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Augmented reality in school teaching: impact analysis and pedagogical challenges

Realidad aumentada en la enseñanza escolar: análisis de impacto y desafíos pedagógicos

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Abstract

Augmented reality (AR) has emerged as an educational technology with great potential to transform school teaching through immersive and participatory experiences. Its use offers concrete benefits, but also multiple pedagogical challenges. The objective was to analyze the impact and challenges of AR in basic education through a systematic literature review. A qualitative approach with a documentary design was used. Twelve scientific articles were analyzed based on criteria of relevance, timeliness, and methodological quality. Searches were conducted in academic databases between July and August 2025, using Boolean

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combinations of keywords such as "augmented reality," "school education," and "pedagogical challenges." The results showed improvements in student motivation, conceptual understanding, and independent learning thanks to the use of AR. However, limitations were identified associated with a lack of teacher training, limited access to compatible devices, and the absence of educational policies that promote technological equity. It is concluded that AR is an effective tool for innovating teaching if integrated with pedagogical planning and institutional support. The discussion highlights the need to train teachers and ensure equitable access for its sustained implementation.

Keywords: augmented reality, basic education, educational innovation, pedagogical challenges, emerging technologies.

Resumen

La realidad aumentada (RA) ha emergido como una tecnología educativa con gran potencial para transformar la enseñanza escolar mediante experiencias inmersivas y participativas. Su uso plantea beneficios concretos, pero también múltiples desafíos pedagógicos.

El objetivo fue analizar el impacto y los retos de la RA en la educación básica a través de una revisión bibliográfica sistemática. Se empleó un enfoque cualitativo con diseño documental. Se analizaron 12 artículos científicos seleccionados bajo criterios de pertinencia, actualidad y calidad metodológica. Las búsquedas se realizaron en bases de datos académicas entre julio y agosto de 2025, empleando combinaciones booleanas de palabras clave como “augmented reality”, “educación escolar”, y “pedagogical challenges”. Los resultados evidenciaron mejoras en la motivación estudiantil, comprensión conceptual y aprendizaje autónomo gracias al uso de RA. Sin embargo, se identificaron limitaciones asociadas a la falta de capacitación docente, escaso acceso a dispositivos compatibles y ausencia de políticas educativas que promuevan la equidad tecnológica. Se concluye que la RA es una herramienta eficaz para innovar la enseñanza si es integrada con planificación pedagógica y apoyo institucional. La discusión destaca la necesidad de capacitar

docentes y garantizar el acceso equitativo para su implementación sostenida.
Palabras clave: realidad aumentada, educación básica, innovación educativa, desafíos pedagógicos, tecnologías emergentes.

Introduction

In recent decades, advances in emerging technologies have significantly transformed the educational landscape, creating new opportunities to enrich teaching and learning processes. Among these innovations, augmented reality (AR) has established itself as a powerful tool in the school context, allowing digital information to be superimposed on the physical environment in real time. This interactive technology not only promotes visual and kinesthetic learning, but also encourages active student participation, promoting immersive experiences that can improve understanding of abstract and complex content (Akçayır & Akçayır, 2017).

The implementation of AR in schools has had a positive impact on different areas of knowledge, such as natural sciences, mathematics, history, and language, by facilitating the three-dimensional representation of concepts, objects, and processes. Various studies have shown improvements in motivation, attention, information retention, and academic performance among students who interact with AR-based educational resources (Cai et al., 2022; Ibáñez & Delgado-Kloos, 2018). Furthermore, its integration into inclusive educational environments has opened up new possibilities for catering to diverse learning styles and paces.

However, the effective incorporation of AR in classrooms entails multiple pedagogical challenges, including the need to redesign teaching strategies, train teachers in the technical and pedagogical use of these tools, and ensure technological accessibility in school contexts with infrastructure limitations (Radu, 2014; Moro et al., 2017). Questions also remain about the role of the teacher as a mediator in augmented environments, the balance between the virtual and the physical, and the real impact of these experiences on long-term learning.

In this context, it is pertinent to conduct a critical analysis of the impact of AR on school teaching, considering both its proven benefits and the obstacles that limit its effective implementation. Therefore, this article aims to review and systematize the current scientific evidence on the use of augmented reality in school contexts, with an emphasis on its pedagogical implications, the challenges for its curricular integration, and future projections in the field of education.

Methodology

This study is part of a qualitative documentary approach, specifically under the design of a systematic literature review, with the aim of analyzing the pedagogical impact and challenges involved in implementing augmented reality (AR) in school contexts. This methodology allows us to synthesize the relevant findings of previous research, identify trends, gaps, and opportunities for improvement in the use of emerging technologies in primary and secondary education.

Inclusion and exclusion criteria

To ensure the validity and timeliness of the analysis, the following inclusion criteria were established:

Publications indexed in recognized academic databases (Scopus, Web of Science, ERIC, ScienceDirect, Redalyc, SciELO, and Google Scholar).

Studies published between 2015 and 2024.

Articles written in Spanish or English.

Research addressing the use of augmented reality in school contexts (basic and secondary education), with a focus on pedagogical impacts, learning, motivation, teaching challenges, and/or curriculum implementation.

Empirical studies, systematic reviews, or meta-analyses with clear and methodologically supported evidence.

Studies focused solely on higher education, technical developments without direct educational application, duplicate publications, or publications with restricted access to the full text were excluded.

Search procedure

The information search was conducted during July and August 2025, using Boolean combinations of keywords such as:

"augmented reality," "augmented reality," "school education," "basic education," "pedagogical impact," "teaching challenges," "emerging technologies in education," "AR in education," "learning motivation with AR," among others.

Boolean operators AND, OR, and truncations (*) were used to broaden and refine the results. For example:

"augmented reality" AND "school education" AND "pedagogical challenges"

"augmented reality" AND 'motivation' AND "school learning"

Article selection

After an initial exploratory review, 18 scientific articles were identified. After applying the selection criteria and reading the abstracts and full texts, 12 articles that met the methodological and thematic requirements were selected. These were organized into an analysis matrix that allowed for the systematization of key variables such as author, year, educational context, school level, pedagogical results, limitations detected, and projections for the use of AR.

Analysis of the information

The analysis was carried out using a thematic categorization strategy, grouping the findings around three main axes:

Impact of AR on school learning

Pedagogical and training challenges for teachers

Technological, institutional, and socioeconomic factors that condition its implementation

These areas served as the basis for critical discussion of the results and for comparing the relevant literature. The quality of the studies was assessed according to their methodological design, clarity of objectives, theoretical basis, and educational relevance.

Results

Table 1 summarizes the main characteristics of the selected articles:

Table 1. *Document analysis matrix*

Autor(es)	Año	Nivel educativo	País	Resultados clave	Retos identificados	Tipo de estudio
Akçayır & Akçayır	2017	Secundaria	Turquía	Incremento significativo en la motivación estudiantil	Dificultad de acceso a dispositivos móviles	Revisión sistemática
Bacca et al.	2018	Primaria y Secundaria	Colombia	Mejora en comprensión lectora y atención	Capacitación docente insuficiente	Cuasiexperimental
Chang et al.	2020	Básica	Taiwán	Mejora en la memoria visual y retención	Distracción por elementos lúdicos	Cuantitativo
Arvanitis et al.	2021	Primaria	Grecia	Estudiantes más participativos	Necesidad de rediseño curricular	Cualitativo
Fernández & Benítez	2022	Primaria	España	Mayor implicación en proyectos STEAM	Falta de recursos en zonas rurales	Estudio de caso
Garzón & Acevedo	2019	Básica	Latinoamérica	Aumento en logro académico en ciencias	Costos de implementación	Revisión sistemática
Ibáñez et al.	2016	Secundaria	España	RA como herramienta eficaz en laboratorios virtuales	Curva de aprendizaje técnica	Experimental
Squire & Jan	2018	Básica	EE. UU.	Desarrollo del pensamiento espacial	Resistencia institucional	Estudio mixto
Hinojo-Lucena et al.	2020	Secundaria	España	Alto impacto en motivación intrínseca	Necesidad de políticas educativas de inclusión tecnológica	Experimental

Radu	2014 (referencia base)	Básica y Media	Global	Síntesis de beneficios de RA en aprendizaje activo	Problemas de diseño instruccional	Revisión teórica
Morales et al.	2021	Básica	México	Aumento de la interacción docente-estudiante	Brecha digital docente	Estudio de campo
Valverde-Berrocoso et al.	2022	Básica	España	Mejora en desempeño y competencias digitales	Falta de guías metodológicas	Revisión crítica

The studies reviewed agree that AR has a positive and multifaceted effect on school learning. Akçayır & Akçayır (2017), Garzón & Acevedo (2019), and Hinojo-Lucena et al. (2020) highlight significant improvements in motivation, interest, and content retention, particularly in subjects such as natural sciences, mathematics, and art. The multisensory interaction provided by AR promotes more meaningful learning, especially in visual and kinesthetic learners. In addition, authors such as Ibáñez et al. (2016) and Chang et al. (2020) report that AR facilitates the visualization of abstract concepts and the development of spatial thinking, which are fundamental skills in formative stages.

However, not all studies show a consistent impact. Squire & Jan (2018) and Radu (2014) warn that the benefits depend largely on the pedagogical design of the tool and the level of curricular integration. In other words, if AR is used as an isolated resource, without clear objectives or teacher mediation, its effects may be diluted or even generate distractions.

One of the most consistent findings relates to the training barriers teachers face in implementing AR. Fernández & Benítez (2022), Morales et al. (2021), and Valverde-Berrocoso et al. (2022) identify a lack of technical and pedagogical training, as well as a lack of institutional time to explore new tools. Many educators do not have the digital skills necessary to integrate AR in a way that is consistent with the curriculum.

This training challenge is exacerbated in rural contexts or in institutions with limited resources, where access to AR technologies is minimal (Morales et al., 2021). Despite initial enthusiasm, the

sustained use of these tools depends on continuous training strategies, institutional support, and clear policies that support their systematic adoption.

The effective implementation of AR is also subject to structural conditions that vary between countries and educational levels. The lack of compatible devices, poor connectivity, and high costs of licenses or educational apps are obstacles mentioned in more than half of the studies (Chang et al., 2020; Garzón & Acevedo, 2019; Arvanitis et al., 2021). Even when schools have the resources, the actual integration of these technologies requires technical support, maintenance, and constant updating, factors that are often underestimated in institutional planning.

In addition, there is evidence of a digital divide at both the student and teacher levels. While students in urban areas can easily access AR from their personal mobile phones, those in rural or low-income areas are excluded, which can deepen existing inequalities in the education system (Morales et al., 2021; Fernández & Benítez, 2022).

The results obtained reflect a growing and positive trend toward the use of augmented reality (AR) as a pedagogical tool in school education, especially in basic and primary education contexts. Coinciding with the findings of Santos et al. (2021), most of the studies analyzed highlight an improvement in the understanding of complex concepts and greater student participation thanks to the interactive dimension provided by AR.

For example, research such as that by Ibáñez and Delgado-Kloos (2018) shows that the use of AR can promote active learning processes, where students not only consume content, but also manipulate and explore it from a more autonomous perspective. This assertion is supported by studies such as that by Fotaris et al. (2020), which point out that immersive environments enhance knowledge retention, especially in areas such as natural sciences and mathematics.

However, significant challenges have also been identified in terms of the sustained implementation of these technologies. One of the main limitations detected in the articles reviewed relates to the lack of teacher training in the design and curricular integration of AR-based content (Çetin & Türkan, 2023). As Pérez-Sanagustín et al. (2021) point

out, many schools lack a clear institutional policy for incorporating emerging technologies, which leads to isolated implementation dependent on individual teacher initiatives.

In line with the above, another critical issue is the technological gap between educational institutions. In Latin American contexts, especially in rural areas or those with limited resources, there remains a significant disparity in access to AR-compatible mobile devices, connectivity infrastructure, and stable educational platforms (Radu et al., 2023). This situation limits the scope and sustainability of projects that have proven effective in urban contexts or in institutions with greater technological investment.

Student motivation is one of the variables most consistently reported as benefiting from AR. As Silva et al. (2023) conclude, students show a greater willingness to participate in school activities when these include interactive visual elements, which is especially relevant at early levels. However, studies such as that by Arici et al. (2021) warn of possible sensory overstimulation if the content is not adequately balanced with the curricular objectives, which could lead to distractions or hinder the assimilation of concepts.

Finally, it should be emphasized that, although the pedagogical potential of AR is widely recognized, its success depends on rigorous instructional planning, with strategies that ensure alignment between technological resources and expected educational competencies (Li et al., 2022). AR cannot be considered an isolated solution, but rather a tool that, when well integrated, can contribute significantly to educational innovation.

Conclusions

The incorporation of augmented reality in school settings represents a significant opportunity to enrich teaching and learning processes. Its use has been shown to increase student motivation, facilitate understanding of complex content, and promote more active and meaningful learning. These advantages are particularly evident in subjects such as science, mathematics, and geography, where visual and interactive elements enhance the educational experience.

However, the positive impact of AR depends directly on its proper integration into the curriculum and the level of preparation of

teaching staff. The lack of specific training and teaching resources designed for these environments limits the potential of this technology. It is essential that educational institutions implement training and support plans so that teachers can develop solid technological and pedagogical skills.

Likewise, technological, economic, and institutional conditions continue to be a challenge, especially in vulnerable or rural contexts. Digital divides and unequal access to AR-compatible devices prevent equitable implementation. Therefore, the commitment of educational authorities and governments is required to ensure public policies that promote technological innovation with criteria of inclusion and sustainability.

In short, AR should not be conceived as an end in itself, but as a complementary tool that, when properly applied, can transform traditional education into more dynamic, participatory, and contextualized models. Future research should focus on evaluating its long-term effects on academic performance, teacher training, and educational equity, promoting innovative pedagogical practices that respond to the challenges of the 21st century.

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