

Educational efficiency of VR visual media. Spain-Germany comparison and study of predictive factors

Eficacia educativa de las narrativas visuales en realidad virtual. Comparativa España-Alemania y estudio de factores predictivos visuales

Eficácia educativa das narrativas visuais em realidade virtual. Comparação Espanha-Alemanha e estudo de fatores preditivos

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Abstract

Purpose: The evolution of emerging technologies, such as virtual reality, has transformed the way narratives are constructed and transmitted and their effectiveness in both narrative and educational terms. This study examines the perception of learning through VR narratives among secondary school students in Spain and Germany. **Methodology:** A quantitative questionnaire approach (n=1042) was applied in six schools, using an adaptation of the Instructional Material Motivational Survey (IMMS), validated by previous research. **Results:** The data, analysed using descriptive and inferential statistics, show significant differences between the two countries in several pedagogical dimensions associated with perceived learning, with Spanish students obtaining higher scores in relevance, attention and confidence-related variables. However, no statistically significant differences were found in the direct measure of perceived learning. **Conclusions:** The findings highlight the primacy of pedagogical factors over technological factors and the need for cultural and methodological adaptations to maximise the educational impact of VR.

Keywords

Virtual reality; Immersive media; Educational innovation; Educational technology; Visual media; STEM.

Resumen

Propósito: La evolución de las tecnologías emergentes, como la realidad virtual (RV), ha transformado la forma en que se construyen y transmiten relatos y su eficacia tanto en términos narrativos como educativos. En dicho contexto, este estudio compara la percepción de aprendizaje utilizando narrativas inmersivas elaboradas en RV entre estudiantes de Secundaria de España y Alemania. **Metodología:** Se llevó a cabo una investigación cuantitativa mediante cuestionario ($n = 1042$) en un total de seis centros de Secundaria españoles y alemanes. Se utilizó para ello una adaptación del test *Instructional Material Motivational Survey (IMMS)* validado en anteriores trabajos. **Resultados:** Los datos, analizados con estadística descriptiva e inferencial, evidencian diferencias significativas entre ambos países en diversas dimensiones pedagógicas asociadas a la percepción de aprendizaje, obteniendo los estudiantes españoles puntuaciones superiores en relevancia, atención y variables relacionadas con la confianza. No obstante, no se encontraron diferencias estadísticamente significativas en la medida directa de percepción de aprendizaje. **Conclusiones:** Los hallazgos destacan la primacía de los factores pedagógicos sobre los tecnológicos y la necesidad de adaptaciones culturales y metodológicas para maximizar el impacto educativo de la realidad virtual.

Palabras clave

Realidad Virtual; Medios inmersivos, Innovación educativa; Tecnología educativa; Medios visuales; STEM.

Resumo

Objetivo: A evolução das tecnologias emergentes, como a realidade virtual (RV), tem transformado a forma como as narrativas são construídas e transmitidas, bem como sua eficácia tanto em termos narrativos quanto educacionais. Este estudo compara a percepção de aprendizagem por meio de narrativas imersivas desenvolvidas em RV entre estudantes do Ensino Secundário da Espanha e da Alemanha. **Metodologia:** Foi realizada uma pesquisa quantitativa por meio de

questionário (n = 1042) em um total de seis instituições de ensino secundário espanholas e alemãs. Para isso, foi utilizada uma adaptação do teste *Instructional Material Motivational Survey* (IMMS), previamente validado em estudos anteriores. **Resultados:** Os dados, analisados com estatística descritiva e inferencial, evidenciam diferenças significativas entre ambos os países em diversas dimensões pedagógicas associadas à percepção da aprendizagem, obtendo os estudantes espanhóis pontuações superiores em relevância, atenção e variáveis relacionadas com a confiança. No entanto, não foram encontradas diferenças estatisticamente significativas na medida direta da percepção da aprendizagem. **Conclusões:** Os resultados destacam a primazia dos fatores pedagógicos sobre os tecnológicos e a necessidade de adaptações culturais e metodológicas para maximizar o impacto educacional da realidade virtual.

Palavras-chave

Realidade Virtual; Meios imersivos; Inovação educacional; Tecnologia educacional; Meios visuais; STEM.

1. Introduction and theoretical framework

The narrative is a fundamental component in human communication and plays a crucial role in the transfer of knowledge, values, identity and cultural experiences. With the breakthrough of emerging technologies, this inherent ability has undergone a significant evolution, facilitating the creation of more sophisticated and efficient ways of constructing and transmitting narratives. In this context, virtual reality (VR) has positioned itself as a transforming tool, redefining the way in which people perceive stories and interact with them (Gregor, 2024). VR has the ability to generate immersive and multi-sensorial environments which extend the boundaries of the traditional narrative. Its use in media such as cinema has made it possible to create experiences which are more dynamic, interactive and all-surrounding than those offered by conventional formats (Zhiyuan & Cheng-Hung, 2023; Huamán Huilca & García-Montero, 2022).

In this way, VR has become established as a disruptive technology which transforms human interaction by making a complete immersion in simulated, three-dimensional

environments possible. This innovation, based on the integration of advanced software and devices such as visors and movement sensors (Kreß et al., 2024), has extended its reach to new fields. Its application covers sectors such as education (Zuñe et al., 2023), health (Zoccali & Mallamaci, 2024), job-seeking (Sigmundstad & Fosli, 2024) or journalism (Peng, 2025; Li, 2024). In addition, VR has shown itself to be a versatile tool in the evolution of contemporary narratives in different areas. Examples of these are to be found in the activities of museums and cultural exhibitions which have used this type of technology to reinterpret historic accounts thus allowing users to experience past environments (Muñoz & Martí, 2020).

In the field of VR, the efficacy of the message may be understood as the narrative's ability to transmit key information concisely, whilst minimizing information overload. This variable can be measured in terms of the retention and comprehension of the information presented as well as the time it takes to reach the established objectives. Although scientific literature in this area is scarce, some studies do highlight key aspects for analysis. One fundamental element is a concise and effective design whereby the user is guided progressively through the new concepts, thus making the experience more motivational (Checa & Bustillo, 2020). Similarly, other authors underline the importance of minimal distractions during the experience (Mondal, 2024) so that the user's attention may focus on the essential contents. To sum up, scientific research explores the efficiency of the VR message from a construct in which the design and ability to hold the user's attention are paramount. Both dimensions are essential variables which will be measured in this research work.

1.1. The efficiency of VR narratives applied to education

The use of VR in education has been the object of academic research for more than two decades (García-Marín et al., 2025). Despite that, some aspects have barely been analyzed and there is an absence of comparative studies of different centres and different countries. The quantity of resources needed to work with the same VR equipment in different countries (which implies, among other things, having to translate the material to the language of each country) makes it difficult to carry out this type of study. Similarly, difficulties are faced when

carrying out studies in different centres of the same country: transporting or buying material for the participating institutions. These difficulties have led to most of the studies until now being carried out in very limited contexts (a single centre or country).

In a similar way, existing research tends to use immersive teaching material which already exists and is available in the market. In other words, specific *ad hoc* content is not produced for the research, which may make it more difficult to incorporate it into the field of work. Likewise, scientific literature has centered more on the university context rather than earlier educational levels such as primary and secondary (García-Marín et al., 2025). On the other hand, the research which has been carried out has tended to focus on practical or instrumental subjects using simulators or virtual laboratories (Muradova, 2020), with less attention being paid to theory-based issues. As we shall see in the next section, the methodological design of our work aims to solve these limitations.

VR has established itself as a technological tool with great potential in education. Recent studies have shown that the introduction of narratives in VR environments may significantly increase motivation and improve performance in these areas (Marrero Galván & Hernández Padrón, 2022). However, not all narratives are equally effective since factors such as the complexity of the story, the level of interaction and the alignment with teaching objectives play a crucial role in the results obtained, as do the visual and immersion features (Rubio Tamayo & Gértrudix Barrio, 2022). At the same time, other authors highlight the need to act with caution when using VR to teach specific concepts such as spatial learning - certain restrictions are inherent in this approach (Belger et al., 2023).

The efficiency of the narrative in VR environments comes as a result of VR's ability to catch the user's attention effectively. VR can create experiences which improve the comprehension and retention of information, increase the relevance of the content being presented and provide experiences which are considerably more significant (Liu et al., 2021).

The narrative plays a crucial role by structuring VR activities in such a way that they can become effective learning experiences. A well-designed narrative can lead users through a flow of information which is logical and emotionally relevant (Bucher, 2017), thus increasing not only knowledge retention but also the ability to apply this knowledge in practical contexts. This type of technology

is not exempt from problems such as stereoscopic visual fatigue caused by depth perception in this type of environment (Guo et al., 2024), motion sickness, which, although it has improved in recent years, still persists (Chiroque Landayeta, 2024), or the ability to isolate the user from the real world (Grassini, 2024).

The analysis of the efficiency of the message in narratives applied to VR not only contributes to the development of teaching tools which are more efficient but also meets the need of adapting them to specific cultural contexts and ensures equality in access to technology (Borja-Salazar, 2024). In education, specifically, VR is a promising tool for tackling traditional challenges by offering interactive and multisensory learning experiences which promote the comprehension of complex concepts (Klingenberg et al., 2020). In addition, its ability to recreate real-world scenarios or create simulated environments in a controlled way encourage not only active learning but also the effective transfer of knowledge to practical situations. This potential, however, is conditioned by the underlying teaching design, which includes factors such as narrative, interactivity and cultural adaptability, which suggests a need to explore approaches which maximize its effectiveness in different contexts (Itasanmi & Ajani, 2023).

One of the main problems found by scientific literature regarding the educational efficiency of VR resides in the limited scope of existing research. It is common for these studies to focus on a single school, or, in the best of cases, their study is made up of national samples from a single country. It is, therefore, essential to expand the focus of studies in this area, with international studies where we can compare the efficiency of these tools in different environments particularly in countries with different cultures. Therefore, the two central questions that guide our study are: (1) How, in comparative terms, does the level of satisfaction with educational VR differ among students from two culturally distinct countries, such as Spain and Germany? and (2) Which factors may be associated with learners' perceived learning outcomes derived from the use of this technology in both countries?

2. Objectives and method

Bearing in mind the theoretical baggage mentioned above, our study set out the following aims:

01. To compare the level of satisfaction and perception of learning obtained in the use of VR immersive narratives in secondary school students in Spain and Germany.
02. To analyze the factors which influence the perception of learning obtained from these technologies in both countries.
03. To observe the existence of gender bias in the perception of learning obtained with the use of these tools among secondary school pupils in Spain and Germany.

2.1. Research design

An eminently quantitative study was carried out, based on the assessment questionnaire of a total of four immersive VR narratives with teaching content related to STEM subjects (Science, Engineering, Technology and Mathematics) as adapted to the Secondary School curriculum (subjects of Physics, Chemistry, Mathematics and Biology). The fieldwork was carried out in six public Secondary Schools –three in Spain and three in Germany– in the months of May and June 2024.

One of the main advantages of this project is that the immersive narratives analysed were created *ad hoc* and exclusively for this research in both Spanish and German (for further information see <https://doi.org/10.6084/m9.figshare.27178068>). The research was carried out in the following phases:

- Phase 1: Choice of content for the immersive educational narratives. The contents chosen were: (1) Geometry and Space Visualization (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 creation of the immersive activities by the company in charge of educational software in VR, in conjunction with the research team.
- Phase 3: Training of teachers in the use of VR. Once the four VR materials had been created, several teachers from the six Secondary Schools taking part in the project attended a one-week training workshop organised at the university of the research team.
- Phase 4. Application of VR software in the classroom.

- Phase 5. Pupils fill in questionnaire. Upon completing each experiment with one of the VR pieces, pupils had to fill in a questionnaire (Table 1), the results of which are published in this piece of work.

2.2. Sample and instruments

A total of 1042 replies were obtained from Secondary School pupils aged between 14 and 16 and specializing in science subjects, from both countries. We managed to obtain an even sample distribution per country: 51.05% of answers from Germany ($n = 532$) and 48.95% from Spain ($n = 510$). The average age of participants was 15.02 years old. 56.62% of the sample was male while 37.04% was female. 6.33% of participants chose the “non-binary” option or preferred not to say. 57.77% of interviewees had some previous experience in the use of VR. Just over half were regular players of video games (53.45%).

The questionnaire was based on the IMMS (Instructional Material Motivational Survey) test, designed by Keller (2010) and validated in later studies for measuring the effectiveness of teaching technologies, such as those of Loorbach et al. (2015) and Cózar Gutiérrez et al. (2019). Questions were grouped in four essential dimensions for the teaching-learning process: (1) attention, (2) relevance, (3) confidence and (4) student satisfaction with the technology or methodology analyzed. The choice of these dimensions was based on the ARCS model (Attention, relevance, confidence, satisfaction) defined by Keller (1987, 2010). By applying this tool to the framework of our study, we understand “relevance” to be the degree of educational usefulness for these immersive subjects, as perceived by pupils. “Confidence” has to do with how sure the pupil is that they will acquire knowledge during their interaction with the VR materials. These dimensions converge on the fourth - the general level of satisfaction with the technology analyzed.

The original version of the tool was made up of 12 items on a Likert scale with 7 options. For our research the questionnaire was adapted as follows: (1) new items were introduced to cover the dimensions of design/gamification/interactiveness and ease of use. The measurement of these potentially predictive factors for perceived learning was considered relevant by the research team, as was also seen in

the theoretical framework, and (2) the number of possible answers was reduced to 5 (1=totally disagree; 5=totally agree). For more detailed information about the questionnaire used, see Table 1.

Table 1. *Final Questionnaire*

Variable (question)	Categories
Q1. Gender	Female
	Male
	Non-binary
	Prefer not to say
Q2. Age	14
	15
	16
Q3. School	Students indicated where they studied
Q4. Immersive VR lesson	Mathematics
	Biology
	Chemistry
	Physics
Q5. I like the subject	Likert (1-5)
Q6. Do you own or have you used VR glasses in the last?	Yes
	No
Q7. I play video games regularly	Likert (1-5)
Instrument IMMS	
Dimension 1. Design-Gamification-Interactivity (Likert 1-5)	
Q8. The immersive piece is like a game	
Q9. I liked the design of the application	
Q10. Perception of interactivity	
Dimension 2. Ease of use and navigation (Likert 1-5)	
Q11. Perception of ease of use	
Q12. Understanding of instructions	
Q13. Perception of ease of navigation	
Q14. Absence of sense of dizziness	

Dimension 3. Attention (Likert 1-5)	
Q15. The VR experience helped me stay focused	
Q16. The design of the experience helped me stay focused	
Q17. Having a lot of activities helped me stay focused	
Dimension 4. Relevance (Likert 1-5)	
Q18. The VR piece is related to topics I had already studied	
Q19. Intention to know more about the content after the experience	
Q20. Perception of educational usefulness	
Q21. Perception of learning	
Dimension 5. Confidence / being sure of learning (Likert 1-5)	
Q22. Confidence of learning	
Q23. Being sure I would pass an exam on the subject after the immersive experience	
Q24. Confidence of learning thanks to the design of the immersive piece	
Dimension 6. Satisfaction (Likert 1-5)	
Q25. General satisfaction with the experience	

Source: authors' own material adapted from Keller (2010), Loorbach et al. (2015) and Cózar Gutiérrez et al. (2019).

It must be borne in mind that to satisfy O2, questions Q8-Q25 (except for Q21) were considered independent variables for the study, whereas the dependent one was Q21, which was related to the perception of learning using VR pieces.

Although initially considered, the use of control and experimental groups was ultimately discarded. In multi-site school contexts, cluster-randomized trials—appropriate when pursuing causal inference—entail substantial logistical and methodological demands (e.g., risk of contamination due to the impossibility of fully isolating the variables under measurement) that do not align with our research question.

2.3. Data analysis

Descriptive and inferential statistical studies were carried out. To decide between the application of parametric calculations and non-parametric ones, Kolmogorov-Smirnov normality tests were done whereby zero normality ($p < .001$) was observed

in all items of the questionnaire (for full normality test results, see <https://doi.org/10.6084/m9.figshare.27178086>). For that reason, non-parametric studies were applied (Kruskal-Wallis test for non-dichotomic variables and Mann-Whitney U Test for dichotomic ones) in order to test for the existence of significant differences between the different categories of variables. For correlated studies, the Spearman value was used. This is typical in non-parametric calculations.

For the study of predictive factors (02), multiple linear regressions were used. The combination of Likert-type scales with multiple linear regression analyses for conducting studies on predictive factors constitutes a widely employed strategy across various fields and geographical contexts. Jiménez-Rodríguez et al. (2024) applied this model in the domain of cognitive strategies for reading-writing comprehension and university students' motivation. Similarly, Posso-Yépez et al. (2025) used this approach to predict burnout among higher education students. Other studies have adopted the same methodological framework to examine factors associated with, perceived quality of learning in hybrid modalities in China (Cheng et al., 2023), life satisfaction in adults, as well as university students' engagement and academic motivation (Cobo-Rendón et al., 2022), stress levels in university populations (Caldera Montes et al., 2024), or satisfaction with academic services at a multicultural engineering university in Bangladesh (Umar & Hasan, 2024). More specifically, within the field of communication, studies such as those García-Marín & Salvar-Mantínrey (2022) and García-Marín et al. (2025) employ the same calculations based on multiple linear regressions to analyze predictive factors.

To analyze the size of the effect in linear regressions, R^2_{adjusted} was taken as a reference. This is commonly used in work of this nature (Domínguez-Lara, 2017). Specifically, to measure the effect of the gender variable in the perception of learning (03), a study was carried out using binary logistic regression, dichotomizing both the gender variable and the one related to perception of learning, as is explained in section. All statistical analysis was carried out using the SPSS v.26 software (full database at <https://doi.org/10.6084/m9.figshare.27966612>).

The study obtained a favorable resolution as good practice from the Ethics Committee of one of the universities of the research team (internal registration number: 200420242632024; approval date: May 7, 2024).

3. Results

3.1. Comparative study Spain-Germany

Tables 2 and 3 show the results of the comparative study between the two countries (01). It should be borne in mind that in Table 2 the data in brackets relate to Germany (whereas there are no brackets round the frequencies of the study carried out in Spain).

Table 2. *Frequencies of each variable in Spain and Germany**

Item / Variable	1	2	3	4	5	Diff. ** (4-5)
Dimension 1. Design-Gamification-Interactivity						
Q8. The immersive piece is like a game	6,1% (6,4%)	6,5% (7,3%)	14,5% (22%)	26,1% (30,3%)	46,9% (34%)	8,7%
Q9. I liked the design of the application	7,1% (7%)	3,9% (8,1%)	13,1% (18,8%)	27,8% (32,5%)	48% (33,6%)	9,7%
Q10. Perception of interactivity	5,1% (5,3%)	3,3% (7,3%)	12,2% (24,2%)	26,3% (26,9%)	53,1% (36,3%)	16,2%
Dimension 2. Ease of use and navigation						
Q11. Perception of ease of use	6,3% (7%)	8,8% (14,7%)	20,6% (30,3%)	29,8% (27,8%)	34,5% (20,3%)	16,2%
Q12. Ease of understanding of instructions	7,1% (8,1%)	8,4% (12,8%)	18% (23,3%)	31,6% (28,2%)	34,9% (27,6%)	10,7%
Q13. Perception of ease of navigation	8% (6,6%)	9% (13,7%)	18,8% (31,8%)	33,1% (25%)	31% (22,9%)	16,2%
Q14. Absence of perception of dizziness	27,8% (21,6%)	14,7% (19,2%)	15,3% (13%)	15,5% (14,7%)	26,7% (31,6%)	4,1%
Dimension 3. Attention						
Q15. The experience of VR helped me stay focused	9,4% (14,1%)	7,5% (17,1%)	21% (25,9%)	27,3% (22%)	34,9% (20,9%)	19,3%
Q16. The design of the experience helped me stay focused	9% (13,2%)	8,6% (16,5%)	23,3% (31%)	27,6% (20,3%)	31,4% (19%)	19,7%
Q17. Having a lot of activities helped me stay focused	8,4% (13,3%)	7,8% (16,7%)	26,3% (32,7%)	29,8% (21,1%)	27,6% (16%)	20,3%

(continued)

Table 2. *Frequencies of each variable in Spain and Germany* (continued)*

Item / Variable	1	2	3	4	5	Diff. ** (4-5)
Dimension 4. Relevance						
Q18. The VR piece is related to topics which I had already studied	9,4% (12,4%)	5,3% (13%)	14,9% (24,6%)	22,5% (24,1%)	47,8% (25,9%)	20,3%
Q19. Intention to know more about the content after the experience	13,7% (17,7%)	10,4% (21,8%)	21% (27,8%)	25,1% (15,2%)	29,8% (17,5%)	22,2%
Q20. Perception of educational usefulness	8,2% (10%)	10,4% (13,7%)	16,9% (27,3%)	28,6% (24,6%)	35,9% (24,4%)	15,5%
Q21. Perception of learning	20,4% (20,3%)	14,7% (16,4%)	23,5% (23,9%)	18,4% (20,5%)	22,9% (19%)	1,8%
Dimension 5. Confidence / security of learning						
Q22. Confidence in learning	15,1% (14,1%)	14,9% (16,2%)	30% (31,2%)	19,4% (20,9%)	20,6% (17,7%)	1,4%
Q23. Confidence of passing an exam on the subject after the immersive experience	20% (25,4%)	15,5% (20,9%)	23,9% (23,7%)	16,5% (16,2%)	24,1% (13,9%)	10,5%
Q24. Confidence of learning thanks to the design of the activity	14,7% (16,9%)	11,8% (20,5%)	28,2% (30,5%)	21,1% (18,4%)	24,1% (13,7%)	13,1%
Dimension 6. Satisfaction						
Q.25. General satisfaction with the experience	7,5% (6,8%)	7,8% (7,5%)	11,6% (14,1%)	22,2% (19,7%)	51% (51,9%)	1,6%

**Results from Germany in brackets.*

***Deviation between the total frequency scores 4 and 5, (expressing agreement) in both countries.*

Source: authors' own material.

Table 3. *Average scores, SD and Mann-Whitney U tests in Spain and Germany**

Item / Variable	Spain	Germany	Total	p**
Dimension 1. Design-Gamification-Interactivity				
Q8. The activity is like a game	4,01 (1,19)	3,78 (1,17)	3,89 (1,18)	< .001
Q9. I liked the design of the application	4,06 (1,18)	3,78 (1,19)	3,92 (1,19)	< .001
Q10. Perception of interactivity	4,19 (1,10)	3,82 (1,15)	4,00 (1,14)	< .001

Dimension 2. Ease of use and navigation				
Q11. Perception of ease of use	3,77 (1,19)	3,40 (1,16)	3,58 (1,19)	< .001
Q12. Understanding of instructions	3,79 (1,20)	3,55 (1,24)	3,66 (1,23)	< .001
Q13. Perception of simplicity of navigation	3,70 (1,22)	3,44 (1,17)	3,57 (1,20)	< .001
Q14. Absence of sense of dizziness	2,98 (1,57)	3,15 (1,56)	3,07 (1,57)	.062
Dimension 3. Attention				
Q15. The VR experience helped me stay focused	3,71 (1,27)	3,18 (1,32)	3,44 (1,32)	< .001
Q16. The design of the experience helped me stay focused	3,64 (1,25)	3,15 (1,27)	3,39 (1,28)	< .001
Q17. Having a lot of activities helped me stay focused	3,60 (1,20)	3,10 (1,24)	3,35 (1,25)	< .001
Dimension 4. Relevance				
Q18. The VR activity is related to topics I had already studied	3,94 (1,29)	3,38 (1,32)	3,66 (1,34)	< .001
Q19. Intention to know more about the topic after the experience	3,47 (1,37)	2,93 (1,33)	3,19 (1,37)	< .001
Q20. Perception of educational usefulness	3,74 (1,27)	3,40 (1,26)	3,56 (1,28)	< .001
Q21. Perception of learning	3,09 (1,43)	3,02 (1,39)	3,05 (1,41)	.392
Dimension 5. Confidence / security of learning				
Q22. Confidence of learning	3,15 (1,32)	3,12 (1,27)	3,14 (1,29)	.624
Q23. Confidence of passing an exam on the topic after completing the immersive experience	3,09 (1,44)	2,72 (1,36)	2,90 (1,41)	< .001
Q24. Confidence in learning thanks to the design of the immersive activity	3,28 (1,34)	2,92 (1,26)	3,10 (1,31)	< .001
Dimension 6. Satisfaction				
Q25. General satisfaction with the experience	4,01 (1,27)	4,02 (1,25)	4,02 (1,26)	.893

**Standard deviation (SD) in brackets*

*** Statistically significant differences when < .05*

Source: authors' own material.

The comparative analysis between Spain and Germany has shown that the immersive narratives used are, in general, more highly rated by Spanish pupils than German ones. There are considerable differences (of up to 15.5%) in the perception of learning usefulness of the VR items analyzed: whereas 2 out of every 3 Spanish students (64.5%) consider them useful from the education point of view, less

than half German students acknowledge that usefulness (49%). Another relevant discrepancy is to be found in the variable related to the intention to know more about the content after the VR experience. 54.9% of Spanish participants state that they intend to know more about content, a score which is 22.2% higher than that of Germany (32.7%).

Similarly, there are very considerable differences (all with a difference of around 20%) in all the variables included in the dimension of attention. For example, while 62.2% of Spanish students agree with the statement “The VR experience helped me remain focused”, the percentage of German pupils only reached 42.9%. Similar results are registered in the rest of the items in this dimension.

In the two most technical/structural dimensions, the differences are also significant. It is most noticeable in the variable related to the perception of interactivity (the dimension related to design, gamification and interactivity): 79.4% of Spanish participants perceive the activities as interactive as compared to 63.2% of Germans (16.2% of difference). In the dimension about ease of use, the most significant differences occur in (1) the perception of ease of navigation (64.1% of Spanish students observed an ease of navigation of the tools as opposed to 47.9% in Germany, a difference of 16.2%) and (2) in the perception of ease of use (64.3% agree in Spain as opposed to 48.1% in Germany, which also represents a difference of 16.2%).

For greater granularity in the data, a Mann-Whitney U test was carried out to compare the average for each of the items assessed in each country in order to check for the existence of significant deviations (Table 3). For all variables the averages are higher in Spain (except in the variable regarding absence of dizziness which scored higher in Germany). As expected, significant statistical differences were observed in practically all items. The only four variables in which no deviations are registered are: (1) absence of perception of dizziness ($p = .062$), (2) perception of learning ($p = .392$), (3) general confidence in learning ($p = .624$) and (4) general satisfaction with the experience ($p = .893$).

Although Spanish students consistently obtained higher mean scores across most variables analysed, statistically significant differences were not observed in the specific item measuring perception of learning (Q21; $p = .392$). However, significant differences were found in several key dimensions strongly associated with perceived learning, particularly in relevance (Q18–Q20), attention (Q15–Q17), and some confidence-related variables (Q23–Q24). These results suggest that, while di-

rect self-reported learning perception does not differ significantly between countries, the pedagogical factors that predict such perception show a more favourable pattern among Spanish students.

The greater familiarity of German pupils with VR may explain this more critical attitude which German students showed regarding the immersive narratives used in the study. According to the results obtained, young Germans acknowledged that they have more experience with VR technology (67.85% of German pupils stated that they either own VR glasses or have used them before, compared to 47.25% of Spanish students). This may account for the smaller initial fascination for the topics analyzed. The fact that the variable "Absence of a sense of dizziness" was the one in which German pupils scored better than their Spanish counterparts is coherent with a greater familiarity and use of this technology among German students.

3.2. Predictive factors in the perception of learning

The study of predictive factors was done with the aggregate sample, including the data from both countries (02). Firstly, the correlational study showed that all independent variables associated positively with the perception of learning ($p < .001$ in all cases). The most robust correlations (all those either strong or moderate) relate to the following variables:

1. Perception of confidence in learning thanks to the design of the immersive activity ($Rho = .641$; $p < .001$).
2. Perception of educational usefulness ($Rho = .601$; $p < .001$).
3. Perception of confidence of learning during their interaction with the immersive activity ($Rho = .599$; $p < .001$).
4. Intention to know more about the content after the experience ($Rho = .533$; $p < .001$).
5. Having a lot of activities helped me stay focused ($Rho = .528$; $p < .001$).
6. The design of the immersive experience helped me stay focused ($Rho = .520$; $p < .001$).
7. Perception of being able to pass an exam after the immersive experience ($Rho = .504$; $p < .001$).

Summing up, the strongest correlations within the learning variable are found in the dimensions related to (1) confidence / security of learning which they generate among pupils (2) relevance and (3) attention. Bearing in mind these data regarding associations between variables, linear regression tests were carried out to determine the specific factors which predict the behavior of the dependent variable.

Table 4 shows the data from the multiple linear regression model. Of all the associated factors, only seven affect the dependent variable. The safety value in learning during the activities is the one which best predicts a high perception of learning ($\beta = .450$, $p < .001$), followed by the perception of educational usefulness ($\beta = .212$, $p < .001$), the fact that the activity is related to topics already studied ($\beta = .099$, $p < .001$) and the intention to know more about the content ($\beta = .088$, $p = .004$). Although the effect is more moderate, three other variables also predict the perception of learning: (1) the absence of a sense of dizziness ($\beta = .072$, $p = .002$), having a lot of activities to stay focused ($\beta = .080$, $p = .008$) and, finally, the confidence in passing an exam about the topic after the immersive experience ($\beta = .061$, $p = .044$). Altogether, these seven factors predict 55.6% of the behavior of the dependent variable ($R^2 = .559$; $R^2_{\text{adjusted}} = .556$) [$R = .747$, $F(7, 1042) = 175.07$, $p < .001$], which constitutes a predictive capacity between moderate and strong (Ferguson, 2009).

Table 4. Predictive variables of the perception of learning

Predictive variable			β	p
Q22. Confidence of learning			.450	< .001
Q20. Perception of educational usefulness			.212	< .001
Q18. The VR experiment is related to topics I had already studied			.099	< .001
Q19. Intention to know more about the content after the experiment			.088	.004
Q14. Absence of a sense of dizziness			.072	.002
Q17. Having a lot of activities helped me stay focused			.080	.008
Q23. Sure I would pass an exam on the topic after the immersive experience			.061	.044
Summary of the model (final step)				
F	p	R		R^2 (R^2_{adjusted})
175.07	< .001	.747		.559 (.556)

Source: authors' own material.

The model observes that the variables of relevance are the ones which best predict the perception of learning, followed by those related to confidence/being sure of learning. Only one attention variable and another about the usefulness of VR technology are relevant. The null predictive capacity of design, gamification and interactivity of VR pieces is significant.

In addition to these quantitative variables, in our study we also explored the effect of the gender variable on the perception of learning (Q3). Given that this is a qualitative variable, independent tests were carried out to check the predictive capacity of this variable. It should be remembered that this calculation was made using the data of those participants who had selected the option “male” or “female” in the question about gender, with the other two categories being missing data. The Mann-Whitney U Test observed statistically significant differences between males and females from both countries ($p < .001$): whilst male participants scored their level of perceived learning at 3.24 (Likert scale 1-5), female participants scored it considerably lower ($M = 2.78$). Linear regression tests confirmed that the gender variable *does* influence the perception of learning ($\beta = .159$, $p < .001$) (Table 5).

Table 5. Predictive models of gender for perception of learning

Linear regression				
Predictive variable		β		p
Q1. Gender		.159		< .001
Summary of model				
F	p	R	R^2 (R^2_{adjusted})	
25.218	< .001	.159	.025 (.024)	
Binary logistic regression				
Predictive variable		B	p	Exp(B)
Q1. Gender		.469	< .001	1.598
Summary of model				
Omnibus coefficient test		R^2 Nagelkerke		
$X^2=12.122$, $gl=1$, $p<.001$		.017		

Source: authors' own material.

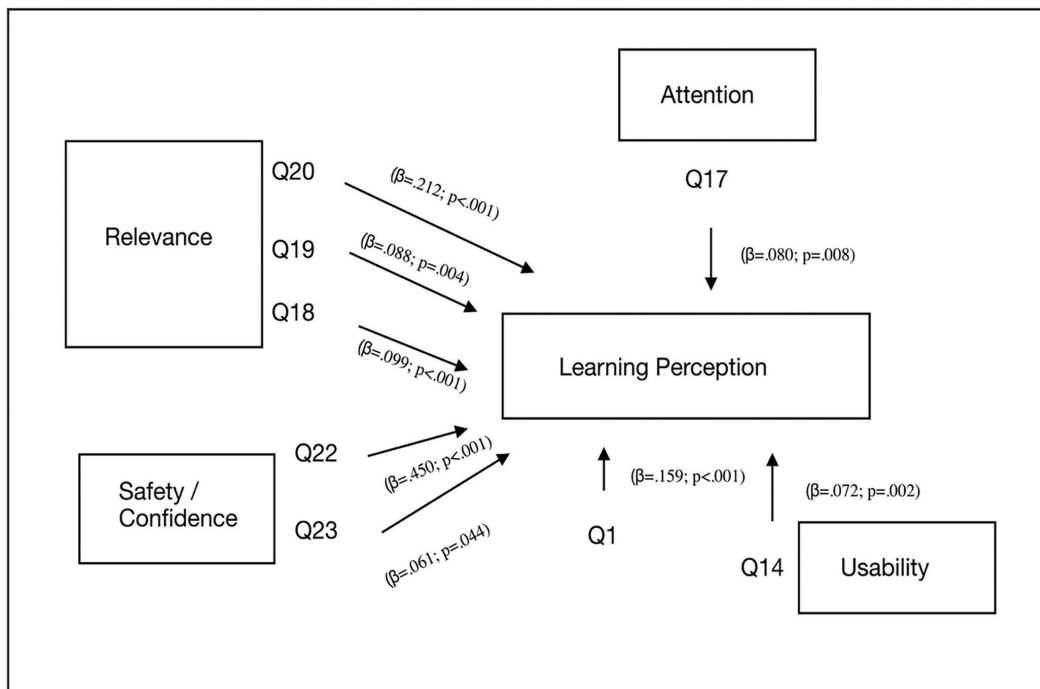
To confirm this association, a logistic regression test was carried out, converting the dependent variable into a dichotomy. From the variable related to perception of

learning, a new variable called “high perception of learning” was created to group the categories as follows: Likert score of 1-3: No, Likert score of 4 or 5: Yes.

The omnibus coefficient tests confirm the model ($p < .001$). It can be observed that men have practically 60% more probability of perceiving a high level of learning with the use of the VR tools analyzed in the study [$\text{Exp}(B) = 1.598$; $p < .001$] (Table 5).

Figure 1 sums up the complete predictive model including all variables which affect the perception of learning with VR.

Figure 1. Predictive model of perception of learning with VR



Source: authors' own material.

4. Conclusions and discussion

According to the data obtained, Spanish students showed a more favourable evaluation of several pedagogical dimensions associated with the use of VR tools in

education, particularly in relevance, attention and certain confidence-related variables. However, no statistically significant differences were found between Spain and Germany in the direct measure of perceived learning. The differences observed were therefore concentrated in the underlying factors that predict learning perception rather than in the perception of learning itself.

The differences in perception between the two countries - which were significant in statistical terms - are particularly striking when it comes to motivation to continue learning about the topics of the immersive experiment. This variable falls under the category of relevance. It is precisely in this dimension where the greatest differences are observed, and it is key to the perception of learning. In fact, the second variable in terms of significant differences is also related to this category: the connection between the VR activities and content studied previously. This last aspect shows the difficulty in applying the same educational content in different contexts where the school curriculum and rhythms of learning diverge. This is a drawback for educational solutions designed for countries where the syllabus is not the same.

It is, therefore, necessary for teachers to carry out analysis and adapt teaching material - all of which can be very complex (Jakubowski et al., 2019). This limitation in the application of VR in education has not been the subject of much scientific literature which tends to focus more on other issues: the need for continuous updates of technology (Boetje & van Ginkel, 2021), the prevalence of application in the field of health science as opposed to other areas of knowledge (Cabrera-Duffaut et al., 2024), the problems associated with the design of tools, the generation of unease, dizziness, burnout or fatigue in users (Marrero Galván & Hernández Padrón, 2022), or the high investment in *hardware* and *software* (Mallek et al., 2024). All of these factors mean that not all schools can afford to acquire this technology.

The differences associated with gender may be caused by the difference in previous experience with VR and video games. The data from our questionnaire reveal statistically significant deviations by gender in both variables. On the one hand, 58.1% of males interviewed state that they have previous experience with VR tools whereas only 42.5% of females do. The Fisher test reveals relevant differences with this variable ($p < .001$). On the other hand, in the question about use of video games, boys scored much higher than girls (4.07 as opposed to 2.74 on

the Likert scale 1-5). There are also significant differences in the Mann-Whitney U Test ($p < .001$). Previous research shows that male pupils tend to have more skills than females in activities which require spatial ability (Heo & Toomey, 2020). This ability is crucial when working with educational VR resources. It is perhaps for that reason that female pupils experienced cognitive overload when working with technologies that require high spatial skills, as is the case with VR. This may, in turn, lead to poorer academic performance (Jian & Abu Bakar, 2024). Future studies may seek to confirm that hypothesis. Consequently, it is important to reduce the cognitive load when producing immersive educational material to allow those pupils with more limited spatial skills to enjoy a more appropriate learning environment (Heo & Toomey, 2020).

The study of predictive factors with the aggregate sample reveals that, firstly, the variables of perceived educational relevance in the immersive experience are the ones which have most influence on the perception of learning. The second most relevant block of variables is the one related to confidence/being sure of learning during the use of VR pieces. The dimensions of attention and usefulness are less transcendental. In the case of usability, only the variable of a sense of dizziness is significant. It is the basic and evident one: an immersive activity is unlikely to be useful from an educational point of view if it causes physical unease in users. Similarly, no technical-structural variable related to design, gamification and interactivity affected the perception of learning. Not even the use of gamified activities nor a more attractive design and not even a greater interactivity seem to have an impact on the perception of learning obtained and neither do other variables related to usability such as ease of use, easy to understand instructions or the perception of ease of navigation.

4.1. Limitations

This study sets out several limitations. The first is its focus on STEM subjects - consequently it would not be appropriate to apply similar studies to other subject areas. Secondly, the work was carried out in two countries which already boast a certain development in immersive technologies, so it would be of interest to investigate the situations of other contexts where these tools have less of a presence.

It is also necessary to consider the possible biases caused by pupils' previous experience using VR technologies (mitigated by the introductory explanations of teachers about the narratives to be assessed). Another factor is the possible tiredness caused by the testing of several experiments in the same day (we tried to solve this problem by dividing the experience into several days). Another possible limitation comes, paradoxically, from one of the strengths of the study: the use of *ad hoc* material may influence some results (integration into the curriculum, perceived relevance, etc.) which could have been different if we had used educational material designed by third parties and already available in the market.

Moreover, it could be of interest to complement the study with clustering analyses in order to further strengthen the statistical examination, given that sufficient data are available for this purpose and the dataset is being made accessible to the scientific community.

Author contributions

Victoria Mora de la Torre: Conceptualization, Formal Analysis, Investigation, Methodology, Validation, Visualization, Software, Writing – Original Draft, Writing – Review & Editing.

Marina Santín: Conceptualization, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing.

David García-Marín: Conceptualization, Formal Analysis, Investigation, Methodology, Visualization, Writing – Original Draft, Writing – Review & Editing.

Ricardo Roncero Palomar: Conceptualization, Formal Analysis, Investigation, Methodology, Visualization, Writing – Original Draft, Writing – Review & Editing.

Benjamin Dally: Conceptualization, Formal Analysis, Investigation, Writing – Review & Editing. All authors have read and agreed with the published version of the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethics Committee

The study received approval from the Ethics Committee of Rey Juan Carlos University (internal registration number: 200420242632024; date of approval: 7 May 2024).

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Complementary material

Lessons in VR: <https://doi.org/10.6084/m9.figshare.27178068>

Normality tests (for statistical calculations):

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