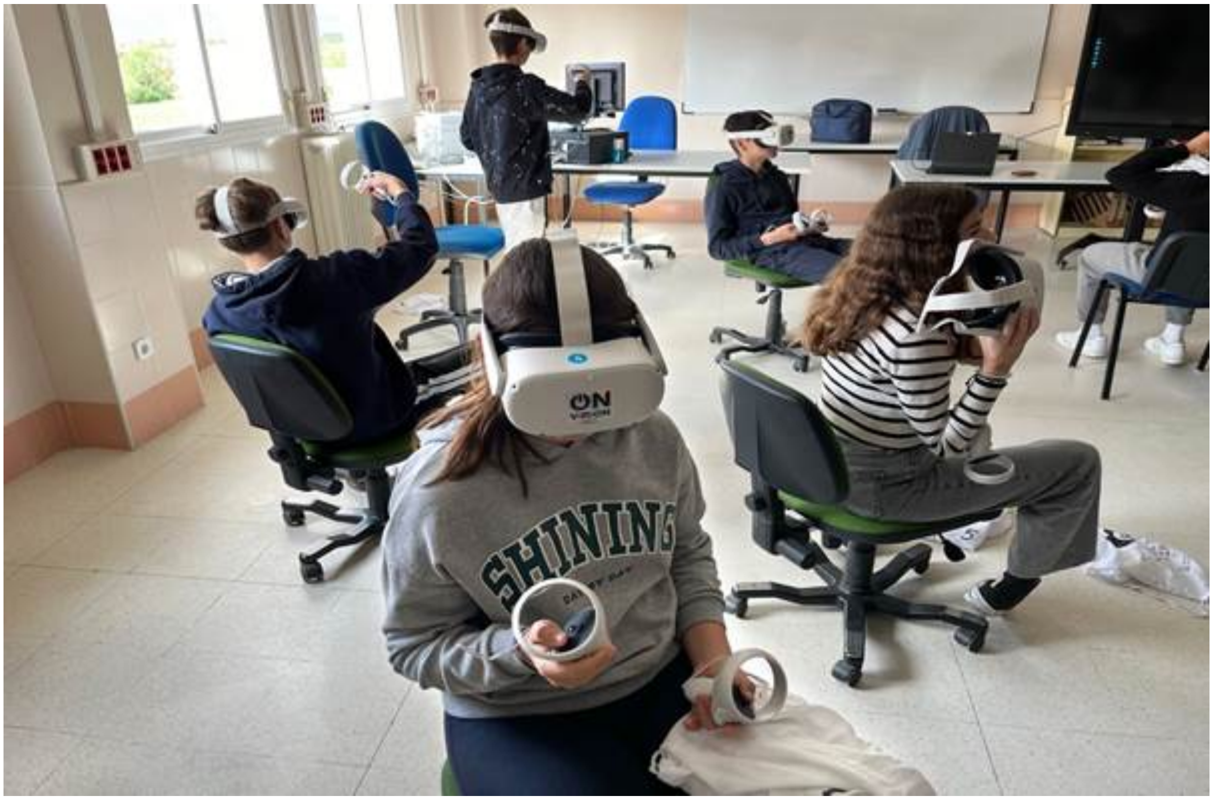

Figure 3
Working with VR material in one of the teaching centres

Sample and instruments

A sample was used for the sake of convenience and all efforts were made to find state centres, from populations of different sizes and socioeconomic profiles and where there were differing levels of technological expertise, as was explained above. Since the same VR equipment was used in the three centres, the centres had to be located relatively near each other and, in addition, near the university of the research team in order to transport the material used in the fieldwork. It was decided that a total of three centres should participate in order to gather a sufficient volume of answers without requiring too much time to carry out the experiment - if more centres had been used, the time needed would have been excessive.

The sample was made up of Secondary School pupils (from science subjects) of between 14 and 16 years of age. A total of 510 results were obtained from the three centres. The average age of participants was 15.10 years (DT = .822). The distribution by gender was as follows: females (n = 188; 36.9%), males (n = 296; 58%), prefer not so say (n = 26; 5.1%). By centres, the origin of the sample participants was: CR (n = 106; 20.8%), CUNE (n = 171; 33.5%), CUE (n = 233; 45.7%). 52,7% of participants had no prior experience in the use of VR. Almost 6 out of 10 participants (56%) were regular users of video games.

As mentioned above, the tool used was a questionnaire based on the IMMS (Instructional Material Motivational Survey) test, set out by Keller (2010) and confirmed by Loorbach et al. (2015). In its original version, the tool establishes 12 items on the Likert scale with 7 possible answers. For our study, the tool underwent the following adjustments: (1) new items were included to include the dimensions of design/gamification/interactiveness and ease of use, (2) the wording of some questions was simplified to make them more easily understood by pupils and (3) the number of possible answers was reduced to 5 (1=Totally disagree; 5=Totally agree). Numerous studies which used the same tool have also adapted the scale in the same way to 5 points (Cardoso-Júnior & Delbone de Faria, 2021; Huang & Hew, 2016). This reduction of the sections is justified by the fact that a scale of 5 points is easier to understand and answer for the participants, thus reducing the cognitive load for its completion. The research team considered this aspect fundamental, given that students had to answer the test just after they completed the experiment with the VR material, with the corresponding tiredness which the activity could cause in some students. The young age of pupils was another reason for reducing the number of points, given that with fewer options, participants could have fewer doubts as to which option they should choose. In certain contexts, as is the case of interviewees with little experience of responding to questionnaires, a scale of 5 points may be more appropriate.

To measure the reliability of the tool, tests of internal consistency reliability were carried out using Cronbach's alpha coefficient (= .946) and using the Split-Half Correlation (Spearman-Brown coefficient = .896), which revealed a high consistency of the questionnaire. Although it was tried, it was not possible to carry out a reliability test using the test-retest method due to operational issues at the centres, the need to move the equipment to the participating schools and the difficulty to access exactly the same students in both tests. In any case, the results for internal consistency (highly satisfactory) together with the fact that the questionnaire had previously been used in many research studies (Cook & Pankratz, 2024) (even reducing the scale to 5 points), led the research team to validate the tool.

Table 1 shows the questionnaire.

Table 1
Questionnaire

Item (question)	Categories
P1. Gender	Female
	Male
	Prefers not to say
P2. Age	14
	15
	16
P3. Centre	Rural (CR)
	Urbano No Especializado (CUNE)
	Urbano Especializado (CUE)
P4. Subject (pill)	Mathematics
	Biology
	Chemistry
	Physics
P5. I like the subject	Likert (1-5)
P6. Do you own VR goggles or have you used them before?	Yes
	No
P7. I have experience using video games and play them regularly	Likert (1-5)
IMMS tool	
Dimension 1. Design-Gamification-Interactiveness	
P8. The lesson is like a game	Likert (1-5)
P9. I like the design of the application	Likert (1-5)
P10. The lesson is interactive	Likert (1-5)
Dimension 2. Ease of use	
P11. The item is easy to use	Likert (1-5)
P12. The instructions of the lesson are easy to understand	Likert (1-5)
P13. Following the application is simple	Likert (1-5)
P14. I do not notice any dizziness when following the lesson	Likert (1-5)
Dimension 3. Attention	
P15. The VR experience holds my attention	Likert (1-5)
P16. The app's design holds my attention	Likert (1-5)
P17. Having a lot of exercises in the app holds my attention	Likert (1-5)
Dimension 4. Relevance	
P18. This class is related to what I have studied	Likert (1-5)
P19. After the experience, I am keen to know more about the lesson	Likert (1-5)
P20. The lesson is useful from the learning point of view	Likert (1-5)
P21. I have learnt new things thanks to this lesson	Likert (1-5)
Dimension 5. Confidence/certainty in learning	

P22. While working on this lesson, I was sure that I was going to learn the content	Likert (1-5)
P23. After working on the lesson, I feel sure that I could pass an exam on the subject	Likert (1-5)
P24. The design of the lesson convinces me that I am going to learn the content	Likert (1-5)
Dimension 6. Satisfaction	
P25. I have enjoyed this VR class so much that I want to know more about the content	Likert (1-5)
P26. I liked this lesson with virtual reality	Likert (1-5)

Source: elaborated by the authors.

It must be remembered that, in order to reach the objectives, questions P8-P26 (in the IMMS tool), function as dependent variables in the study, whereas student gender is the independent variable.

Data analysis

The data gathered was analysed using descriptive and inferential statistics. Before carrying out parametric or non-parametric tests, a Kolmogorov-Smirnov test was used to check normal distribution and the result was null ($p < .001$) in all the items of the question (for full results of normality tests, see https://bit.ly/4gRmD5r). Consequently, we decided not to apply non-parametric tests (Mann-Whitney U test) to determine the existence of significant differences in answers depending on student gender. The gender variable is divided into three responses (Female/Male/Prefers not to say) so for the statistical calculations the options were reduced to Female/Male with the third option (Prefers not to say) being treated as missing data.

Once the items with significant statistical differences were highlighted, we analysed if the gender variable was a factor leading to those results. To do so, ordinal logistic regression was applied. To measure the size of the effect, R^2 testing was used (in this test, Nagelkerke's pseudo-R^2 is more common), being the most recommended in this type of study (Domínguez-Lara, 2017). For all the work on statistics in the study we used SPSS v.26 (full database available at https://bit.ly/4dzW3uK).

The study was approved by the Ethics Committee at the research team's university (internal registration number: 200420242632024).

RESULTS

General data

According to the results obtained (and in compliance with O1), participants were generally satisfied with the learning experience using VR (M = 3.84) (Table 3). Almost 6 out of 10 (58.6%) agree with the statement "I enjoyed the VR class so much that I would like to know more about its content" and virtually 3 out of every 4 (73.2%) said they enjoyed the learning experience with VR (Table 2). Despite the general satisfaction, female pupils rated the items with lower scores than their male counterparts.

Table 2

Score for each item

Item (dependent variable)	1	2	3	4	5
Dimension 1. Design-Gamification-Interactiveness					
P8. The lesson is like a game	6.1%	6.5%	14.5%	26.1%	46.9%
P9. I liked the design of the application	7.1%	3.9%	13.1%	27.8%	48%
P10. The lesson is interactive	5.1%	3.3%	12.2%	26.3%	53.1%
Dimension 2. Facility of use					
P11. The device is easy to use	6.3%	8.8%	20.6%	29.8%	34.5%
P12. The instructions for the lesson are easy to follow	7.1%	8.4%	18%	31.6%	34.9%
P13. The program is easy to follow	8%	9%	18,8%	33,1%	31%
P14. I do not feel dizzy when following the lesson	27.8%	14.7%	15.3%	15.5%	26.7%
Dimension 3. Attention					
P15. The virtual reality experience helps me focus my attention	9.4%	7.5%	21%	27.3%	34.9%
P16. The design of the app helps me focus my attention	9%	8.6%	23.3%	27.6%	31.4%
P17. Having a lot of exercises in the app helps me focus my attention	8.4%	7.8%	26.3%	29.8%	27.6%
Dimension 4. Relevance					
P18. This class is related to things which I have already studied	9.4%	5.3%	14.9%	22.5%	47.8%
P19. After the experience I feel I want to know more about the lesson	13.7%	10.4%	21%	25.1%	29.8%
P20. The lesson is useful for learning	8.2%	10.4%	16.9%	28.6%	35.9%
P21. I have learnt new things thanks to the lesson	20.4%	14.7%	23.5%	18.4%	22.9%
Dimension 5. Confidence/being sure of learning					
P22. While taking part in the lesson, I was sure I was going to learn the content	15.1%	14.9%	30%	19.4%	20.6%
P23. After completing the lesson, I feel confident about passing an exam on the topic	20%	15.5%	23.9%	16.5%	24.1%
P24. The design of the lesson ensures I am going to learn the content	14.7%	11.8%	28.2%	21.2%	24.1%
Dimension 6. Satisfaction					
P25. I enjoyed the VR class so much that I would like to know more about the content	10.4%	9.2%	21.8%	20.6%	38%
P26. I enjoyed the VR lesson	7.5%	7.8%	11.6%	22.2%	51%

Source: elaborated by the authors.

The highest rated dimension is the design of the pieces as highly interactive games (M = 4.08). 73% of participants agree that the lessons are gamified ("The lesson is like a game"), whereas almost 8 out of 10 (79.4%) say that the elements are interactive. On the down side, it is worth highlighting that confidence in learning with the use of different lessons is the lowest scoring dimension (M = 3.17).

Table 3
Average and general standard deviation, and gender breakdown

Item (dependent variable)	Average (SD)	Averagefe males	Averagema les	p[a]
Dimension 1. Design-Gamification-Interactiveness	**4.08**			
P8. The lesson is like a game	4.01 (1.19)	3.97	4.05	.477
P9. I liked the design of the application	4.06 (1.18)	4.03	4.12	.986
P10. The lesson is interactive	4.19 (1.10)	4.13	4.23	.528
Dimension 2. Ease of use	**3.56**			
P11. The device is easy to use	3.77 (1.19)	3.58	3.91	.002*
P12. Instructions for the lesson are easy to understand	3.79 (1.20)	3.61	3.92	.003*
P13. The lesson is easy to follow	3.70 (1.22)	3.54	3.79	.015*
P14. I have no feelings of dizziness when following the lesson	2.98 (1,57)	2.64	3.21	<.001*
Dimension 3. Attention	**3.65**			
P15. The virtual reality experience helps me focus my attention	3.71 (1.27)	3.55	3.83	.016*
P16. The design of the app helps me focus my attention	3.64 (1.25)	3.57	3.72	.218
P17. Having a lot of exercises in the app helps me focus my attention	3.60 (1.20)	3.39	3.77	<.001*
Dimension 4. Relevance	**3.56**			
P18. This class is related to things I have already studied	3.94 (1.29)	3.91	3.97	.858
P19. After the experience I feel that I want to know more about the lesson	3.47 (1.37)	3.37	3.56	.181
P20. The lesson is useful for learning	3.74 (1.27)	3.65	3.80	.128
P21. I have learnt new things thanks to the lesson	3.09 (1.43)	2.85	3.26	.002*
Dimension 5. Confidence / being sure of learning	**3.17**			
P22. While taking part in the lesson, I was sure I was going to learn the content	3.15 (1.32)	2.95	3.32	.003*
P23. After completing the lesson, I feel confident about passing an exam on the topic	3.09 (1.44)	2.76	3.33	<.001*
P24. The design of the lesson ensures I am going to learn the content	3.28 (1.34)	3.12	3.41	.017*
Dimension 6. Satisfaction	**3.84**			
P25. I enjoyed the VR class so much that I would like to know more about the content	3.67 (1.34)	3.46	3.79	.008*

P26. I enjoyed the virtual reality lesson	4.01 (1.27)	3.88	4.10	.268

Source: elaborated by the authors.

Note: [a] Mann–Whitney U test; * Significance level: < .05.

The effect of the gender variable

As can be seen in Table 3, there are considerable differences in answers depending on the gender of participants in 11 of the 19 questions asked (O2). This result has led us to reject the starting hypothesis of the study.

The dimension where the greatest difference is observed by gender is ease of use. Discrepancies are observed in all the questions of this dimension. Female pupils perceive a significantly higher difficulty in the usability of the lessons (U = 32180.50; p = .002). Similarly, they tend to consider the instructions for use more complicated (U = 32127.50; p = .003), while they rate the VR software more difficult to follow when compared with their male counterparts (U = 31318.00; p = .015). However, where the greatest differences are observed - in this section of questions - is in the sense of dizziness: girls said they experienced a greater feeling of dizziness during the use of the VR apparatus (U = 33423.00; p < .001).

These discrepancies in the perceived ease of use may be the result of significant gender differences when it comes to prior experience with VR technology (P6) and the habit of playing video games (P7). In order to check those differences in the question about prior experience with VR technology ("Q6: Do you have VR goggles or have you used them before?"), an analysis was carried out using bivariate tables which revealed that the experience of male students of using this technology was 8 points higher than that of female students (50.3% as opposed to 42.6%). On the other hand, in order to observe the discrepancies by gender in the habit of playing video games ("Q7. I have experience with video games and play them regularly"), a Mann-Whitney U test was performed, the results of which reveal that the habit of male students of using video games is significantly higher than that of their female classmates (U = 43985.50; p < .001). These gender discrepancies related to habits and experience with VR technology and video games could, in part, explain the differences between males and females regarding their perception of the ease of use of VR learning technology as used in our work.

In addition to ease of use, notable discrepancies can be observed in all the questions from the same section referring to confidence in learning. Female pupils have a lower sense of confidence that they will learn from the VR lessons (U = 32245.00; p = .003) and, at the same time, are less confident of passing an exam after their activity in the lessons (U = 34061.00; p < .001). They also tend to perceive to a lesser extent that the design of the VR material ensures the learning of the contents (U = 31314.00; p = .017).

Attention is the third dimension where the most notable gender discrepancies can be observed. Female participants said that the VR experience was less of a help for focusing their attention on the content (U = 31301.00; p = .016). They are also less prone to stating that carrying out a lot of exercises during the VR experiment helped them focus their attention on content (U = 32823.00; p < .001).

Finally, the relevance for learning and the formal aspects of design/gamification/interactiveness are the elements in which gender has less of an impact.

Study of predictive factors

Once we had established which items registered statistically significant differences between the male and female participants of the study (in line with O2a), a study of predictive factors was performed - using ordinal logistic regression - to establish the causal relation between the 11 questions where such deviation exists (dependent variables) and the gender of the pupil (independent variable). To determine the appropriateness of the study, the parallel lines test was carried out, with a satisfactory result (p > .05 for all variables).

We observed that gender is a predictive factor in all 11 dependent variables, which supports the association between the gender variable and the items measured. Table 4 shows the results for the impact of gender in all the variables, in descending order.

Table 4

A study of predictive factors (ordinal regression)

Question (dependent variable)	**"p" value of the model (pseudo R^2 Nagelkerke)**	**ß(ES)**	**Wald**	**p**
P23. After the lesson I feel confident that I could pass an exam about the content	<.001 (.039)	.710	17.922	<.001*
P14. I have no sense of dizziness while following the lesson	<.001 (.031)	-.638	14.428	<.001*
P17. Having a lot of exercises in the app helps me focus my attention	<.001 (.026)	.596	12.422	<.001*
P21. I have learnt new things thanks to the lesson	.002 (.021)	.515	9.570	.002*
P11. The device is easy to use	.002 (.020)	.510	9.119	.003*
P22. While working on this lesson, I was confident of learning the content	.002 (.020)	.506	9.179	.002*
P12. The instructions are easy to understand	.003 (.019)	.505	8.881	.003*
P25. I enjoyed the virtual reality class so much that I would like to know more about the content	.007 (.015)	.450	7.155	.007*
P13. The lesson is easy to follow	.015 (.013)	.412	5.970	.015*
P15. The virtual reality experience helped me focus my attention	.015 (.013)	.408	5.866	.016*
P24. The design of the lesson ensures that I will learn the content	.016 (.012)	.399	5.748	.017*

Source: elaborated by the authors.

Note: * Significance level: < .05.

DISCUSSION AND CONCLUSION

Generally speaking, the pupils who took part in the study gave a positive evaluation of the experience of using VR for the teaching of STEM subjects, although there were some significant differences in the scores obtained in the different variables which were measured. The aspects which scored the highest were those related to the structure and design of the lessons (interactive nature and gamification), as well their capacity to help pupils pay attention to the content. The good results obtained in the question about the usefulness for learning would support the evidence provided by previous research, such as that of Cabero-Almenara et al. (2023) and Bermejo et al. (2023). On the negative side, ease of use, perceived relevance of the content and, in particular, confidence that this technology will help learning are the worst scoring variables. Even so, the overall scores in all the variables measured are positive.

Based on our results, we can extract the following conclusions:

1. Gender bias. In line with recent studies such as that of Pan et al. (2024), our work confirms a significant effect of the gender variable when it comes to attitudes towards VR for education, which would lead us to reject the opening hypothesis of the study. Previous studies had shown that the gender variable influences the learning results obtained in dynamic teaching scenarios such as VR (Saha & Halder, 2016; Castro-Alonso et al., 2019). However, there is also empirical evidence which contradicts that gender bias, both in Spain (Cózar Gutiérrez et al., 2019) and in other contexts (Ateş & Kölemen, 2024; Alsalleeh et al., 2024).
2. Differences in the perception of ease of use. These gender differences are particularly significant when it comes to managing and using the application. The gender difference when it comes to prior experience with this technology and the use of video games (Halpern, 2000) may explain the differences observed, not only in ease of use but also in other dimensions such as confidence in learning, attention or motivation to find out more about STEM subjects after the VR experience. The fact that the gender variable influences the sensation of dizziness also backs up that hypothesis. Similarly, prior studies have shown how male pupils find it easier than female pupils when performing tasks requiring an awareness of space. (Heo & Tommey, 2020; Roach et al., 2021), which is a key feature for VR teaching material. For that reason, female pupils may encounter an excessive cognitive load when interacting with technologies that require a high degree of awareness of space (as is the case with VR). This may lead to a lower learning performance (Jian & Abu Bakar, 2024).
3. Female pupils and STEM subjects. Along that line, our data indicate a possible inefficiency with this technology when it comes to boosting STEM vocations among female pupils, at least at Secondary School level in the context of Spain. It is for that reason that the gender variable should be taken into account so that the entire student population can enjoy a similar experience in their interaction with teaching resources (Castro-Alonso et al., 2019). In the case of immersive material, the cognitive load must be reduced so that people with less experience of using the technology can experience an adequate teaching environment (Heo & Tommey, 2020).
4. Practical recommendations. Even though it is not the core issue of our research, some practical ramifications should be borne in mind when it comes to reducing the cognitive load with VR in order to eliminate the above mentioned gender gaps:
    - Introductory tutorials should be brought in to explain how to use the goggles and controls.
    - Interface design should be clear and intuitive to avoid information overload. Basic controls and a clear and simple user experience should be established.
    - Sessions should be limited to 10-15 minutes per group, with an interval between each session.
    - A system of warnings should be introduced to tell students when to take a break.
    - Emphasis should be placed on short sessions with specific concepts to avoid prolonged and complex usage in one single session.
    - Collaborative activities should be designed where pupils work in pairs to optimize learning.
    - Roles should be alternated: one pupil uses the goggles while the other guides using the screen or tablet.
    - A feedback system should be introduced to assess the teaching impact.
5. False dichotomy between digital natives and immigrants. Our results reveal that it is impossible to credit our young people and teenagers with homogeneous perceptions and attitudes towards technology and, consequently, the dichotomy between digital natives and immigrants. It is obvious that other

variables exist, in addition to age, which influence the perceived ease of use of technologies. This suggests the adoption of a new system of distinctions in terms of digital wisdom (Prensky, 2009), which can be distributed in a dissimilar way within the same age group depending on other social and educational factors.

This research has the usual restrictions common to these types of studies which tend to focus on local or national contexts. Research using the same VR material developed in different countries (or in zones located far away from the host country) can be complicated and, consequently, there are no such studies. Limiting the sample to one single country could condition the final results. Scientific literature shows that cultural differences have a significant effect on beliefs, attitudes and individual intentions regarding technology, which could have a profound effect on the results of the research (Ateş & Kölemen, 2024). The possible variation of data in different cultural contexts underlines the need to bear these differences in mind when interpreting and analyzing the findings (Bedenlier et al., 2020; Lynch et al., 2024). In today's world, where technology transcends geographical boundaries, it is more and more important to remember the cultural context in which the studies are carried out (Arpaci et al., 2020). For that reason it is necessary to see our results in the light of those obtained in other countries with more or less exposure to VR. That would allow us to measure the effect of cultural factors in attitudes towards the application of VR in centres of education. Other future relevant lines of investigation are the application of longitudinal studies using the same instruments as we have and, especially, the triangulation of quantitative data with qualitative techniques which, undoubtedly, would allow a more in-depth study and qualification of the results obtained here.

REFERENCES

Aguilera, D., García-Yeguas, A., Perales Palacios, F., & Vílchez-González, J. (2022). Diseño y validación de una rúbrica para la evaluación de propuestas didácticas STEM (RUBESTEM). *Revista Interuniversitaria de Formación del Profesorado*, *97*(36.1), 11-34. https://doi.org/10.47553/rifop.v97i36.1.92409

Alsalleeh, F., Okazaki, K., Alkahtany, S., Alrwais, F., Bendahmash, M., & Al Sadhan, R. (2024). Augmented reality improved knowledge and efficiency of root canal anatomy learning: A comparative study. *Applied Sciences*, *14*(15), 6813. https://doi.org/10.3390/app14156813

An, F., Xi, L., & Yu, J. (2024). The relationship between technology acceptance and self-regulated learning: The mediation roles of intrinsic motivation and learning engagement. *Education and Information Technologies*, *29*(3), 2605-2623. https://doi.org/10.1007/s10639-023-11959-3

Arce, E., Zayas-Gato, F., Suárez-García, A., Michelena, Á., Jove, E., Casteleiro-Roca, J.-L., Quintián, H., & Calvo-Rolle, J. L. (2022). Experiencia blended learning apoyada en un laboratorio virtual para educación de materias STEM. *Bordón. Revista de Pedagogía*, *74*(4), 125-143. https://doi.org/10.13042/Bordon.2022.95592

Archer, L., Moote, J., MacLeod, E., Francis, B., & DeWitt, J. (2020). *ASPIRES 2: Young people's science and career aspirations, age 10-19*. UCL Institute of Education.

Arpaci, I., Al-Emran, M., & Al-Sharafi, M. A. (2020). The impact of knowledge management practices on the acceptance of massive open online courses (MOOCs) by engineering students: A cross-cultural comparison. *Telematics and Informatics*, *54*, 101468. https://doi.org/10.1016/j.tele.2020.101468

Ateş, H., & Kölemen, C. Ş. (2024). Integrating theories for insight: An amalgamated model for gamified virtual reality adoption by science teachers. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12892-9

Bedenlier, S., Bond, M., Buntins, K., Zawacki-Richter, O., & Kerres, M. (2020). Facilitating student engagement through educational technology in higher education: A systematic review in the field of arts and humanities. *Australasian Journal of Educational Technology*, *36*(4), 126-150. https://doi.org/10.14742/ajet.5477

Bermejo, B., Juiz, C., Cortes, D., Oskam, J., Moilanen, T., Loijas, J., Govender, P., Hussey, J., Schmidt, A. L., & Burbach, R. (2023). AR/VR teaching-learning experiences in higher education institutions (HEI): A systematic literature review. *Informatics*, *10*(2), 45. https://doi.org/10.3390/informatics10020045

Boel, C., Rotsaert, T., Valcke, M., Rosseel, Y., Struyf, D., & Schellens, T. (2023). Are teachers ready to immerse? Acceptance of mobile immersive virtual reality in secondary education teachers. *Research in Learning Technology*, *31*. https://doi.org/10.25304/rlt.v31.2855

Cabero, J., Fernández, B., & Marín, V. (2017). Dispositivos móviles y realidad aumentada en el aprendizaje del alumnado universitario. *RIED-revista Iberoamericana de Educación a Distancia*, *20*(2). https://doi.org/10.5944/ried.20.2.17245

Cabero-Almenara, J., De-La-Portilla-De-Juan, F., Barroso-Osuna, J., & Palacios-Rodríguez, A. (2023). Technology-enhanced learning in health sciences: Improving the motivation and performance of medical students with immersive reality. *Applied Sciences*, *13*(14), 8420. https://doi.org/10.3390/app13148420

Cardoso-Júnior, A., & Delbone de Faria, R. M. (2021). Psychometric assessment of the instructional materials motivation survey (IMMS) instrument in a remote learning environment. *Revista Brasileira de Educação Médica*, *45*(4), e197. https://doi.org/10.1590/1981-5271v45.4-20210066.ing

Castaño-Calle, R., Jiménez-Vivas, A., Poy Castro, R., Calvo Álvarez, M. I., & Jenaro, C. (2022). Perceived benefits of future teachers on the usefulness of virtual and augmented reality in the teaching-learning process. *Education Sciences*, *12*(12), 855. https://doi.org/10.3390/educsci12120855

Castellano, M. S., Contreras-McKay, I., Neyem, A., Farfán, E., Inzunza, O., Ottone, N. E., del Sol, M., Alario-Hoyos, C., Alvarado, M. S., & Tubbs, R. S. (2023). Empowering human anatomy education through gamification and artificial intelligence: An innovative approach to knowledge appropriation. *Clinical Anatomy*, *36*(8), 1171-1183. https://doi.org/10.1002/ca.24074

Castro-Alonso, J. C., Wong, M., & Adesope, O. O. (2019). Gender imbalance in instructional dynamic versus static visualizations: A meta-analysis. *Educational Psychology Review*, *31*(2), 361-387. https://doi.org/10.1007/s10648-019-09469-1

Cook, D. A., & Pankratz, V. S. (2024). Validation of the instructional materials motivation survey among medicine resident physicians. *MedEdPublish*, *14*(58). https://doi.org/10.12688/mep.20408.1

Cózar Gutiérrez, R., González-Calero Somoza, J. A., Villena Taranilla, R., & Merino Armero, J. M. (2019). Análisis de la motivación ante el uso de la realidad virtual en la enseñanza de la historia en futuros maestros. *Edutec. Revista Electrónica de Tecnología Educativa*, (68), 1-14. https://doi.org/10.21556/edutec.2019.68.1315

De Moraes Rossetto, A. G., Martins, T. C., Silva, L. A., Leithardt, D. R. F., Bermejo-Gil, B. M., & Leithardt, V. R. Q. (2023). An analysis of the use of augmented reality and virtual reality as educational resources. *Computer Applications in Engineering Education*, *31*(6), 2091-2105. https://doi.org/10.1002/cae.22671

Domínguez-Lara, S. (2017). Magnitud del efecto en análisis de regresión. *Interacciones*, *3*(1), 3-5. https://doi.org/10.24016/2017.v3n1.46

Fuentes Hurtado, M., & González Martínez, J. (2017). Necesidades formativas del profesorado de secundaria para la implementación de experiencias gamificadas en STEM. *Revista de Educación a Distancia (RED)*, *17*(54). https://doi.org/10.6018/red/54/8

Giakoni-Ramírez, F., Godoy-Cumillaf, A., Fuentes-Merino, P., Farías-Valenzuela, C., Duclos-Bastías, D., Bruneau-Chávez, J., Merellano-Navarro, E., & Velásquez-Olavarría, R. (2023). Intensity of a physical exercise programme executed through immersive virtual reality. *Healthcare*, *11*(17), 2399. https://doi.org/10.3390/healthcare11172399

Halpern, D. F. (2000). *Sex differences in cognitive abilities*. Psychology Press. https://doi.org/10.4324/9781410605290

Heo, M., & Toomey, N. (2020). Learning with multimedia: The effects of gender, type of multimedia learning resources, and spatial ability. *Computers & Education*, *146*, 103747. https://doi.org/10.1016/j.compedu.2019.103747

Huang, B., & Hew, K. F. (2016). Measuring learners' motivation level in massive open online courses. *International Journal of Information and Education Technology*, *6*(10), 759-764. https://doi.org/10.7763/IJIET.2016.V6.788

Huett, J. B., Moller, L., Young, J., Bray, M., & Huett, K. C. (2008). The effect of ARCS-based strategies on confidence and performance. *The Quarterly Review of Distance Education*, *9*(2), 113-126.

Jian, Y., & Abu Bakar, J. A. (2024). Comparing cognitive load in learning spatial ability: Immersive learning environment vs. digital learning media. *Discover Sustainability*, *5*(1), 111. https://doi.org/10.1007/s43621-024-00310-6

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, *10*(3), 2-10. https://doi.org/10.1007/BF02905780

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach*. Springer. https://doi.org/10.1007/978-1-4419-1250-3

Loorbach, N., Peters, O., Karreman, J., & Steehouder, M. (2015). Validation of the instructional materials motivation survey (IMMS) in a self-directed instructional setting aimed at working with technology. *British Journal of Educational Technology*, *46*(1), 204-218. https://doi.org/10.1111/bjet.12138

Lucena-Antón, D., Fernández-López, J. C., Pacheco-Serrano, A. I., García-Muñoz, C., & Moral-Muñoz, J. A. (2022). Virtual and augmented reality versus traditional methods for teaching physiotherapy: A systematic review. *European Journal of Investigation in Health Psychology and Education*, *12*(12), 1780-1792. https://doi.org/10.3390/ejihpe12120125

Lynch, P., Singal, N., & Francis, G. A. (2024). Educational technology for learners with disabilities in primary school settings in low- and middle-income countries: A systematic literature review. *Educational Review*, *76*(2), 405-431. https://doi.org/10.1080/00131911.2022.2035685

Marín-Díaz, V., & Sampedro-Requena, B. E. (2023). Views of secondary education teachers on the use of mixed reality. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.1035003

Martín Carrasquilla, O., Santaolalla Pascual, E., & Muñoz San Roque, I. (2022). La brecha de género en la educación STEM. *Revista de Educación*, (396), 15-39. https://doi.org/10.4438/1988-592X-RE-2022-396-533

Marrero Galván, J. J., & Hernández Padrón, M. (2022). La trascendencia de la realidad virtual en la educación STEM: Una revisión sistemática desde el punto de vista de la experimentación en el aula. *Bordón. Revista de Pedagogía*, *74*(4), 45-63. https://doi.org/10.13042/Bordon.2022.94179

Mercado, A. E., Sánchez, E., & Rodríguez, A. V. (2019). Estrategias de motivación en ambientes virtuales para el autoaprendizaje en matemáticas. *Revista Espacios*, *40*(12), 14-21.

Morales Inga, S., & Morales Tristán, O. (2020). ¿Por qué hay pocas mujeres científicas? Una revisión de literatura sobre la brecha de género en carreras STEM. *Revista Internacional de Investigación en Comunicación aDResearch*, (22), 118-133. https://doi.org/10.7263/adresic-022-06

Palacios Ortega, A., Pascual López, V., & Moreno Mediavilla, D. (2022). El papel de las nuevas tecnologías en la educación STEM. *Bordón. Revista de Pedagogía*, *74*(4), 11-21. https://doi.org/10.13042/Bordon.2022.96550

Pan, J., Liu, Y. J., & Yang, C. (2024). Comparison of intelligent virtual reality first-aid training outcomes among individuals with different demographic characteristics. *Journal of Evaluation in Clinical Practice*, *30*(3), 723-729. https://doi.org/10.1111/jep.14135

Pontes Pedrajas, A. (2022). Uso didáctico de un laboratorio virtual para favorecer la progresión de los modelos mentales de los estudiantes sobre circuitos de corriente eléctrica. *Bordón. Revista de Pedagogía*, *74*(4), 145-160. https://doi.org/10.13042/Bordon.2022.93290

Prensky, M. (2009). H. sapiens digital: From digital immigrants and digital natives to digital wisdom. *Journal of Online Education*, *5*(3).

Roach, V. A., Mi, M., Mussell, J., Van Nuland, S. E., Lufler, R. S., DeVeau, K. M., Dunham, S. M., Husmann, P., Herriott, H. L., Edwards, D. N., Doubleday, A. F., Wilson, B. M., & Wilson, A. B. (2021). Correlating spatial ability with anatomy assessment performance: A meta-analysis. *Anatomical Sciences Education*, *14*(3), 317-329. https://doi.org/10.1002/ase.2029

Saha, S., & Halder, S. (2016). He or she: Does gender affect various modes of instructional visual design? *Journal of Research on Women and Gender*, *7*(1), 47-58.

Spiriev, T., Mitev, A., Stoykov, V., Dimitrov, N., Maslarski, I., & Nakov, V. (2022). Three-dimensional immersive photorealistic layered dissection of superficial and deep back muscles: Anatomical study. *Cureus*, *14*(7), e26727. https://doi.org/10.7759/cureus.26727

Tatiana Cox, F., González, D., Magreñán, Ángel A., & Orcos, L. (2022). Enseñanza de estadística descriptiva mediante el uso de simuladores y laboratorios virtuales en la etapa universitaria. *Bordón. Revista de Pedagogía*, *74*(4), 103-123. https://doi.org/10.13042/Bordon.2022.94121

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