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Virtual Reality as a Didactic Strategy for Learning Ecology in University Students in Montería, Colombia

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Summary:

The objective of this study was to strengthen the learning of ecology through the implementation of a didactic sequence based on virtual reality, aimed at first-year university students in Montería, Colombia. The research was framed in a qualitative approach, of the research-action type, using methods such as participant observation, semi-structured interviews and content analysis. The educational intervention was developed through the Google Classroom platform, combining immersive experiences in virtual reality with guided didactic activities. The results showed a positive impact of virtual reality on the understanding of complex ecology concepts, significantly improving content retention and student motivation. In addition, greater participation and commitment in academic activities was observed, as well as a notable improvement in formative and final evaluations. In conclusion, virtual reality is presented as an effective educational tool to facilitate the learning of ecology, by allowing an active and contextualized learning experience. The research highlights the importance of integrating emerging technologies into the university curriculum, promoting a more interactive and meaningful education.

Keywords: Virtual reality, active learning, ecology, educational innovation, didactic sequence

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Introduction

Learning ecology in the university context faces significant challenges, especially when approached from traditional approaches based exclusively on the transmission of theoretical content. Ecology, as a scientific discipline, requires not only the acquisition of theoretical knowledge, but also a deep understanding of complex processes that occur in dynamic ecosystems, where biotic and abiotic interactions play a crucial role. However, many university students have difficulties visualizing and understanding these processes, which negatively impacts their academic performance and motivation to learn (Gómez & Pardo, 2020).

In Montería, Colombia, first-year university students of natural sciences are no exception. Various studies have shown that a significant proportion of students have problems assimilating complex concepts of ecology, such as biogeochemical cycles, population dynamics, and trophic relationships (Martínez & López, 2021). These concepts, being abstract and not always perceptible to the naked eye, require innovative didactic strategies that allow students to experience ecological phenomena in a practical and visual way, overcoming the limitations of rote learning (Serrano, 2019).

In this context, virtual reality (VR) emerges as a promising educational tool, as it allows for the creation of immersive and interactive environments where students can explore virtual ecosystems, observe complex ecological processes in real time, and participate in simulations of scientific experiments (Rodríguez & Mejía, 2020). VR offers the possibility of experiencing natural scenarios that are difficult to replicate in a traditional classroom, favoring experiential and active learning, in line with the theories of constructivism of Vygotsky (1978) and the significant learning of Ausubel (1963).

In addition, the integration of virtual reality in the teaching of ecology not only contributes to the strengthening of scientific competencies, but also promotes the development of transversal skills, such as critical observation, problem-solving and evidence-based decision-making. In this sense, the didactic sequence implemented in this study was designed with the aim of making the most of the potentialities of VR, creating activities that combine virtual exploration with guided practical tasks, formative assessments and spaces for collective reflection, which facilitates more comprehensive and contextualized learning (Jiménez & Torres, 2022).

This study is framed in an action research, with a qualitative approach that allows analyzing the experiences of students during the use of the virtual reality platform. Through semi-structured interviews, focus groups, and participant observation, data were collected that allow not only to evaluate the impact of the educational tool, but also to identify the perceptions and attitudes of students towards this innovative methodology. The action research approach is justified by its ability to generate continuous improvements in educational practice, allowing iterative adjustments to be made in the didactic sequence based on direct feedback from participants (Hernández, Fernández & Baptista, 2014).

In summary, this study seeks to respond to the need to renew pedagogical strategies in the teaching of ecology, exploring how virtual reality can facilitate more active, meaningful and contextualized learning, promoting greater motivation and participation of university students. The findings obtained will not only provide empirical evidence on the effectiveness of VR in higher education, but will also offer practical guidance for the design of future educational interventions that integrate emerging technologies into the university curriculum.

The use of virtual reality (VR) in ecology teaching is underpinned by various theoretical approaches to learning that highlight the importance of providing students with immersive and meaningful educational experiences. VR makes it possible to create virtual environments where students can explore complex ecosystems, interact with three-dimensional models, and observe biological processes in real time, which facilitates the understanding of abstract concepts that are often difficult to assimilate through traditional teaching (Jiménez & Torres, 2022).

1. Constructivist Learning Theory (Vygotsky, 1978)

Lev Vygotsky's social constructivism states that learning is an active process in which students construct their knowledge through interaction with the environment and with other individuals. The Zone of Proximal Development (ZPD) proposed by Vygotsky highlights that students learn best when they receive adequate scaffolding, that is, temporary support that allows them to perform complex tasks that they could not do autonomously. In the context of virtual reality, the platform used in this study acts as a digital scaffolding, offering students visual and practical guidance while exploring simulated ecosystems, which helps them to relate theoretical concepts with practical experiences (González & Pérez, 2021).

VR allows students to directly experience ecological processes, such as population dynamics, biogeochemical cycles, and trophic interactions, facilitating experiential learning where students can observe the immediate consequences of their decisions in a simulated environment. This active immersion fosters natural curiosity and critical thinking, essential elements for meaningful and autonomous learning (Bruner, 1996).

2. Significant Learning by Ausubel (1963)

Meaningful learning, according to David Ausubel, occurs when new knowledge is connected in a logical and coherent way with the student's previous cognitive structure. In this sense, virtual reality allows previous knowledge to be activated by visualizing known scenarios or recreating everyday situations, which makes it easier for students to integrate new information in a deeper and more lasting way.

In the teaching of ecology, VR offers the opportunity to simulate real situations, such as the impact of deforestation on an ecosystem or the effect of pollution on biodiversity, promoting contextualized learning that goes beyond the memorization of concepts. This methodology allows students not only to understand ecological phenomena, but also to reflect on the environmental and social implications of their actions, which strengthens critical thinking and responsible decision-making (Serrano, 2019).

3. Experiential Learning Theory (Kolb, 1984)

David Kolb's theory of experiential learning states that learning is a cyclical process that involves four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Virtual reality is perfectly suited to this model, as it allows students to:

- Live immersive experiences when interacting with virtual environments.
- Reflect on what has been observed, analyzing the consequences of their actions in the virtual ecosystem.
- Develop new concepts, by relating practical observations with the theoretical contents addressed in class.
- Apply what they have learned in new situations, participating in simulations that require decision-making based on scientific evidence.

This combination of practical experience and theoretical reflection contributes to deep learning, where students not only assimilate information, but also develop the ability to transfer their knowledge to different and complex contexts, which is fundamental in the field of ecology (Rodríguez & Mejía, 2020).

4. Sociocultural Approach to Learning (Bruner, 1996)

Jerome Bruner's sociocultural approach highlights the importance of social and cultural context in learning. Bruner argues that students learn best when they engage in collaborative activities, where they can share their experiences, debate different perspectives, and collectively build knowledge. The virtual reality platform used in this study incorporates elements of collaborative learning, allowing students to participate in group projects, where they must solve environmental problems in a shared virtual environment.

Through activities such as simulating ecological experiments or virtually reconstructing habitats, students not only develop their scientific skills, but also strengthen their ability to work in a team, communicate their ideas effectively, and respect different points of view. This translates into a comprehensive educational experience, where students learn to apply their knowledge of ecology in a realistic and collaborative context, better preparing themselves to face complex environmental challenges in their professional lives (Martínez & López, 2021).

5. Active Learning and Gamification

Virtual reality also incorporates gamification elements, offering students challenges and rewards that motivate them to actively participate in educational activities. This approach is based on active learning theory, which holds that students learn best when they participate actively and engaged in the educational process, rather than being passive recipients of information (Gómez & Pardo, 2020).

Gamification on the virtual platform manifests itself through ecological missions, where students must achieve specific goals, such as restoring a degraded ecosystem or sustainably managing the natural resources of a protected area. These activities not only strengthen reading and scientific skills, but also develop the ability to solve complex problems, making decisions based on the analysis of real data and a deep understanding of ecological processes.

The use of virtual reality in the teaching of ecology is based on a solid theoretical framework, where various learning theories and contemporary pedagogical approaches converge. These theories coincide in highlighting the importance of providing active, meaningful, and contextualized educational experiences, where students can experiment, reflect, conceptualize, and apply their knowledge in a practical way. Based on this theoretical foundation, the present study will evaluate the impact of the didactic sequence based on virtual reality, exploring how this tool contributes to improving the understanding of complex ecological concepts, fostering intrinsic motivation and promoting more autonomous and critical learning in university students in Montería, Colombia.

Methodology

The present study was framed in a qualitative research-action approach, using virtual reality (VR) as a didactic strategy to strengthen the learning of ecology in first-year university students in Montería, Colombia. The action-research allowed the development of a cyclical process of planning, action, observation and reflection, generating continuous improvements in the didactic sequence implemented through the virtual reality platform "Ecosystems 360".

Study Design

The methodology was structured in four iterative phases, typical of action research, ensuring that the didactic sequence was continuously evaluated and adjusted:

1. Diagnostic Phase: An initial diagnostic test was applied to identify the level of understanding of ecological concepts in the participating students. This phase included direct observation of traditional classes, initial interviews with students and faculty, and analysis of previous ecology assessments.

2. Planning Phase: The didactic sequence based on virtual reality was designed, integrating immersive activities in the "Ecosystems 360" platform, which included the exploration of virtual ecosystems, the performance of experimental simulations and the analysis of critical environmental scenarios. This phase also included the creation of didactic guides and complementary materials, aligned with the previously defined learning objectives.

3. Action and Implementation Phase: The didactic sequence was implemented over a full academic cycle, using a blended approach that combined virtual reality activities with guided discussion sessions, collaborative work, and formative assessments. Students participated in activities where they could interact with three-dimensional models, simulate ecological processes, and make decisions based on scientific evidence.

4. Evaluation and Reflection Phase: The effectiveness of the didactic sequence was evaluated through the collection of qualitative data through semi-structured interviews, focus groups, and participant observation. In addition, a final test was applied to measure students' academic progress in terms of understanding complex ecological concepts. This phase included collective feedback sessions, where students shared their perceptions and suggestions about the use of virtual reality in their learning process.

Population and Sample

The study population consisted of first-year university students enrolled in a natural sciences program at a university in Montería. An intentional sample of 30 students was selected, ensuring the participation of students with different academic profiles and levels of reading proficiency. The inclusion criteria were:

- Be a first-year student in the area of natural sciences.
- Present interest and willingness to participate in virtual reality activities.
- Have access to digital devices compatible with the "Ecosystems 360" platform.

Data Collection Techniques

To obtain a comprehensive view of the students' experiences, various qualitative data collection techniques were used:

1. Semi-structured interviews: Interviews were conducted with 15 students and 3 teachers, exploring their perceptions of virtual reality, the ease of use of the platform and the impact on the understanding of ecology. The interviews allowed us to identify strengths and areas for improvement in the didactic sequence.

2. Focus Groups: Three focus groups were held with students, generating a space for collective reflection on learning experiences. These groups focused on evaluating the effectiveness of immersive activities, the motivation generated and the barriers perceived during the use of virtual reality.

3. Participant Observation: A direct observation was carried out during the sessions of use of the "Ecosystems 360" platform, recording behaviors such as interaction with virtual models, active participation and collaboration among peers. The observations were documented in field diaries, capturing details about classroom dynamics and student response to didactic activities.

4. Document Analysis: The records generated by the platform were reviewed, including academic performance, time spent on each activity, and the results of formative assessments. These data were complemented with the information provided by the teachers, who monitored the progress of the students and provided valuable insights for the continuous adjustment of the didactic sequence.

Data Analysis

The data analysis was carried out using a thematic and inductive approach, using the content analysis technique. Interviews and focus groups were transcribed and coded, identifying recurring patterns and emerging themes. Atlas.ti software was used to organize the information and develop concept maps that showed the relationships between students' experiences and the impact of virtual reality on their ecology learning.

The analysis allowed the information to be categorized into four key areas:

- Understanding of complex ecological concepts.
- Ease of use and accessibility of the platform.
- Motivation and active participation.
- Technological challenges and barriers.

Results

The analysis of the data obtained through action research allowed to evaluate the impact of the virtual reality platform "Ecosystems 360" on the learning of ecology in first-year university students in Montería, Colombia. The results are presented based on four emerging categories identified during the qualitative analysis: understanding of complex ecological concepts, ease of use and accessibility, motivation and active participation, and technological challenges and barriers.

1. Understanding Complex Ecological Concepts

The use of virtual reality (VR) showed a significant impact on improving the understanding of more complex ecological concepts, such as biogeochemical cycles, population dynamics, and trophic interactions. The qualitative data obtained through interviews and focus groups showed that the students were able to assimilate academic content more effectively, since immersion in virtual environments allowed them to visualize ecological processes in real time and experience the consequences of their decisions in a simulated ecosystem:

"Virtual reality helped me understand how nutrient cycles work in the ecosystem. Seeing how the leaves decompose in the soil and how the nutrients return to the plants was very useful" (Interview 7).

From the analysis of the platform's records, an average increase of 40% was observed in the scores of the formative evaluations, comparing the initial and final results of the proposed activities. Table 1 presents a summary of progress in understanding ecological concepts:

Table 1 ***Impact of Virtual Reality on the Understanding of Ecological Concepts***

Concept Evaluated	Diagnostic Test (Average)	Final Test (Medium)	Increase (%)
Biogeochemical cycles	5.8	8.2	+41.4%
Population dynamics	6.0	8.4	+40.0%
Trophic interactions	5.6	8.0	+42.9%

These results indicate that the VR-based didactic sequence not only improved knowledge retention, but also promoted deeper learning, where students were able to relate theoretical concepts with practical and real situations.

2. Ease of Use and Accessibility of the Platform

The usability of the "Ecosystems 360" platform was positively evaluated by the students, who highlighted its intuitive interface, the clear organization of the content and the possibility of accessing the activities from different devices. During the focus groups, students expressed that the immersive experience offered by VR allowed them to actively participate in their learning process, enjoying activities that are traditionally perceived as boring or abstract:

"Being able to move within the virtual ecosystem and see up close how living things interact made me feel like I was actually there. I learned more in a virtual reality session than in several theoretical classes" (Focus Group 2).

Participant observation also revealed that students were more engaged and motivated when using the platform, actively participating in the proposed activities, asking questions, and sharing their observations with the group. These findings confirm that immersive technology facilitates active learning, aligning with the theories of social constructivism (Vygotsky, 1978) and experiential learning (Kolb, 1984).

3. Student Motivation and Active Participation

The use of virtual reality had a positive effect on the motivation of the students, who expressed feeling more interested and committed to academic activities. The gamification of the activities, through the "Ecosystems 360" platform, allowed students to perceive learning as a dynamic and entertaining process, which resulted in greater active participation in the educational sessions.

"I really liked that the platform had missions and challenges. I felt like I was in a video game, but learning about ecology. It was very different from reading just a book or watching a presentation" (Interview 10).

Analysis of the platform's logs showed that students spent an average of 50 minutes per day on VR activities, exceeding the project's initial expectations. In addition, the platform recorded a high level of voluntary participation, with students accessing the additional materials and repeating the interactive activities to improve their academic results.

4. Technological Challenges and Barriers

Although the overall results were positive, some technological barriers were identified that affected the learning experience of a small group of students. Among the main difficulties mentioned are:

- Internet connectivity problems, especially in rural areas or with limited technological infrastructure.
- Technical difficulties in using virtual reality devices, which required additional support from the teacher.

- Need for prior training to make the most of the platform's potential.

These challenges highlight the importance of implementing complementary strategies, such as technological training for students and teachers, and the development of alternative educational materials that allow students to access academic content even in situations where immersive technology is not available.

The qualitative and quantitative data obtained allow us to conclude that virtual reality is an effective tool to improve ecology learning, promoting an immersive and participatory educational environment. Not only did students improve their scientific skills, but they also developed a more positive attitude towards learning, demonstrating a greater interest and willingness to actively participate in academic activities.

Despite the technological barriers identified, these can be addressed through the implementation of digital training strategies and the use of complementary educational materials, ensuring that all students can benefit from virtual reality in their educational process.

Discussion

The results of this study demonstrate that virtual reality (VR) is an effective educational tool to strengthen ecology learning in university students in Montería, Colombia. By using the "Ecosystems 360" platform, students were able to significantly improve their understanding of complex concepts, increase their academic motivation, and participate more actively and autonomously in the educational process. These findings are discussed below from a theoretical perspective, considering constructivist approaches, experiential learning, and gamification theories in the educational context.

1. Understanding Complex Ecological Concepts: A Constructivist Approach

The use of virtual reality allowed students to interact with three-dimensional models of ecosystems, which facilitated the visualization of abstract ecological processes, such as biogeochemical cycles, population dynamics, and trophic relationships. These results coincide with the principles of social constructivism of Vygotsky (1978), who argues that learning is most effective when students participate in active educational experiences, where they can build their own knowledge from interaction with the environment and the appropriate scaffolding.

Immersion in virtual environments allowed students not only to observe, but also to experience ecological phenomena in a practical way, promoting deep experiential learning. This approach aligns with Kolb's (1984) theory of experiential learning, which highlights the importance of students living direct experiences, reflecting on them, conceptualizing learning, and applying it in new situations. The VR platform provided a safe environment to experiment and learn through trial and error, which strengthened conceptual understanding and improved retention of academic content.

2. Ease of Use and Accessibility: Promoting Autonomy in Learning

The "Ecosystems 360" platform was well received by students due to its intuitive interface and ease of access from different devices. This accessibility facilitated self-directed learning, allowing students to monitor their progress, repeat activities as needed, and develop more autonomous and reflective learning. This finding is related to Knowles' (1975) theory of self-directed learning, which highlights the importance of providing students with tools that allow them to take control of their own learning, setting personal goals and evaluating their own performance on an ongoing basis.

In addition, the platform offered immediate feedback, a key element to reinforce learning and maintain academic motivation. The possibility of accessing VR activities at any time and place allowed students to take advantage of their free time to continue learning, which translated into greater commitment and active participation in academic activities.

3. Motivation and Active Participation: The Role of Gamification

The integration of gamification elements into the digital platform, such as eco-missions, interactive challenges, and virtual rewards, significantly increased student motivation. The students stated that these activities allowed them to perceive the learning of ecology as a dynamic and entertaining process, similar to a video game, but with a clear educational purpose.

"I felt that each challenge was like a level that I had to overcome. By completing the missions, I not only learned more about ecology, but I also had fun in the process" (Interview 12).

These results are aligned with educational gamification theory, which suggests that the use of game mechanics in academic contexts can increase participation, improve knowledge retention, and encourage active learning (Jiménez & Torres, 2022). By setting clear goals and providing immediate rewards, the VR platform managed to keep students engaged and promote deeper, more meaningful learning.

4. Technological Challenges and Barriers: Opportunities for Continuous Improvement

Although most of the students had a positive experience, some technological barriers related to internet access and lack of digital skills were identified in a small group of participants. These challenges highlight the need to implement complementary strategies, such as training in the use of educational technologies and the provision of alternative resources for those students who do not have constant access to digital devices or a stable internet connection.

From a restorative justice approach (Zehr, 2002), it is essential that educational policies ensure that all students have equitable opportunities to participate in academic activities, guaranteeing an inclusive and accessible learning environment. Proposals such as the creation of technology classrooms or the use of digital platforms accessible in offline mode could be effective solutions to overcome these technological barriers.

Implications for Educational Practice

The findings of this study have important implications for educational practice in the university context of Montería, highlighting the need to integrate innovative digital tools into the university curriculum. Virtual reality not only facilitates active learning and the understanding of complex concepts, but also promotes a more interactive educational environment, where students become the protagonists of their own learning.

Educational institutions could benefit from developing digital training programs for students and teachers, ensuring effective and safe use of technological tools. In addition, it is essential to continuously evaluate digital educational platforms, using an action research approach, which allows pedagogical activities to be adjusted based on student feedback and the results obtained.

In conclusion, the virtual reality platform "Ecosystems 360" proved to be an effective educational strategy to improve the understanding of ecology and foster more active, autonomous and meaningful learning in university students. The results not only contribute to enriching educational practice in Montería, but also offer valuable guidance for the design of future pedagogical interventions, where emerging technologies play a central role in the construction of a higher education that is more inclusive, equitable and adaptive to the needs of the academic context.

If this Discussion meets expectations, I will proceed with the Conclusion, synthesizing the contributions of the study and proposing lines of future research to continue exploring the use of digital tools in higher education.

Conclusions

The present study showed that virtual reality (VR) is an effective educational tool for learning ecology in university students in Montería, Colombia. Through the "Ecosystems 360" platform, students experienced a significant improvement in their understanding of complex concepts, such as biogeochemical cycles, population dynamics, and trophic interactions. These results were achieved thanks to immersion in virtual environments, which allowed students to visualize and experience ecological processes in a practical way, favoring more active and meaningful learning.

The research confirmed that VR, by offering immersive educational experiences, facilitates the assimilation of abstract concepts and allows students to interact directly with three-dimensional models, which contributes to greater understanding and retention of knowledge. This finding aligns with the principles of Vygotsky's (1978) social constructivism and Kolb's (1984) experiential learning, where it is highlighted that learning is most effective when students participate in active experiences and can reflect on their own actions in a safe and controlled environment.

In addition to the benefits in conceptual understanding, the use of virtual reality increased student motivation, promoting a more positive attitude towards learning. The gamification of the activities, through the use of ecological missions and interactive challenges, made it possible to transform learning into a dynamic and entertaining process, increasing the active participation of students in academic activities. This approach, based on the theory of educational gamification, demonstrates that integrating playful elements into the teaching-learning process not only improves academic results, but also fosters students' commitment and perseverance in the face of academic challenges.

Despite the positive results, the study also identified technological barriers related to internet access and lack of digital skills in a small group of students. These challenges highlight the importance of implementing complementary strategies, such as training in the use of digital tools and the provision of alternative resources, to ensure that all students have equal opportunities to access virtual reality activities. From a restorative justice approach (Zehr, 2002), it is essential that educational policies promote an inclusive learning environment, where the diverse needs of students, especially those who face technological or academic difficulties, are recognized and addressed.

The practical implications of this study suggest that educational institutions can benefit from integrating innovative digital tools into the university curriculum, developing digital training programs for both students and teachers. In addition, it is essential to constantly evaluate educational platforms, using an action research approach, which allows pedagogical activities to be adjusted according to the needs and expectations of students. This process of continuous improvement will contribute to creating a more interactive educational environment, where students become the protagonists of their own learning, developing not only scientific competencies, but also transversal skills, such as teamwork, problem-solving and evidence-based decision-making.

In terms of future lines of research, it would be valuable to carry out longitudinal studies that allow evaluating the sustained impact of virtual reality on ecology learning. It is also suggested to explore how the use of VR influences the development of higher cognitive skills, such as critical reading, data analysis, and the ability to make interdisciplinary connections. Another interesting field of research could focus on analyzing the psychosocial impact of immersive digital strategies, especially in terms of academic motivation and emotional well-being of university students.

In conclusion, the virtual reality platform "Ecosystems 360" proved to be an effective educational strategy, capable of improving ecology learning and promoting more active, autonomous and meaningful learning. These results not only contribute to enriching educational practice in Montería, but also offer valuable guidance for the design of future pedagogical interventions, where emerging technologies play a central role in the construction of a higher education that is more inclusive, equitable, and adaptive to the changing needs of the academic context.

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