



## SYSTEMATIC REVIEW

# Systematic review on Augmented Reality in health education

## Revisión sistemática sobre Realidad Aumentada en la formación sanitaria

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### ABSTRACT

**Introduction:** Augmented Reality is an innovative and promising tool for health education, which can improve the teaching-learning process and facilitate the development of professional competencies.

**Objective:** to describe the findings on the applicability of AR in health education.

**Method:** a systematic review was carried out using the PRISMA method, based on the search in databases related to health sciences, PubMed, Science Direct and Scopus, as well as Google Scholar. The aim was to answer the question: What results has the application of AR had in health education?

**Results:** 15 articles that met the inclusion criteria were identified. Most of the studies were conducted in the context of medical education. The results showed that AR has a positive effect on learning, motivation, satisfaction, self-efficacy, confidence and transfer of knowledge and skills to practice. However, some limitations and challenges were also found, such as cost, availability, quality, safety and evaluation of the effectiveness of AR.

**Conclusions:** the use of AR in health education reveals a diverse and promising scenario, but also poses important challenges and limitations that must be overcome to exploit the full potential of these emerging technologies.

**Keywords:** Augmented Reality; Medical Education; Health Education.

### RESUMEN

**Introducción:** la Realidad Aumentada es una herramienta innovadora y prometedora para la formación sanitaria, que puede mejorar el proceso de enseñanza-aprendizaje y facilitar el desarrollo de competencias profesionales.

**Objetivo:** describir los hallazgos sobre la aplicabilidad de la RA en la formación en salud.

**Método:** se realizó una revisión sistemática por el método PRISMA, a partir de la búsqueda en bases de datos relacionadas con las ciencias de la salud, PubMed, Science Direct y Scopus, además de Google Scholar. Se tuvo la finalidad de responder la pregunta: ¿Qué resultados ha tenido la aplicación de la RA en la formación en el sector de la salud?

**Resultados:** se identificaron 15 artículos que cumplieron los criterios de inclusión. La mayoría de los estudios se realizaron en el contexto de la educación médica. Los resultados mostraron que la RA tiene un efecto positivo en el aprendizaje, la motivación, la satisfacción, la autoeficacia, la confianza y la transferencia de conocimientos y habilidades a la práctica. Sin embargo, también se encontraron algunas limitaciones y desafíos, como el costo, la disponibilidad, la calidad, la seguridad y la evaluación de la efectividad de la RA.

**Conclusiones:** el uso de RA en la educación y formación en la salud revela un panorama diverso y prometedor, pero también plantea importantes desafíos y limitaciones que deben superarse para explotar al máximo el potencial de estas tecnologías emergentes.

**Palabras clave:** Realidad Aumentada; Educación Médica; Formación Sanitaria.

## INTRODUCTION

Augmented Reality (AR) is emerging as a technology with significant impact on our contemporary society. Its influence extends across multiple sectors.<sup>(1)</sup> Most definitions conceptualize AR as the incorporation or fusion of virtual elements into the real environment perceived by the user.<sup>(2)</sup>

This innovative technology offers an interactive and enriched experience, transforming the way we interact with the world. It spans from gaming applications that integrate virtual elements into physical environments to educational tools that allow for the practical exploration of complex concepts.<sup>(2)</sup>

AR refers to the combination of digital and physical information in real time through diverse technological devices such as tablets, smartphones, and glasses. This technology involves the use of devices that superimpose virtual information onto existing physical information, thereby creating a new reality where both types of information play a significant role.<sup>(3)</sup>

This technology stands out for its distinctive features that make it appealing to various sectors: it provides a mixed reality experience, seamlessly integrates information in real time, enables the combination of different sources and formats of data (text, 3D, websites, videos, etc.). It is interactive, requiring user participation in content construction, and enriches or modifies real-world information with integrated data.<sup>(2)</sup>

An expansion of the horizons of creativity and functionality in various fields is observed through the application of AR. Its growing acceptance not only predicts a change in the way digital content is consumed but also promises to transform the way we learn, work, and communicate, opening up new perspectives and possibilities in these areas.<sup>(4,5)</sup>

By integrating elements of the real world with overlaid digital information, AR offers an interactive and immersive learning approach that transcends the limitations of traditional methodologies. This technology enables students to explore concepts in a practical and contextualized manner, fostering deeper and long-lasting understanding.<sup>(4,5)</sup>

In the education sector, it unfolds a vast array of opportunities to strengthen understanding, retention, and application of concepts, especially in challenging disciplines such as health sciences. Its implementation in this field has aroused steadily growing interest due to its ability to facilitate the assimilation of complex concepts, improve information retention, and promote more practical and application-oriented learning.<sup>(4,6)</sup>

In medical education, the utilization of AR provides a learning environment that unites theory with practice in an exceptional manner. It enables students to visualize and manipulate anatomical models, as well as explore complex medical processes, all while practicing clinical procedures in a realistic virtual environment. This tool offers an immersive and practical learning experience that complements traditional theoretical instruction, preparing students to tackle real-world challenges more effectively.<sup>(1,3,4)</sup>

The use of simulation in medical training has emerged as a valuable method that complements traditional teaching. Simulation, which involves substituting or amplifying real experiences with controlled situations that replicate key aspects of the real world, offers an interactive way of learning. This technique provides an opportunity for students to practice clinical skills safely and effectively, allowing them to gain practical experience before facing real-life situations.<sup>(2,4)</sup>

However, it is important to highlight that the effective implementation of AR in the field of medical education presents significant challenges. The adoption of this technology requires adequate infrastructure, including the availability of compatible devices and training of teaching staff in its effective use.<sup>(7)</sup>

Additionally, the creation of relevant and high-quality AR content can be complex and costly. Furthermore, it is crucial to address the ethical and privacy concerns associated with the utilization of AR in formative environments, especially regarding the confidentiality of patients' medical information. Therefore, while AR offers significant potential to enhance medical education, careful consideration of these challenges and the adoption of appropriate measures to address them are required.<sup>(7)</sup>

Considering the necessity to exhaustively collect and synthesize the available evidence in the scientific literature in the context of AR in health education, conducting a systematic review would allow for the identification and critical analysis of different approaches, findings, and limitations of prior studies on this subject.

The objective of this study is to describe the findings on the applicability of AR in health education.

## METHODS

A systematic review was carried out using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology.<sup>(8)</sup> The study aimed to answer the research question: What results has the application of AR had in health education?

The search was conducted using databases related to health sciences, including PubMed, Science Direct and Scopus, as well as Google Scholar. The following search strategy was employed, adapted to the specificities of each database: ((Augmented Reality) AND (Health training)), with filters for English language and the time interval from 2019 to 2023.

All journal articles related to the topic were included if they provided or summarized relevant findings and did not have a technical focus on the implementation of virtual reality solutions. Articles lacking relevance to health or approached from an overly personal or impractical perspective were excluded from the study.

## RESULTS Y DISCUSSION

The results of the study identification process are summarized in Figure 1. The searches yielded a total of 1519 records, of which 1310 were eliminated through the application of filters and automated tools, duplicate removal, and other reasons. 209 records underwent screening.

According to the established criteria and after reviewing the titles, 112 articles were excluded during the screening phase as they were found not to be directly related to the objectives of this study, based on title reading. 97 articles were retrieved, and out of these, 85 were evaluated for eligibility.

Throughout the review process, 70 records were excluded for not being relevant to the addressed topic, as they did not pertain to the health field and solely focused on technical, technological, or support aspects in the implementation of AR. Finally, 15 articles were included in the study.

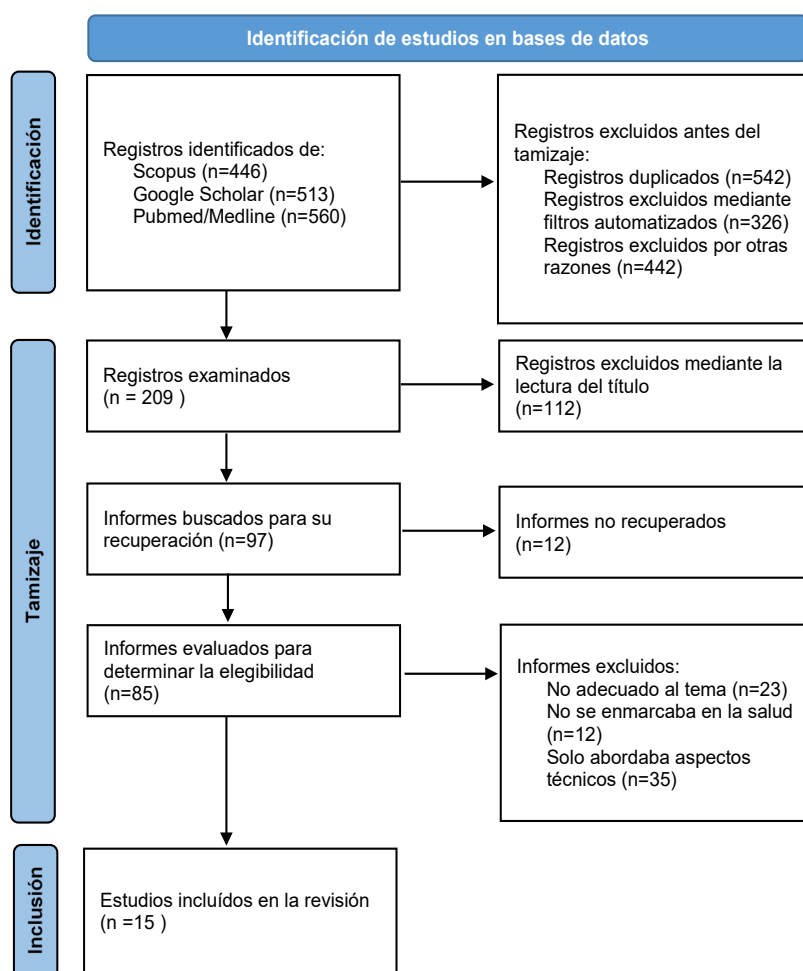


Figure 1. PRISMA Flowchart of the review

The use of AR in health education has been explored in several studies. Papadopoulou et al.<sup>(9)</sup> and Dhar et al.<sup>(10)</sup> highlight the potential of AR in medical education, with its ability to provide practical training and enhance learning outcomes.

This is particularly relevant in the context of the COVID-19 pandemic, which has accelerated the shift towards online learning. McCarthy et al.<sup>(11)</sup> and Campisi et al.<sup>(12)</sup> also discuss specific applications of AR in health education, including teaching anatomy, simulating emergencies, and guiding patients through treatments.

In the present review, in 100 % of the reviewed articles, the transformative potential of AR was considered. Similarly, there was agreement on the practical applications and benefits for professionals and students.

Th studies by Campisi et al.<sup>(12)</sup>, Omarov et al.<sup>(13)</sup> and Dixit et al.<sup>(14)</sup> provided specific areas of application.

60 % addressed the limitations that persist in the application and generalization of AR in learning experiences. There was also variability regarding the measurement and evaluation methods of the benefits of AR.

In table 1, the most relevant elements addressed by the authors regarding the use of AR in health education are presented. In cases where limitations are not specified, they refer to AR technology. In some instances, there were limitations concerning the study methodology.

Most relevant elements addressed by several authors regarding the use of AR in health education.

**Table 1.** Most relevant elements addressed regarding the use of AR in health education by authors

Study	Year	Results and Conclusions	Limitations
Papadopoulou et al. <sup>(9)</sup>	2019	<ul style="list-style-type: none"> <li>Virtual Reality (VR) and AR transform medical education.</li> <li>They are innovative and cost-effective solutions for better and faster practical training.</li> <li>Virtual environments have the potential to enhance experiential understanding of learning objectives.</li> </ul>	<ul style="list-style-type: none"> <li>Early stage of VR and AR in medical education.</li> <li>Necessity for more research to establish effectiveness.</li> <li>Implementation costs.</li> <li>Necessity for standardized guidelines.</li> <li>Possible limitations such as dizziness and technological dependence.</li> </ul>
Dhar et al. <sup>(10)</sup>	2021	<ul style="list-style-type: none"> <li>AR-based programs effectively prepare medical professionals.</li> <li>AR experiences are positive and enjoyable.</li> <li>AR prepares for complex social situations in controlled environments.</li> </ul>	<ul style="list-style-type: none"> <li>Lack of comprehensive evaluation of AR programs.</li> <li>Challenges of equity and accessibility.</li> <li>Criticisms of limited AR hardware.</li> <li>Growing issue of social isolation.</li> </ul>
McCarthy et al. <sup>(11)</sup>	2019	<ul style="list-style-type: none"> <li>VR and AR platforms are increasingly utilized in health education. They are used for teaching anatomy and simulating emergencies.</li> </ul>	No limitations specified.
Campisi et al. <sup>(12)</sup>	2020	<ul style="list-style-type: none"> <li>AR guides patients in treatments without access to medical professionals.</li> <li>AR has potential in education and patient guidance.</li> </ul>	No limitations specified.
Dixit et al. <sup>(14)</sup>	2020	<ul style="list-style-type: none"> <li>AR as a tool for health training transfer.</li> <li>Positive impact on work training transfer.</li> </ul>	<ul style="list-style-type: none"> <li>Reliance on qualitative evaluations.</li> <li>Necessity for more research in organizational learning.</li> </ul>
Omarov et al. <sup>(13)</sup>	2022	<ul style="list-style-type: none"> <li>AR methods benefit sports training.</li> <li>VR and AR technologies are expanding in various industries.</li> </ul>	<ul style="list-style-type: none"> <li>Potential inefficacy of traditional training approaches.</li> <li>Inconsistent academic descriptions.</li> <li>Focus on the development of AR technology in sports businesses.</li> </ul>
Ricci et al. <sup>(15)</sup>	2022	<ul style="list-style-type: none"> <li>AR/VR systems are superior or comparable to traditional training methods.</li> <li>Emphasis on defining user and simulator purpose.</li> </ul>	<ul style="list-style-type: none"> <li>Fragmentation and combination of studies.</li> <li>Heterogeneity in research.</li> <li>Lack of comparison with traditional methods.</li> <li>Necessity for standardized tests.</li> </ul>
Raith et al. <sup>(16)</sup>	2022	<ul style="list-style-type: none"> <li>Virtual educational environments save resources and increase participation.</li> <li>AR has potential in radiology and medical visualization.</li> </ul>	No limitations specified.
Hernández et al. <sup>(17)</sup>	2023	<ul style="list-style-type: none"> <li>AR virtual patients improve relevance and applicability of medical education.</li> <li>Review of aspects to make AR more immersive.</li> </ul>	No limitations specified.
Leung et al. <sup>(18)</sup>	2019	<ul style="list-style-type: none"> <li>Development of AR mobile application for medical education modules.</li> <li>Satisfactory functionality on diverse platforms.</li> </ul>	<ul style="list-style-type: none"> <li>Limited scope.</li> <li>Possible generalization issues.</li> </ul>
Chimakurthi <sup>(19)</sup>	2019	<ul style="list-style-type: none"> <li>AR can be useful in medical education and has various applications in medicine.</li> </ul>	No limitations specified.

Ivanov et al. <sup>(20)</sup>	2020	<ul style="list-style-type: none"> <li>• Significant transformation in medical education due to digital technologies.</li> <li>• Rapid growth of medical simulations.</li> </ul>	<ul style="list-style-type: none"> <li>• Difficulties in producing realistic images in surgical simulator. Challenges in incorporating graphic solutions in a complex modeling engine.</li> <li>• Necessity for more precise modeling results.</li> <li>• Potential limitations in cost-effectiveness of haptic system.</li> </ul>
Hong et al. <sup>(21)</sup>	2019	<ul style="list-style-type: none"> <li>• AR displays offer unique opportunities for health educational experiences.</li> </ul>	No limitations specified.
Zafar et al. <sup>(22)</sup>	2021	<ul style="list-style-type: none"> <li>• AR transforms health education, surpassing traditional techniques in 11 studies.</li> <li>• Challenges for students in the implementation of AR applications.</li> </ul>	No limitations specified.
Bianchi et al. <sup>(23)</sup>	2020	<ul style="list-style-type: none"> <li>• Limited number of studies meet the criteria for AR games in medical education.</li> <li>• Lack of standard evaluation protocol.</li> </ul>	Lack of standard usability evaluation protocol.
Sushereba et al. <sup>(24)</sup>	2021	<ul style="list-style-type: none"> <li>• Task-centered design and natural environments improve effectiveness of AR training.</li> </ul>	Limitations in devices.

One of the recurring findings in several studies, such as those by Papadopoulou et al.<sup>(9)</sup>, Dhar et al.<sup>(10)</sup>, and Zafar et al.<sup>(22)</sup>, is that VR and AR, when combined, offer greater potentialities. These technologies represent innovative and cost-effective solutions for practical training and experiential understanding of medical concepts. Additionally, their capacity to prepare professionals for complex social situations and enhance the relevance and applicability of medical education is highlighted, as mentioned by Hernández et al.<sup>(17)</sup>

However, several studies also point out significant limitations that must be addressed to ensure the success and effectiveness of VR and AR implementation in this context. One of the main challenges is the lack of exhaustive research to establish the effectiveness of these technologies.<sup>(9)</sup> The need for more empirical evidence and standardized guidelines is highlighted in several reports, including those by Papadopoulou et al.<sup>(9)</sup>, Dhar et al.<sup>(10)</sup> and Bianchi et al.<sup>(23)</sup>

The implementation costs also pose a significant barrier, which limits the accessibility of these technologies, especially in resource-limited environments. Additionally, technological dependency and possible side effects, such as dizziness, are important concerns that must be addressed to ensure the safety and comfort of users.<sup>(9,24)</sup>

Several studies point out specific challenges related to the implementation. For instance, the study by Dhar et al.<sup>(10)</sup> highlights the lack of comprehensive evaluations of AR-based programs, suggesting the need for more rigorous research on the effectiveness of these interventions. Moreover, issues of equity and accessibility, as well as criticisms regarding the limited AR hardware, pose additional challenges that must be addressed to ensure these technologies are accessible to all students.<sup>(24)</sup>

Likewise, other studies highlight the need to overcome technical and methodological obstacles to maximize the potential of AR in health education. For instance, the study by Ivanov et al.<sup>(20)</sup> points out difficulties in producing realistic images in surgical simulators and the need for more precise modeling outcomes. Similarly, the study by Bianchi et al.<sup>(23)</sup> emphasizes the lack of standardized evaluation and usability protocols, complicating the comparison and generalization of results across different studies.

Despite these limitations and challenges, the reviewed studies provide evidence of the favorable outcomes resulting from the implementation of AR in healthcare professional education. The ability of these technologies to create immersive and personalized learning environments could revolutionize the way medical concepts are

taught and learned, enhancing knowledge retention and the ability to apply skills in real clinical situations.<sup>(25)</sup>

However, to make the most of this potential, it is essential to address the identified limitations and challenges by developing effective strategies to overcome technical, financial, and methodological barriers, ensuring that these technologies are accessible and safe for all students and medical professionals.

## CONCLUSIONS

The analysis of multiple studies on the use of AR in health education and training reveals a diverse and promising scenario. However, it also highlights important challenges and limitations that must be addressed to exploit the full potential of these emerging technologies.

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#### **CONFLICT OF INTEREST**

None.

#### **AUTHORSHIP CONTRIBUTION**

*Conceptualization:* Jose Ignacio Robaina Castillo.

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