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Immersive Sciences: Engaging Young Minds in Natural Sciences through Virtual and Augmented Reality

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Abstract. This study investigated the impact of virtual environments (VEs), such as Virtual Reality (VR) and Augmented Reality (AR), on learning processes within Natural Sciences course of second-grade primary education. To address this objective, an experimental study was designed using a sample of 24 students aged 7 to 8 years from Spain. The subjects used VR and AR to teach about the human body. Knowledge gains were evaluated with pre-tests, post-tests, and delayed tests. Results showed significant improvements in student understanding of the human body. All students improved their results after the experience using VEs, and 14 students achieved post-test scores 80% higher than their pre-test results. The gains obtained through the experience were sustained over time, even after 52 days. While VEs were generally well-received and sparked interest among students in continuing their use, some expressed a preference for traditional learning methods. This research highlights the potential of using VR and AR to overcome challenges in learning abstract or inscrutable concepts in Natural Sciences, such as understanding the internal elements of the human body. By offering immersive experiences, these tools provide a more realistic and tangible view of the subject matter. However, they should be used to complement, not replace, other methodologies, ensuring they align with the student' interests and needs.

Keywords: educational technology; experiential learning; primary education; virtual environments

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1. Introduction

The rapid advancement of technology is transforming the way we approach education, especially in the realm of science. As digital tools evolve, so does the potential for creating more engaging and effective learning environments. Virtual Environments (VEs), including Virtual Reality (VR) and Augmented Reality (AR), offer unique opportunities to explore complex topics in ways that traditional methods cannot. This study delves into the potential of these immersive technologies to enhance the learning of natural sciences in primary education.

Internationally, various policies have been formulated to integrate Information and Communication Technologies (ICT) into the school curriculum. Examples include the International Society for Technology in Education (ISTE) in the United States, the Standards for the Award of Qualified Teacher Status (QTS) in the United Kingdom, the European Pedagogical ICT License as part of European Commission policy, and initiatives from international organizations such as UNESCO (Leiva et al., 2018). In Spain context, the current educational system, regulated by Organic Law 3/2020 (LOMLOE), emphasises the importance of developing digital competence in students.

In this context, an emerging resource in the educational field is the use of Virtual Environments (VEs) such as Virtual Reality (VR) and Augmented Reality (AR) to create realistic and immersive experiences for the students (Meccawy, 2023). VR creates computer-enabled simulations that replicate real-world experiences within a virtual environment (Bailenson et al., 2008). AR is defined as an enhanced version of the physical world achieved using digital visual elements, sound, or other sensory stimuli delivered via technology. It is a technology that layers computer-generated enhancements atop an existing reality to make it more meaningful through the ability to interact with it (Billinghurst et al., 2015).

Learning through VEs can serve as a powerful tool to enhance experiential learning and boost student motivation and engagement by making learning more attractive and relevant (Oubibi & Hryshayeva, 2024). The intrinsic properties of VEs, including their ability to represent complex systems, allow them to play a pivotal role in training and learning processes. Furthermore, by creating immersive experiences that closely mimic real-world environments, VEs increase the authenticity of content, making it more relatable and realistic for learners (Parong & Mayer, 2018). This creative and sensory-rich approach fosters innovative thinking and deeper understanding (Dede, 2009).

Checa and Bustillo (2019) assessed the strengths and weaknesses of VR compared to educational videos, focusing on the depiction of the city of Briviesca in the 15th century. Their findings indicated a strong preference among students for the VR environment over traditional video formats. Similarly, Sun et al. (2019) found that learning performance was superior in VR-based environments compared to traditional methodologies. Kwon (2019) also highlighted the enhanced learning effects facilitated by direct interaction within virtual environments. Sulisworo et al. (2022) explored VR's effectiveness in Primary Education, particularly its use in teaching about animals in their natural habitats. The results showed not only improved learning outcomes but also significant gains in competencies such as higher-order thinking skills, spatial abilities (e.g., spatial visualization and spatial orientation), and conceptual understanding. Martarelli et al. (2023) used VR with 11-12-year-old children and found that those who used VR outperformed those using computers in learning about the water cycle. According to the authors, VR is a promising tool for teaching science topics that involve otherwise inaccessible aspects of the world. With respect to the use of AR, the benefits reported in the literature include: improvement in the understanding of abstract concepts and an increase in student motivation (Su et al., 2022); increase in student interaction and participation, and improvement in learning outcomes (Chen et al., 2017); facilitation of more immersive and hands-on learning, especially in science and mathematics (Kipper & Rampolla, 2012); improvement in spatial skills, an increase in information retention, and overall student satisfaction (Akçayır & Akçayır, 2017); and the promotion of collaborative learning and enhancement of problem-solving skills (Radu, 2014). In the context of science teaching, Abdullah et al. (2022) found students benefitted in five ways by using AR: satisfaction, ability to obtain information, learning ability, learnability level in learning science, and interest level towards science education.

According to the mentioned studies, the educational benefits of VEs appear promising. However, as Liu et al. (2022) noted, the current literature remains limited. The use of advanced technologies for interactive science learning is gaining interest, improving visualization and interaction with complex concepts. For example, students often struggle with natural science topics like weather phenomena or the respiratory system. VEs can enhance comprehension and learning outcomes in these areas, offering real-time feedback to quickly correct misconceptions and reinforce learning (Garzón & Acevedo, 2019). This study contributes by offering valuable insights into how students interact with VEs, helping educators understand how these technologies affect the learning process and student engagement. It also sheds light on the students' levels of satisfaction with using VEs, revealing whether they find it more appealing and effective compared to traditional methods.

Building on the successful implementations of VEs in educational settings, this study posed the following research question: How do Virtual Environments (VEs) impact the acquisition of science concepts related to the human body, and how do students perceive their satisfaction when using VEs for learning purposes in second-grade primary education? To address this question, the study aimed to achieve three objectives:

1. To analyse the impact of VEs on the acquisition of science concepts related to the human body among second-grade primary education students.
2. To evaluate the satisfaction levels of students when engaging with VEs for learning purposes.
3. To analyse the relationship between the acquisition of science concepts related to the human body and the satisfaction levels of students using VEs.

2. Methodology

2.1 Research Design

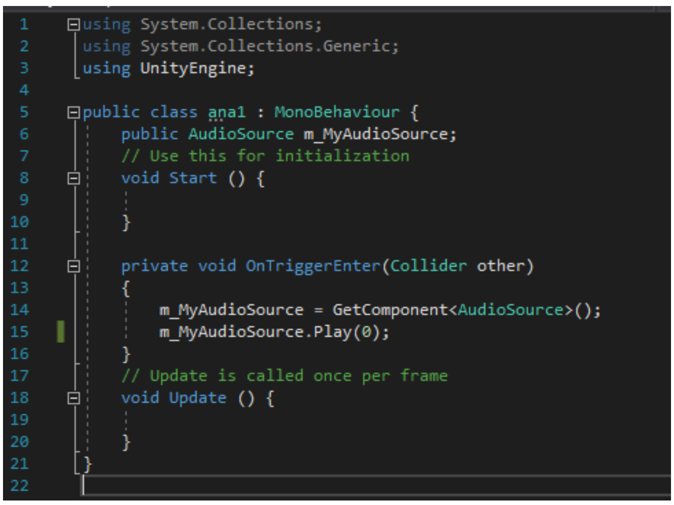
An experimental study was designed to meet the research objectives. Based on Córcoles-Charcos et al. (2023), two dependent variables were assessed: student performance and satisfaction. To achieve this, two groups of second-grade students from a school in the Community of Madrid participated in this study. The intervention proposal was contextualized within a didactic unit on the human body.

2.2 Participants and Context

The study was conducted with two groups of second graders at a semi-private school located in the city of Alcalá de Henares (Madrid). A total of 24 students aged between 7 and 8 years (12 male and 12 female) participated in this study. This age range was chosen due to the difficulties that children sometimes exhibit in understanding abstract content, making it a stage where the use of VEs can be potentially beneficial. The sample selection was based on convenience and accessibility due to the difficulties of randomly accessing a sample of school-aged students. This non-probability sampling method is commonly used in educational research when time or resources are limited (Golzar et al., 2022). Permission was requested from the school and families to carry out the study, and informed consent was provided to all families to implement the experience and collect and process the data anonymously.

2.3 Materials

To implement VEs in the school, we employed two resources: Unity software and the Body Planet app. To implement VR in the class, the Unity development environment (a multi-platform video game development engine) programmed in C#, Blender 2.8 for 3D graphics modelling, and GIMP for texture creation were used. Figure 1 shows an example of the programming of the explanatory audios in the virtual environment.



```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ana1 : MonoBehaviour {
    public AudioSource m_MyAudioSource;
    // Use this for initialization
    void Start () {

    }

    private void OnTriggerEnter(Collider other)
    {
        m_MyAudioSource = GetComponent<AudioSource>();
        m_MyAudioSource.Play(0);
    }
    // Update is called once per frame
    void Update () {

    }
}
```

Figure 1: Programming of the explanatory audios in the virtual environment

Subsequently, to facilitate the experience for the students, Jugetrónica VR Phone Glasses 2.0 were used, which allowed projecting the VR experience through a Samsung Galaxy A40 mobile device.

To implement AR, the Body Planet app was utilized. This is an educational tool designed to teach the human body. By utilizing AR technology, users could explore various human body parts, including the muscular, skeletal, circulatory, and respiratory systems, by simply pointing their mobile device at a special T-shirt or a provided human body map. The app brings printed images to life on the device's screen, displaying animated 3D models of organs and body systems, allowing users to see the heart beating, lungs breathing, blood circulating, and more.

2.4 Implementation

The implementation of VEs was carried out during two classes in the context of the didactic unit that lasted 3 weeks. Days before the implementation, at the beginning of the didactic unit, students took a pre-test based on contents related to the human body and the respiratory system. In the third class of the didactic unit, students employed VR glasses for approximately 10 minutes. During this time, students completed a tour inside the human body. In the sixth class, AR was implemented for 60 minutes.

After the experience, the students took the initial test again (post-test) to analyse the concepts they had acquired. Fifty-two days after the intervention, the same test was administered to verify whether the students retained the concepts learned (delayed test). The decision to administer the delayed test after 52 days was based on Martarelli et al. (2023), who conducted similar research on the impact of VR on learning and implemented a delayed test after 8 weeks. Studies indicate that the spacing effect, where information is reviewed or tested after extended intervals, enhances long-term retention (Rohrer & Taylor, 2006).

2.5 Didactic Proposal

The pedagogical proposal was framed within the subject of Natural Sciences and as part of the project called "Interdisciplinary Educational Project, Once upon a time my body". The pedagogical objectives of the proposal were:

1. To recognise the main systems and organs of the human body and their functions.
2. To know the physical characteristics of the systems and organs of the human body.

These objectives were chosen to be addressed through VEs due to their abstract nature, which could be challenging for students when taught using traditional methodologies and non-visual materials. The proposal was carried out by the same teacher, maintaining the stability and homogeneity of the intervention in both groups.

In the use of VR, first, the students accessed a first virtual screen located in a welcome room in which an explanatory video was shown as seen in Figure 2.

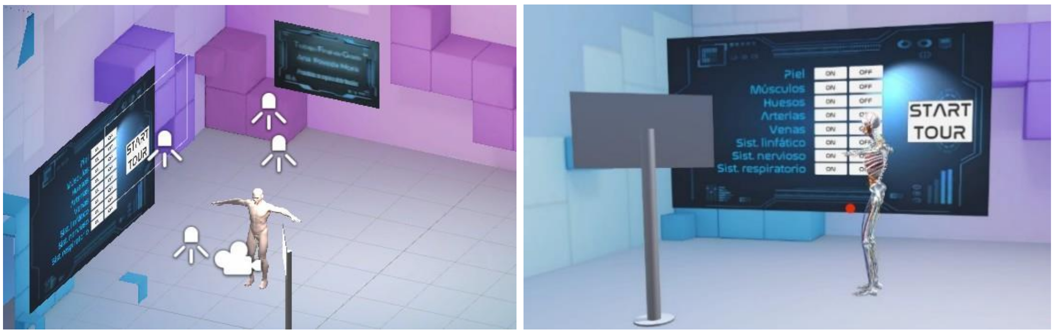


Figure 2: Welcome screen to the virtual scenario

Subsequently, from this room, students could access to a tour through the respiratory system. This journey began in the mouth and ended in the lungs. An example of this journey is presented in Figure 3.

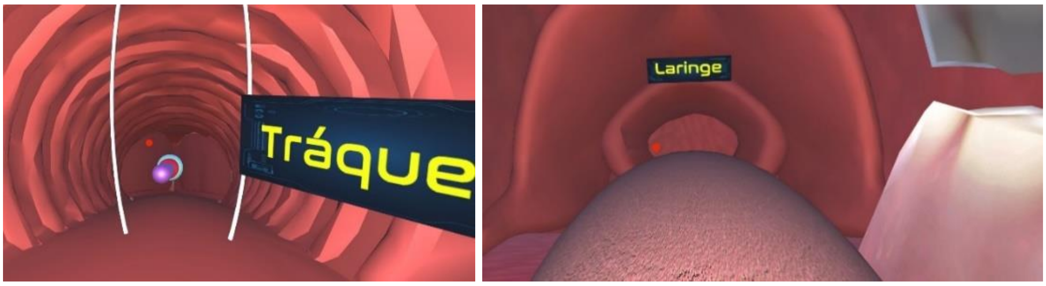


Figure 3: Examples of the virtual environment of the larynx and trachea

The implementation of VR was framed within a 3.5-hour session. At the beginning, students arrived at the classroom and discovered something new that had appeared. It was a giant mouth facilitating access to the classroom, simulating what they would later experience within the VR (Figure 4). Over the mouth, it was written the title “"Once upon a time my body".

Figure 4: Entrance doors to the classrooms

Initially, the students were gathered in an assembly being encouraged to express their thoughts about what they saw at the entrance. Afterwards, the project was explained. Subsequently, the students moved to another classroom where they discovered a box containing a surprise inside. Inside the box, there was Valentina, which was the name given to the VR glasses. This name was chosen in honour of Valentina Tereshkova, the first woman to travel to space, analogous to the students being the first to travel inside the human body.

The AR tool was incorporated in one of the educational project sessions. This is the Magic T-Shirt by Body Planet, a shirt that allows you to see inside the human body with an electronic tablet or iPad. At the beginning of the session, the T-shirt and its operation with the tablet were presented to the students. The students were able to see the organs of the human body, as well as the functioning of the digestive and circulatory systems using AR, so that in a more visual and experiential way, they could see inside the human body and locate the different organs of the human body (Figure 5).

Figure 5: The magic T-Shirt. Planet Body

2.6 Evaluation Procedure

To assess the degree of achievement of the didactic objectives, as well as the objectives of the study, two evaluation activities were carried out. The first was the knowledge test. Students were required to draw and complete on a given outline of the human body 19 elements and their functions: Brain, larynx, trachea, heart, esophagus, lungs, liver, kidneys, large intestine, small intestine, stomach, mouth, tongue, eyes, nose, ears, ovaries, nervous system and neurons. Each response was considered correct when the element was drawn in its location and its function explained. The test was developed by two expert researchers in the field, achieving 100% agreement in defining the correct answers. Additionally, the test was created in coordination with the school's teachers to ensure that the content aligned with the educational objectives of the subject. Also, given the developmental psychosocial stage of the students in this course, the test was developed with a visual and manipulative component as it is presented in Figure 6 (Gardner, 2006). The selected contents were in accordance with the official curriculum of the Community of Madrid.

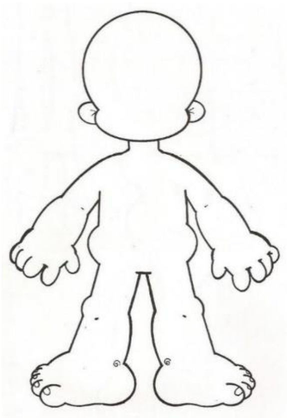


Figure 6: Human body worksheet to be filled in by the students

This test was administered on three occasions in a quiet room: pre-test, post-test, and delayed-test. The test was always administered in the same way, without any modifications between the different evaluation moments. Additionally, no feedback on the test results was provided to the students when they completed it.

The second evaluation activity was a satisfaction survey. Following the model of Córcoles-Charcos et al. (2023), an ad hoc questionnaire was designed to evaluate student satisfaction with the use of VR during the learning process. The survey was designed by two experts with more than 2000 hours teaching and included 10 items which had to be rated from 1 to 5 following the Likert scale (1-"Not at all", 2-"A little", 3-"Moderately", 4-"Quite", 5-"A lot"). This questionnaire was administered at the end of the intervention. The person in charge of administering the survey ensured that the students correctly understood the questions, addressing any doubts they had.

2.7 Statistical Analysis

In accordance with Berlanga and Rubio (2012), given the number of participants ($N < 30$), statistical analyses were conducted using non-parametric tests. Result variations from the pre-test and post-test were tested using the Wilcoxon signed-rank test. Likewise, to establish differences between groups, the Mann-Whitney U test was also carried out. To explore differences in satisfaction with the use of VEs between students with higher and lower performance on knowledge tests, two groups were established using a two-means Cluster test dividing all participants into "students with high results" and "students with lower results". The differences between male and female were analysed to control possible gender effects on results according to Hyde (2014).

Cronbach´s alpha coefficient was calculated to assess the instrument reliability (George & Mallery, 2003). To assess the effect size between continuous and dichotomous variables, we utilised the biserial rank correlation parameter (Jacobs & Viechtbauer, 2017). Finally, the relationship between the studied variables was obtained using Spearman's correlation. In all statistical tests, a significance value of $p < 0.05$ was established. All statistical analyses were done using the SPSS 28.0 package.

3. Results

In order to address the research question, the results below are presented in alignment with the three objectives set to guide the study:

3.1 Impact of VEs on the Acquisition of Science Concepts Related to the Human Body

Table 1 displays the results achieved by the groups on each test conducted at three different times: a pre-test before the intervention (PRE), a post-test immediately after (POST), and a delayed test (DT). It also presents these results for the combined groups. Furthermore, the table details the significance levels of the differences observed between each of the evaluation moments, both within each individual group and across the combined groups.

Table 1: Body elements recognized by students before and after the intervention

Sample	PRE	POST	DT	Sig. PRE-POST	Sig. PRE-DT	Sig. POST-DT
Class 2º A N = 12	8.14 ± 2.98	11 ± 3.19	13 ± 2.11	0.02*	0.01*	0.05*
Class 2º B N = 12	4.64 ± 1.86	10 ± 3.11	9.21 ± 3.38	0.01*	0.01*	0.11
Total (N = 12)	6.39 ± 3.02	10.5 ± 3.13	11.1 ± 3.37	0.01*	0.01*	0.29

*Sig. $p < 0.05$

These results indicated that both groups exhibited significant improvement in the knowledge test concerning the human body and its functions after the intervention ($p < 0.05$). It was also observed that this enhanced understanding was sustained over time, with significant differences noted between the initial evaluation and the long-term follow-up. Furthermore, every student showed improvements in the knowledge tests conducted before and after the intervention, with no instances of stagnation or decline in knowledge levels. The data suggested that most students experienced an improvement exceeding 80% relative to their baseline performance.

Group A outperformed Group B in both the pre-test and the delayed test, achieving higher scores with a significant difference ($p < 0.05$). This demonstrated a substantial effect size in both assessments, with rb values of 0.6 for the pre-test and 0.64 for the delayed test. Figure 7 illustrates the range of improvement levels among students who participated in the VEs' immersion experience.

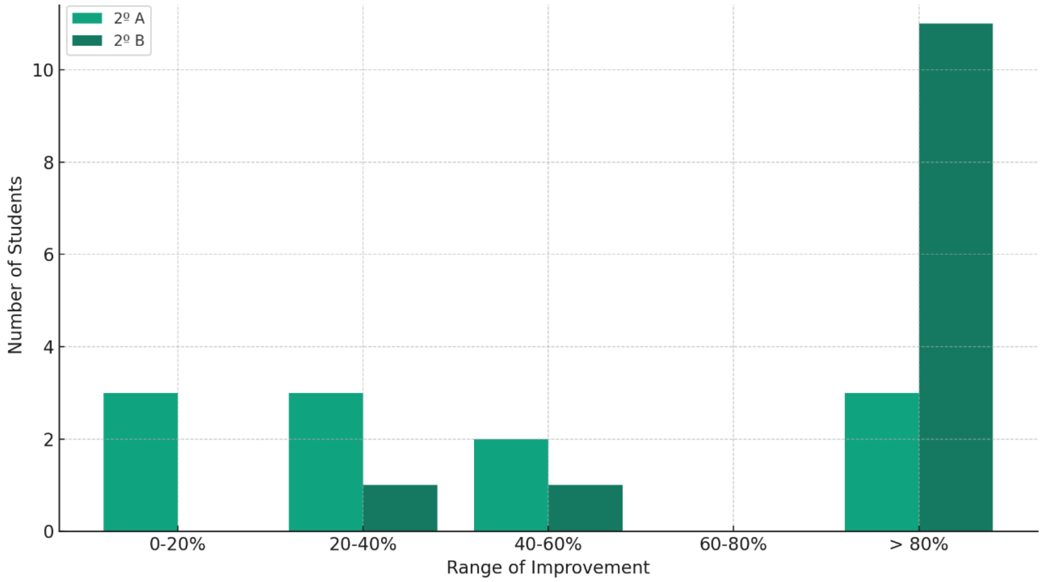


Figure 7: Distribution of students based on the percentage of improvement before and after the intervention

3.2 Satisfaction Levels of Students when Engaging with VEs Tools for Learning Purposes

Table 2 presents the levels of satisfaction among students with the incorporation of VEs into the classroom setting. The reliability of the instrument was assessed using Cronbach's alpha coefficient, which yielded a value of 0.77. This result indicates an acceptable level of reliability for the instrument, suggesting that the measurements are consistent and reliable for the purposes of this study (George & Mallery, 2003).

Table 2: Student satisfaction with the use of VEs in the classroom.

Items assessed	Group A	Group B	Total	Sig.	Size Effect
1. I prefer using the classroom book over using computers, tablets, virtual reality...	3.6 ± 1.3	4.14 ± 1.2	3.86 ± 1.3		
2. It's easy to learn about the human body parts with Valentina (the virtual reality goggles) and the Body Planet t-shirt.	4.47 ± 1.1	3.9 ± 1.3	4.21 ± 1.2		
3. The virtual reality goggles and the t-shirt help me learn about the human body better.	4.47 ± 1.1*	3.36 ± 1.5*	3.9 ± 1.4	2ºA > 2ºB	0.46
4. It's easy to learn using the virtual reality goggles and the Body Planet t-shirt.	4.29 ± 1.0*	3.23 ± 1.5*	3.78 ± 1.4	2ºA > 2ºB	0.42

5. I would like to use this material at home.	4.27 ± 1.4	3.77 ± 1.7	4.03 ± 1.6		
6. In the classes where I've used Valentina and the Body Planet t-shirt, I've been more attentive than in other classes.	4.2 ± 1.1	3.36 ± 1.4	3.79 ± 1.3		
7. The classes in which I've used Valentina and the Body Planet t-shirt have seemed more interesting to me.	4.6 ± 0.8	3.86 ± 1.4	4.24 ± 1.1		
8. I would like to have more classes where I can work with Valentina and the Body Planet t-shirt.	4.7 ± 0.6*	3.57 ± 1.4*	4.13 ± 1.2	2ºA > 2ºB	0.48
9. It's easier to follow the teacher with these materials (Valentina and Body Planet).	4.4 ± 0.6	4.0 ± 1.2	4.2 ± 0.9		
10. I have felt better in those classes than in others.	3.9 ± 1.3	4.0 ± 1.4	3.97 ± 1.3		

*Sig. $p < 0.05$

The results reflected a generally positive assessment regarding the use of VEs in the classroom. The most notable values among students indicate that using VEs makes it easy to learn about the human body systems, that they found it more interesting, and that they would like to have more classes using VEs. However, the lower values referred to the preference for using textbooks over computers, tablets, or VEs, which is consistent with the other data presented and indicated that using VEs allowed them to be more attentive. It is noteworthy that significant differences were found in both groups on questionnaire items 3, 4, and 8.

Additionally, the relationship between test results at different times was explored. The correlation between the pre-test and post-test was high (Rho = 0.7), as well as between the pre-test and delayed test (Rho = 0.65), and between the post-test and delayed test (Rho = 0.7).

3.3 Relationship between the Acquisition of Science Concepts Related to the Human Body and the Satisfaction Levels of Students Using VEs

Table 3 explores the relationship between the results on the knowledge tests and the items on the satisfaction questionnaire to determine if there was any correlation between academic performance and satisfaction with the use of VEs. Academic performance results were taken from the number of correct answers in the PRE, POST, and delayed POST tests, as well as the number of elements that had improved between the PRE and POST, appearing in Table 3 as "Improvement".

Table 3: Relationship between satisfaction items and test results

Items assessed	PRE	POST	DT	Improvement
1. I prefer using the classroom book over using computers, tablets, virtual reality...	-0.473*	-0.038	-0.186	*0.455
2. It's easy to learn about the human body parts with Valentina (the virtual reality goggles) and the Body Planet t-shirt.	0.366	0.201	0.020	-0.182
3. The virtual reality goggles and the t-shirt help me learn about the human body better.	0.168	-0.160	-0.114	-0.470*
4. It's easy to learn using the virtual reality goggles and the Body Planet t-shirt.	0.227	0.239	0.041	-0.034
5. I would like to use this material at home.	-0.208	-0.092	-0.013	-0.141
6. In the classes where I've used Valentina and the Body Planet t-shirt, I've been more attentive than in other classes.	0.114	0.105	0.032	-0.305
7. The classes in which I've used Valentina, and the Body Planet t-shirt have seemed more interesting to me.	0.312	0.188	0.018	-0.022
8. I would like to have more classes where I can work with Valentina and the Body Planet t-shirt.	0.447*	0.126	0.070	0.304
9. It's easier to follow the teacher with these materials (Valentina and Body Planet).	-0.281	-0.348	-0.343	-0.307
10. I have felt better in those classes than in others.	-0.165	0.099	-0.248	0.389

*Sig. $p < 0.05$

The table reveals that there was a positive relationship between students who had shown the most improvement with the use of VEs and their preference for using the textbook over computers, tablets, and virtual reality. Similarly, there was an inverse relationship between the improvement achieved and the perception that virtual environments (VEs) helped them better understand the human body.

To further explore the relationship between academic performance and student satisfaction with the use of VEs, a two-means Cluster was applied to the entire sample on the results immediately after the intervention. The resulting groups were:

- Group of students with high results: N = 13, Mean = 13.4 ± 1.4
- Group of students with lower results: N = 11, Mean = 7.9 ± 1.4

When contrasting the differences in satisfaction between these groups in the use of VEs, no significant differences were found between the groups; consequently, satisfaction was not influenced by final outcomes. Differences related to gender were explored; however, no significant differences were observed in most of the variables collected. The only exceptions were that males showed a higher preference (4.3 ± 1.2) for using the classroom book over using computers, tablets, virtual reality, etc., compared to females (3.5 ± 1.3; $p < 0.05$; rb = 0.42). Additionally, females presented higher pre-test results (7.58 ± 3.1) than males (5.0 ± 2.4; $p < 0.05$; rb = 0.51).

4. Discussion

The study results clearly demonstrate that using VEs positively influenced learning about the human body among 2nd grade Primary Education students in Natural Sciences. All students exhibited an improvement in their knowledge, with most showing over 80% enhancement compared to their initial test scores. This improvement was significant ($p < 0.05$) across both participant groups. These results were consistent with the starting hypothesis.

The initial factors contributing to these improvements include the enhanced spatial interaction opportunities VEs provides for students (Dalgarno & Lee, 2010). A key factor in supporting associative memory through virtual spaces is ensuring these environments realistically incorporate characteristic elements, without detracting from student attention, as suggested by Innocenti et al. (2019). Furthermore, long-term outcomes also surpassed those of the initial tests, corroborating the findings by Al-Gindy et al. (2020) that VEs enhances learning retention over time. In line with the results obtained in our study, Al-Amri et al. (2020) indicated that there is a correlation between learning through VEs and the improvement of academic results. Therefore, the use of VEs can foster positive attitudes in students towards knowledge acquisition (Plass & Kaplan, 2016), as well as facilitate learning content about the human body. Also, Abdullah et al. (2022) observed significant improvement using VEs in science education because students can visualize abstract or complex phenomena carried out in the field. To further contextualize these findings, the relationship between VEs and virtual spaces in education should be explored in depth. Analysing how these technologies interact with virtual learning environments will provide more robust insights into their potential for enhancing student learning.

Upon comparing the two groups (A and B), it was observed that students from Group B exhibited lower pre-test scores; however, they demonstrated greater improvement. Consequently, it appeared that experiences predominantly benefit those starting from a lower baseline. In accordance with Hattie (2009), this phenomenon is not exclusive to the use of VEs but generally applies to all interventions targeting students with lower initial academic performance. The comparison between the post-test and delayed results indicated that the acquired concepts were retained over time. This is consistent with Kong (2021), who points out that experience-based learning may be a contributing factor in reinforcing the impact of VEs on long-term learning. Furthermore, the strongly positive correlation observed between the pre-test, post-test, and delayed test results suggested that students who began with high scores also continued to achieve good results following the intervention.

Nevertheless, a limitation of this study is that it focused only on 2nd grade students, limiting the generalizability of the findings across other grade levels. A comparative analysis with different grades is needed to better understand the broader applicability of VEs in primary education. Additionally, the cultural and environmental factors specific to the Spanish educational context may have influenced these results. Thus, further research should examine how these factors affect the implementation and effectiveness of VEs by comparing results across different contexts and cultures.

The results regarding student satisfaction after the activity were positive, especially highlighting three values. In the first one (N. 7), we can observe that learning using VEs is more appealing than traditional methodology. The second (N. 2) refers to the ease of learning the human body through VEs; and the third (N. 9), addresses the comprehensibility when following the teacher's explanations. Also noteworthy is item N. 8, which affirms that students have greater desire to incorporate VEs into a greater number of classes. All these aspects are directly related to the capacity of VEs as a motivational tool compared to those not using VEs in learning (Abdullah et al., 2022; Laine et al., 2023; Sulisworo et al., 2022).

Despite these results, a significant difference between the groups was shown. In the Group A, students indicated that VEs helped them learn better and that they would like to have more classes using VEs. This might be due to these students having had prior contact with new technologies and feeling more familiar when using these types of digital tools. It is essential to ascertain prior interests and experiences when designing the implementation of VEs (Makransky & Lilleholt, 2018). Indeed, lacking this background information severely limits our capacity to clarify these differences is evaluating the digital competence and previous experience of the participating students.

Regarding the relationship between student learning outcomes and the satisfaction survey, a significant correlation ($p < 0.05$) was observed between students' academic performance and satisfaction with the use of VEs. Córcoles-Charcos et al. (2023) indicated that the use of VEs generates a set of positive impressions that increase student motivation and, consequently, improve student academic performance. These authors noted that students who use VEs have higher motivation than students who learn through a traditional methodology. However, the content and the use of this tool are also important factors that can determine the impact of VEs on teaching-learning processes. Therefore, the teacher must know the motivations of the students and plan specific environments that produce a real improvement in student learning.

Contrary to what might be expected, a positive relationship was observed between students who had improved with the use of VEs and their preference for using the textbook over computers, tablets, and virtual reality. This could be due to the prominence given to textbooks in recent years (Gómez-Carrasco et al., 2022) and, therefore, a lesser development of digital competence. There was also an inversely proportional relationship between the improvement obtained and the idea that VEs can be a helpful tool. This may be because digital resources are often limited to recreational use (Gómez-Carrasco et al., 2022), limiting the ability of students to associate the use of digital tools with the content addressed in school. Likewise, the incorporation of any novel tools can itself be a challenge and an added burden for students.

In the gender comparison, there are no significant differences between males and females across most assessed items, including in the post-test and delayed evaluations. These outcomes are particularly positive, indicating that the previously identified technological barriers for females (Virtanen et al., 2015) were not evident in this study. This outcome may stem from advancements in ICT access within the social context and the educational institution's commitment to promoting ICT access with a focus on equity and equality.

Further research is needed to address the mentioned controversies and limitations in existing studies, including issues of access and cost (Fransson et al., 2020), financial viability (Innocenti et al., 2019), teacher training (Córcoles-Charcos et al., 2023), dizziness and nausea in young students (Hui et al., 2022), and the technical challenges teachers face in developing virtual environments for science classes (Cook et al., 2019).

5. Conclusion

The objectives of this study were to examine the impact of Virtual Environments (VEs) on student acquisition of scientific knowledge related to the human body, assess their satisfaction with using VEs as learning tools, and explore the relationship between academic performance and satisfaction. The findings reveal that VEs significantly enhanced the student understanding of human body systems, with all participants showing improvements in their test scores after the intervention. This demonstrates that immersive technology not only aids in immediate learning but also supports long-term retention of knowledge. Furthermore, while both student groups exhibited significant gains, the group that started with lower pre-test scores demonstrated the most improvement.

The results also underscore the high level of student satisfaction with using VEs in the classroom. Students generally found learning with VEs to be more engaging and effective than traditional methods. The positive relationship, however, between improved performance and a preference for traditional textbooks suggests that digital competence and prior experience with technology may influence how students perceive and interact with virtual learning tools.

This study highlights the potential of VEs as a powerful tool for enhancing both learning outcomes and student engagement in primary education. Educators can leverage VEs to provide experiential learning opportunities that are otherwise difficult to replicate in traditional settings. However, to maximize the benefits of VEs, it is crucial to consider students' prior digital experiences and tailor the use of technology accordingly. Future research should focus on teacher training, addressing technical challenges, and ensuring equitable access to ICT resources. These considerations will be vital in integrating VEs into broader educational practices to improve learning outcomes across diverse student populations.

6. References

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