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ORIGINAL

Minecraft as a teaching-learning environment for Natural Sciences. A quasi-experimental case study

Minecraft como ambiente de enseñanza-aprendizaje de las Ciencias Naturales. Un estudio de caso cuasiexperimental

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ABSTRACT

Introduction: this article presents the results of an evaluative process around the integration of Minecraft as a virtual teaching and learning environment for the mastery of the scientific content of the subject of Natural Sciences in the upper elementary school, highlighting a constructivist learning approach, the promotion of problem-solving skills, critical thinking and the integration of new technologies in traditional teaching environments.
Method: a quasi-experimental design was implemented, incorporating an experimental group and a control group with a total of 57 participants. A questionnaire was used as a pre-test and post-test to measure the conceptual understanding of scientific contents, which were evaluated after one month of application.
Results: the experimental group had a significant majority in academic performance, marking the effectiveness of a virtual environment such as minecraft versus traditional pedagogicalism.
Conclusions: it was demonstrated that Minecraft can improve science learning and facilitate the integration of ICT in education, becoming a virtual environment conducive to be replicated in various contexts and educational levels.

Keywords: Technology; Educational Technology; Science Education; Constructivist Learning.

RESUMEN

Introducción: el presente articulo expone los resultados de un proceso evaluativo en torno a la integración de Minecraft como ambiente virtual de enseñanza aprendizaje para el dominio del contenido científico de la asignatura de Ciencias Naturales en el subnivel de básica superior, destacando un enfoque de aprendizaje constructivista, el fomento de habilidades de resolución de problemas, el pensamiento crítico y la integración de las nuevas tecnologías en ambientes tradicionales de enseñanza.
Método: se implemento un diseño cuasiexperimental, incorporando un grupo experimental y un grupo de control con un total de 57 participantes. Se utilizó un cuestionario a modo de pre-test y post-test para medir la comprensión conceptual de los contenidos científicos, los mismos que fueron evaluado tras un mes de aplicación.
Resultados: el grupo experimental tuvo una mayoría significativa en el rendimiento académico, marcando la eficacia de un entorno virtual como minecraft frente al tradicionalismo pedagógico
Conclusiones: se demostro que Minecraft puede mejorar el aprendizaje de las ciencias y facilitar la integración de las TIC en la educación, convirtiéndose en un ambiente virtual propicio para ser replicado en diversos contextos y niveles educativo.

Palabras clave: Tecnología; Tecnología Educativa; Educación Científica; Aprendizaje Constructivista.

INTRODUCTION

The present research evaluated the implementation of Minecraft as a virtual teaching-learning environment in the Natural Sciences subject. Minecraft is a popular video game that offers a virtual world in which students can explore and build. Therefore, in this study, a quasi-experimental design was carried out to examine how the use of Minecraft improves the understanding of scientific concepts and the practice of theory.

In this way, the integration of Minecraft promotes a form of constructivist learning where students can interact with real-world simulations and visualize abstract concepts that are often difficult to understand through traditional teaching methods.[1,2,3] For example, Minecraft allows ecological systems, biogeochemical cycles, or physical principles to be simulated, enabling students to observe and manipulate variables in real time and offering a practical experience that reinforces the theory learned in class.[4]

This video game encourages the development of problem-solving and critical thinking skills, as students not only replicate what they learn theoretically but also have to apply the knowledge acquired in new and often unpredictable situations within the game.[5,6,7] This translates into more profound and lasting learning, as scientific concepts are actively explored rather than passively received. Minecraft's flexibility in adapting to different subjects and educational levels makes it a versatile resource, supporting the notion that its use can significantly improve scientific understanding and the practical application of theory in academic contexts.

However, the teaching of Natural Sciences is characterized by being a theoretical, practical, and experimental subject. However, it has been shown that the teaching of Natural Sciences is traditional, with little experimentation and more theoretical and conceptual work based on texts.[8,9,10] This approach has generated little or no scale development of scientific content and the development of theory with practice through incorporating digital competencies, which is declared to be transcendental in the curricular reform of 2021. Therefore, the failure to develop a teaching process that integrates ICT limits students' development and acquisition of skills and knowledge.[11,12,13]

Therefore, the proposal was applied to 57 seventh-year general basic education students from the Unidad Educativa Nacional Tena, Tena, Ecuador. The students are around 10 to 12 years old, a population characterized by being digital natives. Therefore, by having traditional didactics of the natural sciences, they face a generational clash, and significant learning is limited because the students, immersed in new technologies, establish learning preferences that the teachers little or poorly attended. Thus, Minecraft, being an online game widely known and appreciated by students, is an opportunity to integrate and innovate the teaching-learning process through the comprehensive development of digital skills. Adding substantial academic and social value to students for the technological challenges of the 21st century and an increasingly digitalized world.

The rise of technology has driven innovation in teaching and learning processes at all levels of education, in which ICTs have been significantly integrated into the daily work of teaching.[14,15,16] Technology has created new opportunities for educators to personalize the teaching process to meet the needs of each student and thus actively engage them in their learning. Through technology, teachers can manage meaningful, fun, and engaging education for students as it integrates various digital tools and multimedia resources that can be used to improve the teaching-learning process. These tools integrate educational games, simulations, videos, infographics, and interactive activities.[17,18]

ICTs do not transform education alone; teachers can transform the teaching and learning process by integrating them into their pedagogical practice.[19,20] Therefore, multimedia in education can improve students' understanding and help them retain information more effectively.[6] Including playful elements in the teaching process can increase students' motivation and commitment to learning.

However, what happened with the COVID-19 pandemic at the end of 2019 made clear the need for trained teachers who completely master digital skills.[21] Worldwide, there were shortcomings in the adoption of virtual education. Given this fact, research into the application and usability of various technological tools and resources has increased, where delimiting and addressing the issues that have arisen is an arduous task that never ends due to the constant evolution of new technologies.[7,8,9,10]

The use of video games in education has become a growing trend in recent years, and since the launch of Minecraft in 2009, this game has stood out as one of the most popular and versatile in this context. Minecraft is an open-world video game that allows users to build and explore virtual worlds using cubic blocks. Its educational potential has been widely recognized, and it has been used in education to promote learning in areas such as science, technology, engineering, and mathematics (STEM), as well as to develop critical thinking, creativity, and collaboration skills.[11,22]

Minecraft is not limited to entertaining; it has become a versatile and powerful educational tool. Its essence is based on a virtual world of unlimited dimensions made up of cubic blocks that users can manipulate as they wish. This characteristic of construction and exploration in a digital environment has been exploited in various ways in the educational field.[23] One of the highlights of Minecraft in academic terms is its ability to stimulate critical thinking and problem-solving. Players must plan and design their constructions, considering factors

such as geometry, physics, and logic. This encourages the development of problem-solving skills in a fun and practical way.

In addition, Minecraft promotes creativity by allowing users to give free rein to their imagination. Students can create personalized virtual structures, landscapes, and scenarios, allowing them to express their ideas uniquely. This creative capacity also extends to programming, as the game offers tools for creating modifications (mods) that involve concepts of coding and programming logic.[24,25] On the other hand, collaboration is another essential element that Minecraft encourages in the educational environment. Students can work together on shared projects, which helps them develop social, communication, and teamwork skills.

The use of Minecraft in education has also been valued for its ability to motivate students in an attractive and entertaining way. The experience of playing and creating worlds in this video game can enrich students, encouraging them to continue learning and exploring the virtual world and, therefore, acquiring new knowledge.[12] Thus, Minecraft in education can effectively improve students' motivation and commitment to learning.

To successfully integrate Minecraft into education, it is necessary to overcome the main challenge, which is that teachers have the digital skills required to effectively integrate technology into teaching, as well as knowledge and mastery of the game of Minecraft. Following that, the challenge for any proposal incorporating the constant use of technology or virtual environments such as Minecraft is access to the necessary technology and resources.[14] Therefore, these limitations must be considered, and ways must be found to provide access to the technology and resources needed to use Minecraft effectively in school. Consequently, there is the challenge of ensuring that the use of Minecraft in the classroom is aligned with learning objectives and curricular standards, that is, developing a didactic and pedagogical foundation for the content to be carried out in the virtual environment. The use of Minecraft in the classroom must be linked to established learning objectives and curricular standards to ensure that students are learning effectively.[15]

Another important challenge is the development of effective assessments to measure student learning through the use of Minecraft in the classroom. Educators must develop ways to assess student learning through Minecraft through formal or informal evaluations.[26,27] In this way, the teacher must provide a systematic subjective assessment that includes procedural, behavioral, and conceptual elements.

Finally, one of the most critical challenges is the development of a safe and appropriate environment for the use of Minecraft in the classroom. The teacher must be aware of the potential risks associated with the use of Minecraft in school, such as online bullying and access to inappropriate content.[28,29,30] Therefore, it is essential to establish clear rules and procedures to ensure that the use of Minecraft in the classroom is safe and appropriate for students, where the role of the teacher is to provide a specialized server with free but controlled and secure access, where students connect and not external agents.

Despite the challenges above, Minecraft is currently being projected to be used in different areas, disciplines, and fields of science.

METHOD

The present research subscribes to the constructivist paradigm, an approach that postulates the construction of knowledge through the interaction of the individual with their environment and previous experiences. The constructivist paradigm supports the idea that learning is an active and social process, where interaction between peers and the mediation of the environment are essential for the assimilation and accommodation of new knowledge.[17]

From this constructivist perspective, a mixed research approach is advocated, where the capacity of qualitative methods to delve into the depth of individual experiences and perceptions is valued. At the same time, the importance of quantitative methods is recognized for their potential to provide objectivity and possibilities for generalizing results. This methodological combination allows for a richer and more multifaceted understanding of the phenomena studied, in line with the complex and constructed nature of social reality (learning outcomes such as a deep understanding of student experiences.[31,32,33]

The research is conceived from an interpretive case study, which aims to provide dense and detailed descriptions to interpret and theorize about the case in question, which in turn seeks to develop conceptual categories that not only illustrate the uniqueness of the case but also allow for the ratification or challenging of existing theories. An inductive analysis model will be used, where the collected data generates emerging patterns that facilitate understanding the phenomenon studied. Similarly, a quasi-experimental design is established, which is justified by its ability to observe the real impact of an intervention in a specific educational environment, providing significant insights in an applied context.[34]

This study's population comprises students in basic secondary education, focusing specifically on those enrolled in the seventh grade between 2023 and 2024. A non-probabilistic sample of two parallel groups has been selected within this sublevel: an experimental group with 28 students and a control group with 29 students. The participants will be divided into these groups to evaluate the impact of integrating Minecraft into the Natural Sciences curriculum.

The experimental group will be subjected to didactic interventions that include using Minecraft. In contrast, the control group will continue with the institution's normative, traditional, and general curricular activities. Conceptual understanding and the intervention results will be evaluated using pre-and post-tests. These tests will be complemented by perception questionnaires and observation diaries, which will document the students' commitment and interactions with the learning environment.

The choice of Minecraft as an educational tool is based on existing literature that highlights its effectiveness in creating a solid connection between theory and practice, encouraging active and meaningful learning. [12,16] This experimental approach aims to effectively contrast traditional teaching methods with pedagogical innovations, providing valuable data on the effectiveness of virtual environments in education.

From a quantitative perspective, standardized pre- and post-intervention knowledge (pre-test and post-test) will be used to measure students' conceptual understanding of the competencies, skills, and knowledge stated in the curriculum for the seventh-year sub-level of basic general education. These tests will be designed specifically for this study and are based on current curricular standards, guaranteeing their relevance and alignment with learning objectives.

Therefore, these tests will provide comparable and quantifiable data on the direct impact of the teaching intervention on student learning. The results obtained will allow for the implementation of a rigorous statistical analysis, such as the Student's t-test, to identify significant differences between the control and experimental groups.

From a qualitative perspective: to complement the quantitative data and offer a more contextualized perspective based on the Student's experience, a focus group will be held at the end of the intervention, which will allow for flexibility to adapt to the dynamics of the student population and for its potential to explore in the experimental group the perceptions, attitudes, and reflections of the students on the use of Minecraft in their learning. In the control group, the perceptions and opinions of generating a change in class dynamics were also discussed.

In addition, participant observations will be made during class sessions and recorded in field diaries or observation sheets. These instruments will be constructed based on the specialized literature on interactive teaching methods and gamification, ensuring that the questions and topics addressed are relevant and meaningful.

The combination of these techniques will allow for data triangulation for greater validity and the possibility of correlating qualitative and quantitative results for a comprehensive understanding of Minecraft's impact as an educational tool. In terms of resources, access to the T-Launcher 1.12.16 version of Minecraft and digital platforms such as Google Forms for the administration of tests and surveys has been secured, as well as the availability of recorders and quantitative analysis software such as StatGraphics to process the results.

Proposal

The model proposal developed for this research is based on a teaching plan that integrates Minecraft as a virtual environment in teaching Natural Sciences to lower secondary school students. The proposal emerges as a quasi-experimental study in response to the growing importance of Information and Communication Technologies (ICT) in education. It has, therefore, been designed to demonstrate how Minecraft provides a teaching environment that facilitates interactive and meaningful learning while aligning with the curricular objectives of the Natural Sciences subject. The structure of this proposal includes a starting point characterized by the analysis of the results of the pre-test carried out on the two groups of students, followed by a detailed didactic plan that incorporates innovative pedagogical strategies adapted to the virtual environment of Minecraft.

Starting point

The starting point is a pre-test that was previously validated by experts, and which obtained reliability and approval by three experts. This test consists of a questionnaire of 10 questions that address the topics of Unit III of studies and is made up of different types of questions, such as: open questions, multiple-choice questions, matching with a line, true and false, completing ideas and pairing.

The test was administered to the control and experimental groups on the same day, with 100 % participation of the student population, 28 students in the experimental group and 29 students in the control group, with an approximate time of 45 minutes of resolution for each group. The following results were obtained, classified in the learning domain table established by the Ministry of Education of Ecuador (2019).

In the experimental group, 10,7 % of the students did not achieve the required learning outcomes, 46,43 % came close to achieving them, 32,14 % achieved them and 10,71 % mastered the required learning outcomes. Meanwhile, in the control group, 6,89 % did not achieve the learning outcomes, 41,47 % were close, 37,93 % achieved them and 13,79 % mastered them. These results suggest that both groups present similar challenges in terms of understanding the content, with a slight advantage in the control group at the highest levels of mastery, as evidenced in the following box and whisker plot.

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Table 1. Learning domain results in the pre-test

Learning Domains	Experimental Group	Control Group
No (24ance the required learning (0 to 3,99 points)	3 (10,71 %)	2 (6,89 %)
Close to achieving the required learning outcomes (4 to 6,99 points)	13 (46,43 %)	12 (41,47 %)
Achieves the required learning outcomes (7 to 8,99 points)	9 (32,14 %)	11(37,93 %)
Has mastered the required learning (9 to 10 points)	3 (10,71 %)	4 (13,79)

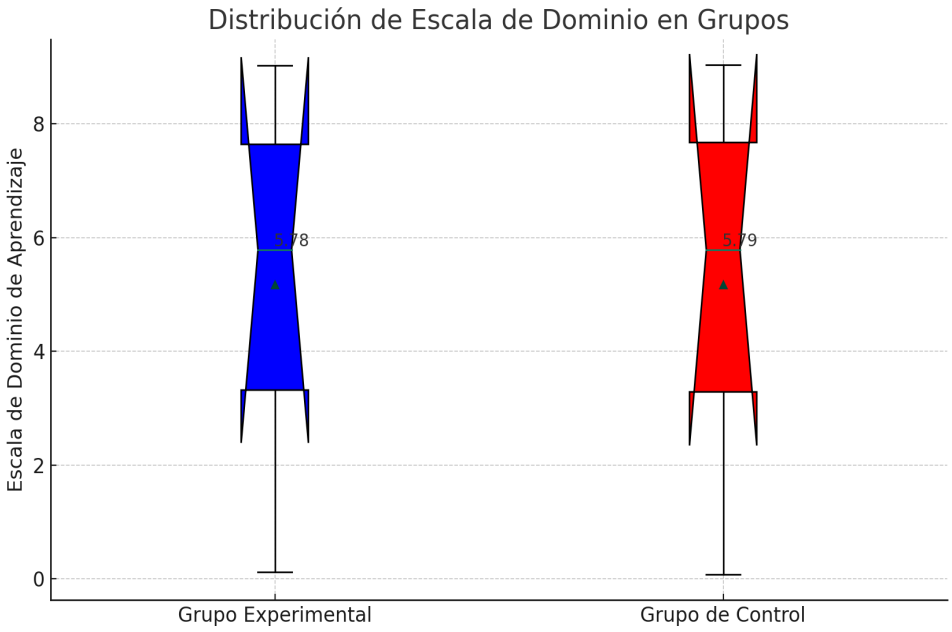

Figure 1. Distribution of learning domain scale

It is evident that in the experimental group, the median is 5,78, and in the control group, it is 5,79, which indicates that half of the students in both groups are at or below this point on the near mastery of learning scale. Thus, for both groups, the representation of the boxes is similar and demonstrates the majority of the performance scale that the students are on. At the same time, the whiskers extend to the highest and lowest scores outside the interquartile range, providing a view of the extremes in student performance, which is similar for both groups.

Therefore, the median and the mean in both groups suggest that, while there is decent performance overall, there is still room for improvement, especially for those students whose results are below the median. Both groups have significant room for improvement, especially in achieving a deeper understanding of the content. Implementing the teaching intervention with Minecraft in the experimental group represents an opportunity to investigate whether this innovative methodology can effectively improve learning outcomes compared to the traditional methods used in the control group.

A teaching plan was drawn up focusing on the use of Minecraft as a virtual environment for teaching Natural Sciences. The institution's board approved the plan of directors and focused on providing five sections with 5 hours of classes per week, for 20 hours.

RESULTS

At the end of the month of teaching intervention, the same questionnaire was applied as at the starting point, giving the following results.

The experimental and the control groups showed a notable improvement, going from having students in this category in the pre-test to having none in the post-test. This indicates that all the students overcame the lowest level of learning mastery. Within the second level of learning mastery, the experimental group,

there was a significant decrease from 46,43 % to 17,85 % in this category, which suggests that the intervention positively moved students towards higher levels of mastery. A decrease was also observed in the control group, although less pronounced, from 41,47 % to 31,03 %, indicating an overall improvement, but not as outstanding as in the experimental group.

Table 2. Comparative pre-test and post-test results

	Pre-test		Post-test	
	Experimental group	Control Group	Experimental group	Control Group
Does not meet the required learning outcomes (0 to 3,99 points)	3 (10,71 %)	2 (6,89 %)	0 (0 %)	0 (0 %)
Close to achieving the required learning outcomes (4 to 6,99 points)	13 (46,43 %)	12 (41,47 %)	5 (17,85 %)	9 (31,03 %)
Achieves the required learning outcomes (7 to 8,99 points)	9 (32,14 %)	11(37,93 %)	11 (39,29 %)	13 (44,83 %)
Has mastered the required learning (9 to 10 points)	3 (10,71 %)	4 (13,79)	12 (42,85 %)	7 (24,14 %)

On the third scale, learning mastery, the experimental group showed a slight increase in this category, going from 32,14 % to 39,29 %, while the control group also experienced a rise, going from 37,93 % to 44,83 %. This reflects an improvement in the average performance of both groups. Finally, on the scale of mastery of the required learning, here we see the most significant change in the experimental group, which went from 10,71 % to 42,85 %, a clear indication that the Minecraft intervention had a positive impact on achieving a high level of understanding and mastery of the content. There was also an increase in the control group, although smaller, from 13,79 % to 24,14 %. For better visualization, the following graph systematizes a line of projection of improvements in the didactic intervention compared to the experimental and control groups.

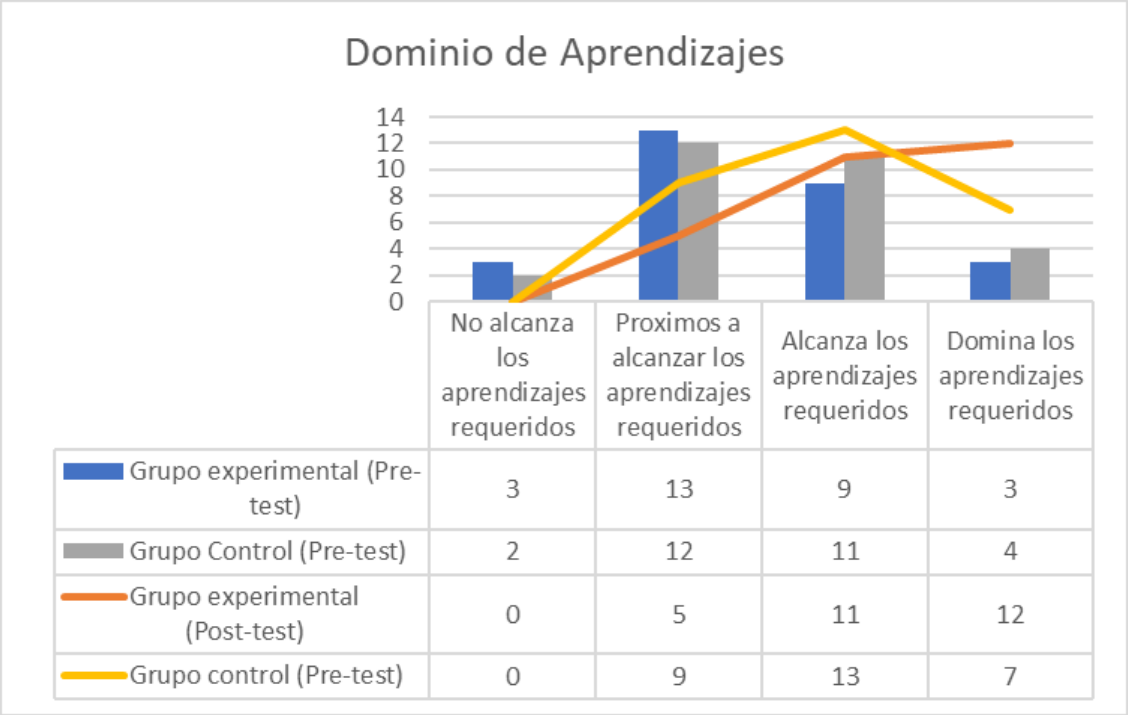

Figure 2. Projected improvements on completion of implementation

In general, these results indicate that the intervention in the experimental group had a significant impact on improving student performance, especially in taking them to higher levels of learning mastery. The comparison with the control group, which also showed improvements, but to a lesser extent, suggests that the use of innovative methodologies such as Minecraft can be an effective tool in improving learning in Natural Sciences.

The data presented in a descriptive manner gives us an initial look and validation of the proposal; however, to have greater objectivity, we proceed to carry out an analysis from inferential statistics, specifically with a Student's T-test. For this, we see the need to match the sample, leaving a total of 28 participants for each group, with the following results:

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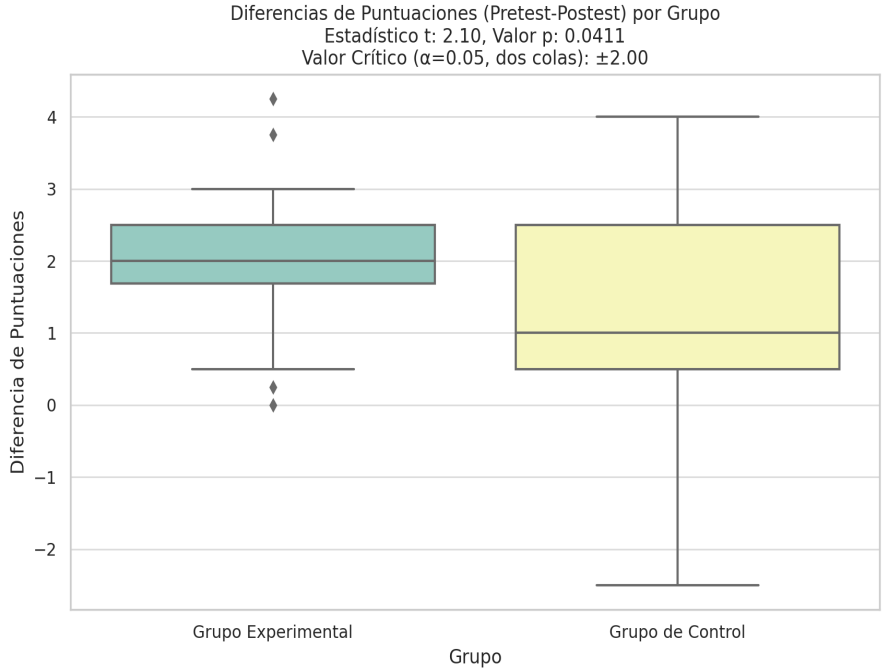

Figure 3. Differences and comparison of group averages

The Student's t-test was used to compare the differences in pre-test and post-test scores between the experimental and control groups. The results indicate a t-statistic of 2,0979 with a p-value of 0,0411, which suggests a statistically significant difference between the groups. This result implies that the incorporation of Minecraft in the teaching and learning process had a positive impact on the conceptual understanding of the students in the experimental group, in comparison with traditional teaching methods. Additionally, to corroborate this data, a Shapiro-Wilk test was carried out to evaluate the normality of the score distributions and to determine if the student's t-test had statistical basis to be carried out, with the following results:

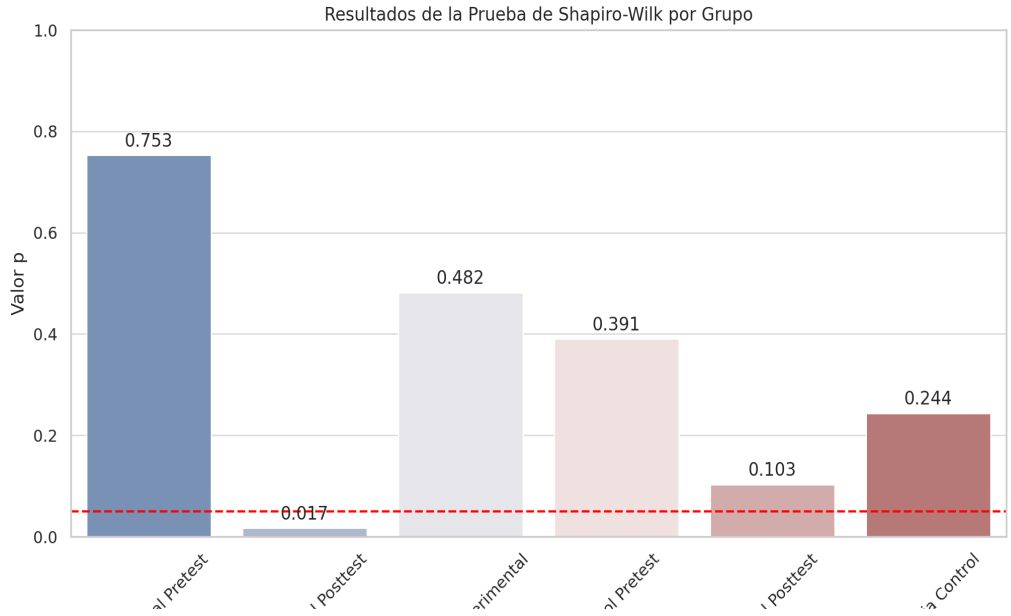

Figure 4. Test validation

The results show that, except in the post-test of the experimental group (statistic = 0,907, p-value = 0,017), all other distributions (including pre-test and differences in scores in both groups) appear to follow a normal distribution (p-values > 0,05). This validates the application of Student's t-test, which assumes normality of the data. Finally, from a qualitative analysis, a focus group was held with the students who participated in the

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experimental group, with the aim of understanding and delving deeper into the motivation and perspective of the participating students, where the following results were obtained:

Table 3. Focus group results

Category	Results
Initial Experiences	The students expressed initial enthusiasm for incorporating Minecraft into their learning. Most had never considered a video game as an educational tool, but they found it to be an engaging and fun way to explore scientific concepts.
Impact on Conceptual Understanding:	Many students mentioned that Minecraft helped them to visualize and understand complex topics better. For example, the construction of ecosystems in the game allowed students to experience concepts such as food chains and life cycles in a practical way.
Motivation and Commitment	The students reported a significant increase in their motivation and commitment. Minecraft offered them a more interactive and participatory form of learning, which was especially beneficial for those who usually found Natural Science classes challenging or boring.
Interactions and Collaboration	Collaboration within Minecraft was described as an enriching experience. Students learned to work as a team, sharing resources and problem-solving strategies, which strengthened their collaboration and communication skills.
Comparison with Traditional Education:	The majority of students preferred learning through Minecraft compared to traditional methods. They appreciated the ability to directly experiment with scientific concepts in a virtual environment, which they found more engaging and memorable than theoretical lessons.
Knowledge Retention	The students felt that using Minecraft reinforced their retention and application of knowledge. Many were able to recall specific details of their Minecraft projects and relate them to the scientific concepts they had learned.
Challenges and Recommendations:	Some students faced technical and time challenges when using Minecraft, suggesting the need for more solid technical support and dedicated time within the school curriculum. They recommended greater integration of Minecraft with learning objectives and better guidance from teachers in the use of the game.
Role of the teacher:	The students emphasized the importance of the teacher's role in facilitating and guiding the use of Minecraft. They pointed out that the teachers' active support and guidance were crucial to maximizing the learning potential of the game. Teacher training in the use of Minecraft and its integration into the curriculum were seen as essential elements for an effective and enriching learning experience.
Conclusions	In general, the students saw Minecraft as a valuable tool for improving their education in Natural Sciences. They suggested continuing and expanding its use, emphasizing the importance of adequate guidance and support from teachers to maximize its educational potential.

By way of discussion, the application of the Student's t-test showed a statistically significant difference between the experimental and control groups in the pre-test and post-test scores. This suggests that Minecraft positively impacted students' conceptual understanding, standing out in comparison with traditional teaching methods. In addition, the Shapiro-Wilk test validated the normality of most of the score distributions, reinforcing the relevance of the Student's t-test for this study.

At the same time, the results of the focus group provided an enriching qualitative insight. The students expressed apparent enthusiasm for Minecraft, finding that it transformed the learning of scientific concepts into a more engaging and fun experience. They highlighted how Minecraft facilitated a better understanding of complex topics, such as the construction of ecosystems, allowing them to experience concepts such as food chains and life cycles practically. In addition, a significant increase in motivation and engagement was observed, which was especially valuable for those who generally found Natural Science classes challenging.

CONCLUSIONS

The present research has addressed an innovative topic in education: the incorporation of Minecraft, a popular video game, as a teaching tool in teaching Natural Sciences for seventh-grade students. This project, which is based on a case study, set out to evaluate the impact of this methodology on the conceptual understanding of the subject of Natural Sciences, as well as on the student's motivation and commitment to learning. A mixed approach combining quantitative and qualitative analysis has achieved a deep and nuanced understanding of how digital tools, specifically Minecraft as a virtual environment, can enrich the teaching-learning process.

The research answered the research questions, stating in the theoretical framework the didactic foundations of Minecraft as a virtual environment and teaching tool for Natural Sciences. This was done by means of an exhaustive bibliographic review, which also made it possible to highlight the elements of how to implement Minecraft effectively, analyzing the results of previous research.

The effects of Minecraft in the teaching-learning process of Natural Sciences were detailed, and the necessary evidence and verification of the research hypotheses were obtained through a quasi-experimental and mixed approach. From a quantitative perspective, the results obtained through the student's t-test were revealing. A statistically significant difference was observed in the pre-test and post-test scores between the experimental and control groups. This finding confirms the initial hypothesis that the integration of Minecraft could improve students' conceptual understanding and highlights the effectiveness of incorporating interactive and playful methodologies into the school curriculum. The statistical significance obtained suggests that Minecraft transcends mere entertainment, positioning itself as a didactic tool with a concrete impact on learning.

In addition, the Student's t-test was validated using the Shapiro-Wilk test, providing a solid basis for validating the results obtained from the Student's t-test, demonstrating that most of the score distributions followed a normal distribution. However, the exception observed in the experimental group's post-test invites critical reflection on the additional factors that may influence the effectiveness of tools such as Minecraft in different educational contexts. From the qualitative realm, the focus group results have shed light on the experiences lived by the students. These narrative perceptions have enriched the quantitative findings, providing a deeper understanding of the impact of Minecraft in the classroom. The students reported increased interest and motivation, which is fundamental at a time when education is constantly looking for ways to engage today's digital learners. In addition, the aspects of collaboration and teamwork within the game have highlighted the value of Minecraft as a tool for fostering social and problem-solving skills in a collaborative and creative environment.

The main result of the research framework was the teaching proposal that was applied and validated, demonstrating that technological integration and innovation in the field of education is possible, overcoming traditional and monotonous teaching methods and promoting playful, gamified, contextualized, and meaningful learning for students. However, the possibility of further exploring the interactions between different educational variables and the use of Minecraft remains open.

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FINANCING

None.

CONFLICT OF INTEREST

None.

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