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The impact of technology integration in natural science education

Impacto de la integración de la tecnología en la enseñanza de las ciencias naturales

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ABSTRACT

The aim of the current review article is to analyse the impact of the integration of technology in the teaching of natural sciences. From a methodological context, it was developed from a descriptive documentary review of a documentary population of 27 scientific articles. From the articles reviewed, it appears that the incorporation of emerging technologies in the teaching of natural sciences has generated a significant impact on the understanding of complex concepts, positioning itself as a tool to transform teaching-learning processes. Therefore, technologies such as augmented reality and virtual reality have proven to be especially effective in allowing for the interactive and immersive visualisation of abstract phenomena, such as biological processes or chemical cycles, facilitating meaningful learning. This impact is enhanced when these tools are combined with active methodologies, such as project-based learning and scientific inquiry.
Descriptors: educational technology; science education; basic science education. (Source: UNESCO Thesaurus).

RESUMEN

El actual artículo de revisión tiene por objetivo analizar el impacto de la integración de la tecnología en la enseñanza de las ciencias naturales. Desde un contexto metodológico se desarrolló desde una revisión de tipo descriptivo documental en una población documental de 27 articulos científicos. A partir de los articulo revisados, se tiene que la incorporación de tecnologías emergentes en la enseñanza de las ciencias naturales ha generado un impacto significativo en la comprensión de conceptos complejos, posicionándose como una herramienta para transformar los procesos de enseñanza-aprendizaje. Por lo tanto; tecnologías como la realidad aumentada y la realidad virtual han demostrado ser especialmente efectivas al permitir la visualización interactiva e inmersiva de fenómenos abstractos, como procesos biológicos o ciclos químicos, facilitando un aprendizaje significativo. Este impacto se potencia cuando estas herramientas se combinan con metodologías activas, como el aprendizaje basado en proyectos y la indagación científica.
Descriptores: tecnología educacional; enseñanza de las ciencias; enseñanza de ciencias fundamentales. (Fuente: Tesauro UNESCO).

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articles section

INTRODUCTION

The incorporation of emerging technologies in educational processes has generated significant transformations in pedagogical practices, particularly in the teaching of natural sciences; these technologies not only respond to the demands of contemporary education, but also enhance the development of essential transversal competences, such as critical thinking, creativity and problem solving, framed in the principles of meaningful learning and active pedagogy (Oliveira et al., 2019; Ardanuy, Sulé & Borrego, 2024; Matías-Olabe et al., 2023).

In the field of natural sciences, technological mediation has made it possible to overcome the limitations of traditional approaches, offering immersive experiences and interactive visualisations that enrich the teaching-learning processes. AR and VR facilitate the representation of natural phenomena and scientific processes that, in a conventional environment, would be difficult to approach, such as the carbon cycle or human anatomy (Sousa-Ferreira et al., 2021; Mendoza-Fuentes, 2021); therefore, they not only favour conceptual understanding, but also promote the active participation of students, strengthening the retention of knowledge and the construction of lasting learning.

Based on the above, the current review article aims to analyse the impact of the integration of technology in the teaching of natural sciences.

METHOD

The research from a methodological context was developed from a descriptive documentary type review, complemented with the analytical method, which was used to break down the information collected into its essential components, allowing a detailed examination of the elements that influence the integration of emerging technologies in the teaching of natural sciences.

A search was conducted in academic databases such as Scopus, Web of Science, and Google Scholar, using keywords such as "augmented reality in education", "emerging technologies in natural sciences", "virtual reality in teaching" and "pedagogical strategies with technology". Priority was given to studies published between 2000 and 2024. A documentary population of 27 scientific articles was obtained.

Inclusion and exclusion criteria

Inclusion: Studies that address the pedagogical impact of emerging technologies in the teaching of natural sciences, that include analysis of didactic strategies and that present empirical results or grounded theoretical reviews.

Exclusion: Sources not directly related to the field of education, research with significant methodological limitations or publications without peer review.

The data were organised in a table and content analysis was applied as a procedure for the exploration of the documents scrutinised as the study population.

RESULTS

This section offers a systematic analysis of the impact of the integration of emerging technologies in the teaching-learning processes of natural sciences, based on a review of academic research, organising the information around the topics of analysis of each article, their pedagogical impact and the didactic strategies suggested for their implementation in educational contexts. From a pedagogical perspective, it emphasises how tools such as augmented reality, virtual reality, mobile devices and other digital technologies enhance the construction of meaningful learning, favouring the intrinsic motivation of students and promoting innovative educational practices that respond to the demands of contemporary education.

Table 1. Integration of technology in the teaching of natural sciences.

Author(s)	Topic of analysis	Pedagogical impact	Strategies to apply in the classroom
Ardanuy, J., Sulé, A., & Borrego, Ángel (2024)	Use of augmented reality (AR) in natural science education	AR improves understanding of complex concepts and encourages interaction in the classroom.	Incorporate AR applications to visualise complex natural phenomena, such as the water cycle or the solar system.
Bantwini, B. (2017)	Analysis of science and technology teaching in primary schools	Lack of technological resources limits effective learning; greater investment in educational technology is recommended.	Use basic technological resources such as interactive videos and accessible simulations to complement teaching.
Barráez-Herrera, D. P. (2022)	Use of the metaverse in education	The metaverse offers new opportunities for immersive teaching, but requires teacher training.	Design immersive activities in virtual environments to explore ecosystems or scientific experiments.
Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021)	Emergency remote teaching in higher education	Technology enabled educational continuity, but revealed inequalities in access.	Implement platforms accessible to all students and encourage the use of online collaborative tools.
Cabascango-Trávez, G. (2023)	Augmented reality in secondary education	AR facilitates meaningful learning and student motivation.	Create group projects where students use AR to explore concepts such as photosynthesis or human anatomy.
Dorta-Pina, D., & Barrientos-Núñez, I. (2021)	AR in higher education	AR improves knowledge retention and students' active participation.	Incorporate laboratory simulations in AR for virtual practices in subjects such as chemistry or biology.
Dron, J. (2022)	Educational technology and how it works	Educational technology must be adapted to pedagogical needs in order to maximise its impact.	Select technology tools that align with the specific learning objectives of the class.
Fracchia, C., Alonso-de-Armiño, A., & Martins, A. (2015)	Application of AR in natural sciences	AR enables visualisation of complex phenomena and improves conceptual understanding.	Use AR applications to model processes such as volcano formation or the carbon cycle.
Hennessy, S., et al. (2007)	Pedagogical approaches to technology integration	Technology integration requires teacher training and clear pedagogical strategies.	Train teachers in the use of technological tools and design practical activities using technology.
Kalogiannakis, M., et al. (2018).	Use of mobile devices in science education	Mobile devices combined with hands-on activities enhance learning in young children.	Incorporate educational mobile applications for simple experiments and interactive activities.
Marín-Díaz, V., & Sampedro-Requena, B. E. (2020)	AR in primary education	Students perceive AR as a motivating and useful tool for learning.	Design playful activities with AR, such as interactive games to learn about the human body or ecosystems.
Matías-Olabe, J. C., et al. (2023)	AR in natural sciences	AR strengthens learning by enabling interactive and visual experiences.	Implement research projects where students use AR to explore

			natural phenomena.
Mendoza-Fuentes, C. A. (2021)	Teaching strategies with AR	AR enhances learning by facilitating understanding of abstract concepts.	Use AR to represent abstract concepts such as physical forces or chemical molecules.
Musakhonovna, K. L. (2022)	Modern educational tools in science	Technological tools foster autonomy and active learning.	Encourage the use of interactive platforms where students can conduct virtual experiments.
Nawzad, L., et al. (2018).	Effectiveness of technology in science education	Technology enhances teaching by making it more interactive and accessible.	Incorporate digital simulations to explain complex scientific phenomena.
Oliveira, A., & Pombo, L. (2017)	Technology-mediated strategies	Technological strategies personalise learning and increase motivation.	Design personalised activities using technological platforms that adapt the content to the pace of the learner.
Oliveira, A., et al. (2019)	Emerging technologies as pedagogical tools	Emerging technologies enrich learning by offering innovative experiences.	Introduce tools such as virtual reality or advanced simulations to explore scientific concepts.
Poultsakis, S., et al. (2021)	Management of digital objects in science	Digital objects and simulations enhance practical science teaching.	Use digital simulators to perform experiments that cannot be done in the classroom due to resource constraints.
Sousa-Ferreira, R., et al. (2021)	Virtual reality in education	Virtual reality enables immersive experiences that enrich learning.	Implement virtual tours to explore environments such as the ocean floor or outer space.
Stankova, E. N., et al. (2016).	Use of computer technology in science	Computer technology increases efficiency and understanding in science teaching.	Use specialised software to model physical or chemical phenomena in real time.
Tairab, H. H. (2001)	Teachers' perceptions about science and technology	Teacher training is key to effectively integrating technology into teaching.	Offer in-service training workshops for teachers to learn how to integrate technology into their classrooms.
Uçar, S. (2015)	Use of technology in teaching science to young children	Technology fosters early learning and scientific curiosity .	Incorporate hands-on activities with technological devices to explore basic science concepts.
Urbina-Aguirre, M. B., et al. (2023)	AR in science learning	AR promotes active learning and knowledge retention.	Design hands-on activities with AR to explore topics such as biodiversity or biogeochemical cycles.
Veselinovska, S. S., et al. (2010)	Interactive learning in natural sciences	Interactive tools enhance participation and learning in science.	Use interactive tools such as digital whiteboards and simulations to teach biology.
Zainuddin, Z., et al. (2020)	Science, Technology and Society (STS)-based teaching materials	STS materials promote contextualised and meaningful learning.	Design teaching materials that connect scientific concepts with current social problems.

Source: Own elaboration.

Table 1 shows that one of the most favourable results is the positive impact of augmented reality on the understanding of abstract and complex concepts; in this sense, Ardanuy et al. (2024), Matías-Olabe et al. (2023) and Mendoza-Fuentes (2021) show that AR encourages active student interaction, which favours the construction of meaningful learning and the retention of knowledge; therefore, AR allows the visualisation of phenomena such as the carbon cycle or human anatomy, which would otherwise be difficult to approach in a traditional environment. Likewise, Sousa-Ferreira et al. (2021) explain that virtual reality offers immersive experiences that enrich the teaching of complex subjects, such as the exploration of ecosystems or natural phenomena, providing a safe and controlled environment that facilitates experimentation and scientific enquiry.

The use of mobile devices and digital platforms has also proven to be a tool for personalising learning and adapting it to the individual needs of students, with Kalogiannakis et al. (2018) and Poultsakis et al. (2021) noting that these technologies enable simulations, virtual experiments and hands-on activities that would otherwise be unfeasible due to resource or infrastructure constraints. Furthermore, these tools foster learner autonomy by giving them the possibility to actively explore and construct their own knowledge, in line with the principles of self-directed learning; thus, Nawzad et al. (2018) reinforce this idea by highlighting that digital technologies not only enhance interaction in the classroom, but also promote collaborative and dynamic learning, favouring the development of transversal competences such as communication and teamwork.

However, the implementation of these technologies is not without challenges, as the lack of teacher training in the pedagogical use of technological tools, as pointed out by Hennessy et al. (2007) and Tairab (2001), represents a significant barrier to their effective integration in the classroom; therefore, it is essential that teachers not only acquire technical competencies, but also develop pedagogical skills that allow them to design innovative teaching activities aligned with learning objectives. Furthermore, Bond et al. (2021) and Bantwini (2017) explore inequality in access to technology resources, especially in economically constrained educational contexts, which remains a major obstacle to ensuring equitable and sustainable implementation.

From a pedagogical perspective, the studies reviewed agree on the need to adopt integrative approaches that combine emerging technologies with active methodologies, such as project-based learning, scientific enquiry and collaborative learning. In this sense, Oliveira et al. (2019) comment that emerging technologies, when integrated with innovative pedagogical strategies, not only enhance learning, but also develop key competences such as critical thinking, problem solving and creativity. In addition, Uçar (2015) notes that the use of technologies in science education for young children fosters scientific curiosity from an early age, which contributes to the development of fundamental scientific skills and interest in STEM (Science, Technology, Engineering and Mathematics) disciplines. In terms of instructional design, materials based on approaches such as science, technology and society (STS), discussed by Zainuddin et al. (2020), offer an opportunity to contextualise learning and connect scientific concepts to current social issues, which not only enriches curricular content, but also promotes more relevant and meaningful learning for students by linking scientific knowledge to their everyday environment and reality.

On the other hand, one of the main contributions of technology in the teaching of natural sciences is its ability to facilitate the understanding of abstract concepts and complex phenomena; tools such as augmented reality (AR) and virtual reality (VR) allow students to visualise and experience processes that would otherwise be difficult to observe in a traditional environment. In addition, studies such as those by Ardanuy et al. (2024) and Matías-Olabe et al. (2023) highlight that AR allows the representation of phenomena such as the carbon cycle, photosynthesis or human anatomy, which fosters more meaningful and long-lasting learning. Likewise, Sousa-Ferreira et al. (2021) indicate that VR offers immersive experiences that enrich the teaching of complex subjects, such as the exploration of ecosystems or natural phenomena, providing a safe and controlled environment for experimentation.

Likewise, the integration of emerging technologies has also contributed to the development of essential transversal competences for the 21st century, such as critical thinking, problem

solving, creativity and collaboration, in this order, tools such as digital simulations and interactive platforms encourage the active participation of students, promoting learning based on enquiry and experimentation; therefore, Kalogiannakis et al. (2018) and Nawzad et al. (2018) note that the use of mobile devices and digital platforms not only enhances classroom interaction, but also promotes collaborative work and student autonomy; these technologies allow students to explore and construct their own knowledge, developing skills that transcend academia and prepare them to face the challenges of the contemporary world.

Another significant impact of technology in the teaching of natural sciences is its ability to personalise learning and adapt it to the individual needs of students; authors such as Poultsakis et al. (2021) and Oliveira et al. (2017), point out that digital platforms and mobile applications allow for the design of personalised activities that fit the pace and learning style of each student, which not only improves student motivation and engagement, but also facilitates educational inclusion by providing accessible resources for students with different levels of skills and background knowledge.

CONCLUSION

From the articles reviewed, the incorporation of emerging technologies in the teaching of natural sciences has generated a significant impact on the understanding of complex concepts, positioning itself as a tool to transform the teaching-learning processes. Therefore, technologies such as augmented reality and virtual reality have proven to be particularly effective in allowing interactive and immersive visualisation of abstract phenomena, such as biological processes or chemical cycles, facilitating meaningful learning. This impact is enhanced when these tools are combined with active methodologies, such as project-based learning and scientific enquiry, which promote not only the acquisition of knowledge, but also the development of transversal competences such as critical thinking and problem solving.

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