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Review

Applications Analyses, Challenges and Development of Augmented Reality in Education, Industry, Marketing, Medicine, and Entertainment

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Abstract: This study aims to develop systematic research about augmented reality (AR) problems, challenges, and benefits in the current applications of five fields of interest. Articles were selected from scientific, technical, academic, and medical databases of digital journals and open access papers about AR. Therefore, the method used to develop the investigation was PRISMA, which allowed us to observe interesting facts and coincidences about complexities and successful cases of AR implementation in the disciplines of education, marketing, medicine, entertainment, and industry. The summary provided in this study was the result of the exploration of 60 recent articles found and selected by relevance using the PRISMA method. The main objective of this paper is to orient and update researchers regarding current applications, benefits, challenges, and problems in AR implementation for future studies and developments.

Keywords: augmented reality; education; industry; medicine; entertainment; marketing

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1. Introduction

Different articles review augmented reality (AR) history and current applications, software and hardware used, problems and implications to apply this technology in certain areas, among suggestions for future exploration [1]. Most of those summary papers are oriented to education, where topics such as the quantitative analysis of geographical AR contributions, experiences in the development of AR prototypes, interaction with students, and application areas (art, manufacturing, construction, medical, and services) are well analyzed [2]. Additionally, other AR reviews consider the type of deployment devices, designs such as marketing, and AR performance evaluation methods [2]. Furthermore, in medicine, we can find AR reviews proposing improvements in information search systems in libraries and analyzing challenges of AR in orthopedic surgeries, where in a study of 62 articles, it was possible to find that AR tools can be useful for training and practice, but there are still hardware limitations and a lack of registration and tracking systems as well as security protocols [3]. In addition, in AR reviews for the area of industries, it is possible to find propositions to evaluate AR applications for knowledge transfer considering authoring, adaptation, and interaction toward augmented content [4]. The stages of AR application and the factors that these have generated have been considered within four articles studied about reviews for AR; however, in this paper, we will focus on the difficulties that these studies have had and bring them up to date for 2023, as well as the changes that have arisen and manifested in the implementation of some AR projects.

Additionally, advances in any discipline are constantly present and one of the areas that manifest this situation in a latent and rapid way is technology, therefore, this literature review provides opportunities for improvements that were exhibited in the articles published from the period of 2017 to 2023. The relevance of the knowledge of this information helps to simplify, understand, and reveal different areas of industry, education, medicine, etc., with similar situations, and how the solution or the progress to achieve can be of great significance for the adoption of AR by society.

To make the differences between our statement of purpose in this paper clearer, we have made a summary of some of the articles of the literature review about AR in Table S1 (Supplementary Materials).

Beforehand, it is necessary to define what AR is and to understand some of the important criteria we undertook in the development of our study.

We can describe AR as a technology that allows the superposition of 2D and 3D digital objects in common real-life settings; this works by using a device that has the functionality of tracking the position of the user and markers collocated in real scenarios to project extra digital information, thereby enhancing reality [4].

To clarify the definition of AR, three characteristics can describe it simply:

- It is the mixture of the real and the virtual coexisting in one scenario [5].
- Both contexts, real and virtual, act together in real time [5].
- There is an implementation of 2D or 3D digital images and videos [5].

To better understand the disparities between AR and VR, we can use Paul Milgram and Fumio Kishino's Reality—Virtuality Continuum [1] (Figure 1) to picture that the user in AR is proximate to the real world but in VR it is isolated in the total digital setting.

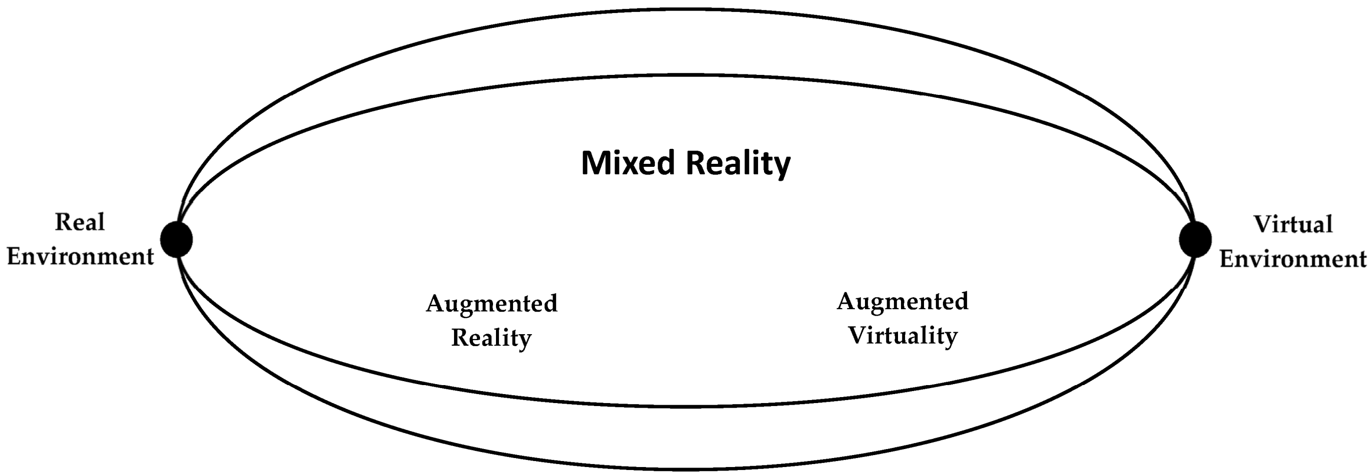

Figure 1. Milgram's Reality–Virtuality Continuum [1].

Furthermore, AR can be described as a computer system that can react to user input and produce related visuals in real time, a tracking system that allows for detecting a user's standpoint status, as well as a display that can blend real and virtual images [6].

The software used to develop systems for AR is every time more accessible and innovative. Some frameworks and platforms currently applied are ARToolKit®, WikiTude®, Vuforia®, ARCore®, ARJS®, <Model-Viewer>®, EasyAR®, among others.

Smartphones today are trendy devices used for AR because they can project digital objects in real settings with a location-based function such as GPS or a more advanced global positioning feature. However, there are other examples of hardware used for AR such as the Microsoft HoloLens, Google Glass, Magic Leap, Atheer, and Osterhout Design Group [7]. Additionally, there exist current investigations into new systems of more sophisticated gadgets that allow the user to access AR more easily and ergonomically [8].

Among the fields where AR and VR can be disruptive and have more investment by 2025, according to a Goldman Sachs excerpt from "Virtual and Augmented Reality: Understanding the Race for the Next Computing Platform" [7], the authors made a forecast, shown in Table 1, that shows the most significant areas where AR and VR can be applied and have a promising future according to the investment, estimated users, and markets disrupted.

Table 1. Goldman Sachs Global Investment Research [7].

AR and VR Fields	Estimated Users	Market Disrupted	Investment in Dollars
Videogames	216 mn	Videogames	$11.6 bn
Live events	95 mn	Live ticket sales	$4.1 bn
Video Entertainment	79 mn	Online streaming	$3.2 bn
Retail	32 mn	E-commerce	$1.6 bn
Real Estate	0.3 mn	Commissions	$2.6 bn
Education	15 mn	K-12 and higher-ed software	$0.7 bn
Healthcare	3.4 mn	Patient monitoring	$5.1 bn
Military	0.7 mn	Defense training and simulation	$1.4 bn
Engineering	3.2 mn	CAD/CAM software	$4.7 bn

For the development of our analysis in this article, we are taking into consideration some of these areas described, which we encompassed with the terms of entertainment, marketing, education, medicine, and industry engineering.

In summary, this research examines AR application papers selected from the period from 2017 to 2023. Through this exploration, we found coincidences in current AR uses, important obstacles, challenges, problems, and benefits that are necessary to consider for the future application of this technology.

Finally, the main contribution of this investigation is to present the key gaps in AR reported in the literature, as summarized below:

- The main areas that implement AR in industry, education, medicine, etc. [7].
- AR benefits encountered in practical applications in current years [9–13].
- AR challenges in its implementation in industry, education, medicine, etc. [14–18].
- Recommendations for AR implementation.

In summary, this revision can provide pertinent scientific material about AR to those who are at this time developing applied research for this technology in any of the study fields presented.

2. Materials and Methods

2.1. Literature Search

This section shows the process for obtaining data by searching for information in different databases and a metasearch engine where it was necessary to look at and introduce keywords and variables to find the required information. The websites or databases chosen for the study were IEEExplore, ScienceDirect, Taylor & Francis, Springer, and a metasearch engine, Google Scholar. Those websites were considered because they contained scientific, academic, and technical articles of great prestige with the possibility of finding open access studies.

Additionally, we applied the PICOS [19] approach in constructing the research questions for our article: People (P), Intervention (I), Comparison (C), and Outcome (O).

Considering the objective of our study, only articles related to education, industry, marketing, medicine, and entertainment (P) where AR is applied (I) were selected and analyzed to obtain current AR applications, benefits, challenges, and problems that will orient and update researchers for future AR studies and developments (O).

The questions designed for our study were created to identify the main aspects to fulfill the aim of our research:

1. Which aspects link AR with the five chosen areas of study?
2. What are the benefits, challenges, and problems that AR mostly faces in all areas?

2.2. Selection Process

Likewise, for this study, we selected the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) method, which is the development of 27 items in a checklist and four-phase flow chart with the phases of identification, screening, eligibility, and inclusion, which will allow us to have a better systematic review of the articles encountered. The general items are title, abstract, introduction, methods, results, and funding [20]. This article also includes discussion, recommendations, and conclusions sections.

Inclusion criteria:

- Augmented reality applied to the areas of interest.
- Publication periods from 2018 to 2023.
- Articles that talk about the difficulties and benefits of augmented reality.
- Desirable articles that show tools in the use of AR.
- Articles with open access.

Exclusion criteria:

- Items outside of the 2018 to 2023 range.
- Articles of slight relevance according to views in the chosen areas of study in databases and metasearch engines.

2.3. Systematic Search

In the systematic search, the main concept of relevance was "Augmented reality", but there were other more specific concepts that helped to find better results such as: "Augmented Reality in industry", "Augmented Reality in education", "Augmented Reality in marketing", "Augmented Reality in medicine", and "Augmented Reality in entertainment".

To find detailed information about the areas selected in the different databases, it was necessary to look for strategic terms that guided us to the articles selected. For instance, in AR for industry, we wrote strings of search in Google Scholar such as Industry "augmented reality" -Overview -meta-review -survey. In this case, we excluded words such as overview, meta, review, and survey to obtain articles with current AR implementations rather than reviews. The result of this search gave us 232 scientific articles. Later, in IEEE Xplore, a simple search with the terms Augmented reality in industry produced the result of 46 articles. Then, in ScienceDirect, the search string was Augmented reality Title, abstract, keywords: industry Procedia CIRP, Procedia Computer Science, producing a result of 290 studies. For Taylor & Francis, we looked with the search string [All: augmented reality] AND [All: industry] AND [Abstract: materials] AND [Abstract: process] AND [Publication Date: (1 January 2018 TO 31 December 2023)], which produced 31 papers. Finally, for Springer, we used the string search AR augmented reality industry' within Engineering Article, which produced 150 results. A summary of the searches and findings is shown in Table 2.

The PRISMA flow diagram was applied for the selection of 60 relevant articles about AR chosen according to the PRISMA method (identification, screening, eligibility, and inclusion) [20]. In this case, we describe the flow diagram for augmented reality in industry for the Springer database to demonstrate the method applied.

In the level of identification, it was possible to obtain 27,391 articles in four databases and 51,900 in the metasearch engine just by looking for the term AR in industry. Later, at the screening level, we obtained 779 articles by applying the exclusion and inclusion criteria and taking off the 78,512 articles that did not match the parameters. In the eligibility level, we took 150 articles from the Springer database, so the remainder (629) are from the other databases (IEEE Xplore, Taylor & Francis, ScienceDirect, and Google Scholar). Finally, we obtained two articles selected by relevance (Figure 2).

Table 2. Strings of search in the selected four databases and metasearch engine.

Databases	Education	Marketing	Industry	Medicine	Entertainment
IEEE Xplore	Augmented reality in education	Augmented reality in marketing	Augmented reality in industry	Augmented reality in medicine Augmented reality surgery	("Document Title": augmented reality in entertainment) OR ("Document Title": Game) OR ("Document Title": Treatment)
Results	66	13	56	46	664
Science Direct	Augmented reality Title, abstract, keywords: Education teaching learning Social Sciences, Computer Science	Augmented reality Title, abstract, keywords: augmented reality marketing International Journal of Information Management	Augmented reality Title, abstract, keywords: industry Procedia CIRP, Procedia Computer Science	Game Title, abstract, keywords: training Title: augmented reality	Augmented reality Title, abstract, keywords: game Computer Science, Social Sciences
Results	201	259	67	271	296
Google	allintitle: application learning OR preparation OR education "augmented reality" -Overview -virtual -meta -review -survey	allintitle: marketing OR brands "augmented reality" -Overview -virtual -meta -review -survey	allintitle: Industry "augmented reality" -Overview -meta-review -survey	allintitle: medicine "augmented reality" -Overview -virtual -meta -review -survey	Game learning interactive "augmented reality" OR "augmented reality" AND "sports" AND "entertainment" AND "system" AND "application"
Results	383	160	311	42	6760
Taylor & Francis	[Publication Title: augmented reality] AND [All: learning] AND [All: education] AND [Publication Date: (1 January 2018 TO 31 December 2023)]	[Publication Title: augmented reality] AND [All: marketing] AND [All: customers] AND [Publication Date: (1 January 2017 TO 31 December 2023)]	[All: augmented reality] AND [All: industry] AND [Abstract: materials] AND [Abstract: process] AND [Publication Date: (1 January 2018 TO 31 December 2023)]	[All: augmented reality] AND [Abstract: surgery] AND [All: medicine] AND [Publication Date: (1 January 2018 TO 31 December 2023)]	
Results	222	51	195	381	0
Springer	'augmented reality in education' within English Education Article 2018–2023	Title: augmented reality 'marketing AND (innovative)' within Article 2017–2023	'ar augmented reality industry' within Engineering Article	'augmented reality medicine' within English Imaging/Radiology Surgery Article 2018–2023	Title: augmented reality 'games OR (entertainment)' within English Article 2018–2023
Results	497	30	150	54	139

By applying this method, it was possible to select 60 relevant articles to get deep into our analysis and find the information needed for the aim of the study. The documents were selected by the authors reviewing the abstract where it was shown that RA was applied in the study(s), obtaining partial or concrete results, and showing information on current AR applications, benefits, challenges, and/or problems. Moreover, the articles selected showed in the titles and/or keywords, AR and/or some of the disciplines such as education, industry, marketing, medicine, and entertainment. Nonetheless, it is considered that the risk of bias may be from selection derived from not contemplating all existing databases.

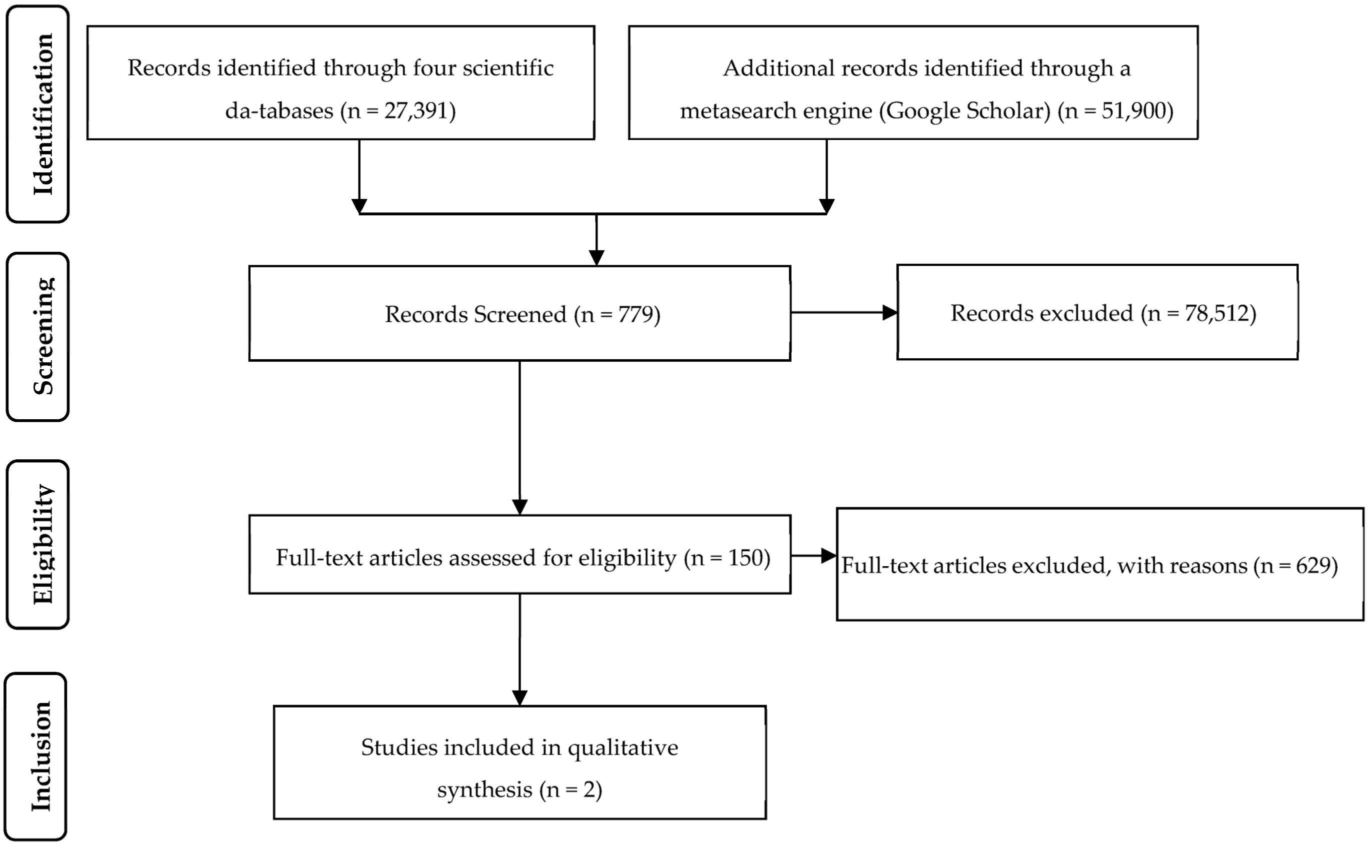

Figure 2. The PRISMA flow chart for AR in industry in the Springer database.

2.4. Manual Search

Because open access articles were not found in all of the journals selected, we decided to carry out a new search with the same keywords and with the criteria of relevance applied on the Google Scholar website, since it is a metasearch engine with a greater spectrum and precision in its content. As a result of the new search, the 60 articles were completed and analyzed together with the articles already selected from the databases.

3. Results

The initial exploration was carried out in the databases and metasearch engine where the first topic searched was "Augmented Reality". Figure 3 shows the number of scientific articles found on the topic of augmented reality on the websites, sorted from the lowest to highest quantity in the period selected. As can be seen, Google Scholar is the site with the most papers published as it is a metasearch engine.

It was possible to see that the AR studies made had an important growth from 2018 to 2023, as AR production reached its highest peak with 254,731 studies in total. On the other hand, it was interesting to observe that in the last 20 years, AR has had a pronounced and continuous growth (Figure 4).

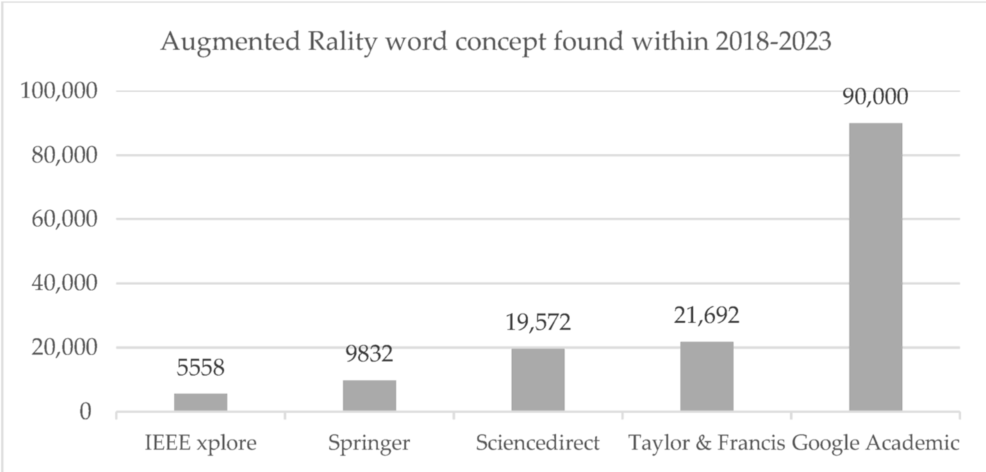

Figure 3. "Augmented Reality" articles found in databases.

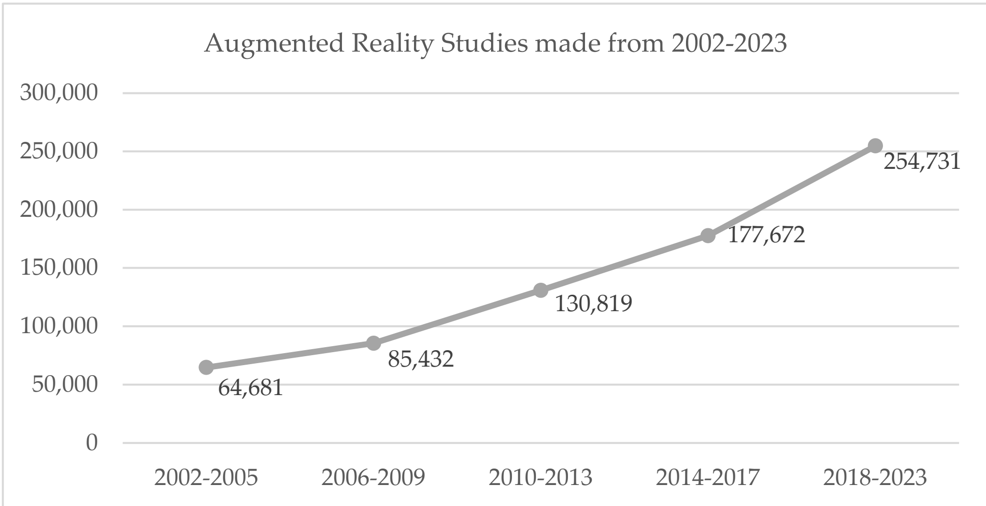

Figure 4. AR research trends.

In Figure 5, it is appreciated that the tendency of the different platforms is similar, i.e., there is an increase in scientific production chronologically growing and encountering the highest progress in 2023. AR, today, is at its highest point in Google Scholar, meanwhile, in the other websites, AR scientific production has its own pace growing continually to have its highest progress in the last 5 years.

In Figure 6, it is possible to visualize the total scientific articles found in the five platforms used and divided into the disciplines chosen. It was interesting to note that in the past few years, the study of AR is more prominent in education, with 98,812 results in scientific production, in second place, industry with 79,291, later, marketing with 68,867, next, medicine with 72,357, and the last one is entertainment, with 55,301 articles relating to AR.

For a deeper analysis, the titles of the papers chosen according to the inclusion and exclusion criteria are shown in Tables S2–S6 in the Supplementary Materials.

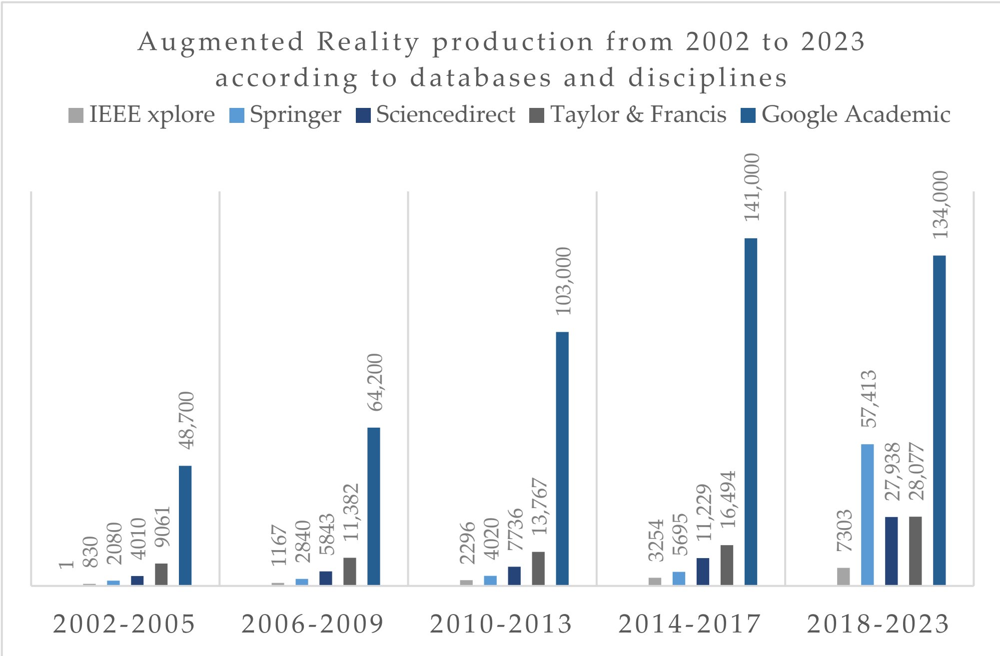

Figure 5. AR research trends according to databases and disciplines.

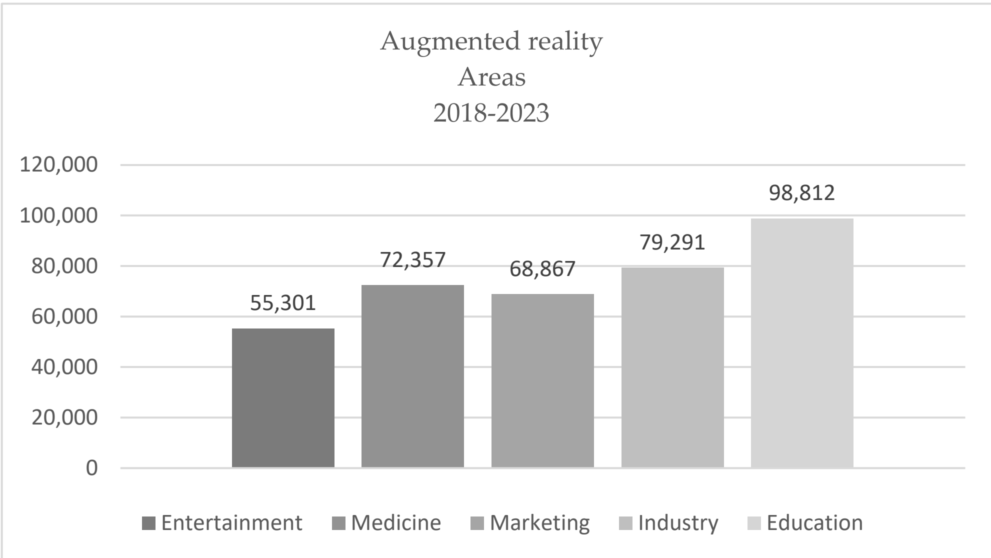

Figure 6. AR articles encountered by discipline.

3.1. Summary of the Selected Articles

The following section contains the summary of the AR articles determined by the PRISMA method in the different areas proposed, i.e., education, marketing, industry, medicine, and entertainment.

3.1.1. Education

According to the studies found, education is probably one of the most explored fields where AR has been applied, with 98,812 articles found in the five databases chosen; it was the discipline with the most scientific production in the period chosen. It was interesting to find that training or education is implicit in all disciplines since AR is a technology that needs to be learned before its application. Additionally, there were certain coincidences in the benefits of AR application in education that were mostly an important increment in learning motivation.

From the 12 articles studied, there was an AR education (AREd) app where students from different educational levels received 3D materials to be applied in school practices; this was evaluated to determine the knowledge obtained, and it was found that AREd incremented the learning speed and understanding. However, one of the difficulties encountered was that the adaptation to AREd was complicated for some of the students [21].

Different from the last example, in another study, although the use of AR was complicated at first, the students adapted to it easily and soon showed acceptance. AREd was implemented to interact in inquiry-based learning in a teacher–student system. For this research, four videos were implemented in two high schools, with two of the videos being adapted to AR, leaving the other two without this feature. AREd again showed a positive impact; however, teachers still had to develop timely questions and suggestions to increase the battery of data. This clearly supported the inquiry-based learning performance. The model was built with 3D Max, and the AR application program was developed with Unity3D and Vuforia [22].

Understanding was also part of a study of AREd, applied and compared to a common booklet written to improve knowledge about cerebrovascular accidents. In this research, 101 participants were randomized and placed into two groups to complete a lesson using a printed handout (n = 50) or an AR digital mode (n = 51). The educational interventions were identical and described important aspects of the physiology and pathophysiology of a stroke, as well as the anatomy of the brain. Applicants answered a pretest multiple-choice questionnaire to assess prior understanding before the lesson, followed by an additional multiple-choice test and a Likert-scale survey after completion. In the end, participants had better interaction and stimulation with AR, although the results given showed that the two forms of learning obtained almost the same accomplishments [23].

AREd is at an early stage for students of applied health sciences at the University of Ciudad del Cabo, where this research was applied to impact the motivation of student learning. Intrinsic motivation theory was used to explain motivation in the context of learning. The attention, relevance, trust, and satisfaction (ARCS) model guided understanding. A total of 78 participants were examined who used the augmented reality mobile app and completed the pre- and post-use questionnaires. The results showed that the use of an AR mobile application increased the students' learning motivation. The motivating factors of attention, satisfaction, and trust increased, and these results were found to be significant. Although the relevance factor showed a decrease, this turned out to be trivial [24].

Geo + was an AR application presented to support the learning of solid geometry in 96 third-grade students, looking for the effectiveness of learning and the workload in the acquisition of knowledge. The results were satisfactory in gaining learning with great appreciation by students for its simplicity of use. The tools used were Unity, UnityLibrary, Unity Engine, GameObject, and Vuforia [25].

Additionally, in medicine, a biological microscope based on virtual reality (VR) and AR technology was made for a learning system. With VR, a detailed model in 3D was developed, while AR worked as a guidance system for the microscope, allowing users to switch between VR and AR subsystems. This technology is seen as a great achievement for AREd in open spaces [26].

The "Mirror World" was designed and developed with +Andscape; this is an interactive AR sandbox that was applied for collaborative games and storytelling in children (5–6 years, N = 16). A qualitative analysis was carried out to infer how children play with the AR sandbox. It was obtained as a result of the expansion of imagination, allowing children to create unique media events by manipulating the zones for storytelling [27].

Similarly, there was a great achievement in enhancing the understanding of physical phenomena thanks to AREd environments. This AR application was created to facilitate the comprehension of a common but complicated concept in physics called "torque". This AR app, designed with Vuforia and Unity 3D, was implemented in educational scenarios with students in the first year of mechanics at the KTH Royal Institute of Technology. The implementation allowed students to visualize and interact with this technology to evaluate its usability by making a comparison between a scenario of a common lesson and in an enhanced context with an AREd application. In the end, the students obtained a great improvement in their comprehension, unlike those who implemented nothing. Even though the sample taken was too small, the results were revealing [28].

Additionally, there was an implementation of AREd based on ARTutor and the use of a mobile application for undergraduate courses at the Institute of Technology of Eastern Macedonia and Thrace. It allowed for improving the experience of reading books in high school students by adding digital content where satisfactory results were shown in 84% of the people who used it. This study considered the average experience in the use of AR technology, where its main evaluation measure was the user experience [29].

Extended Reality (XR), which is defined as the mixture of virtual reality and augmented reality, has been implemented erroneously in education due to the lack of a method that distinguishes the contexts in which it can be applied. XR in education is expensive and difficult to learn, and it requires interaction between teacher and students for the development of content and understanding of these new technologies. Apart from that, it was found that XR produces problems of dizziness in users, and when the XR aligns but does not adapt to educational environments, it might be ineffective. In this article, Fernández proposes a six-step methodology for the adoption of AR: (i) teacher training; (ii) development of conceptual prototypes; (iii) teamwork involving the teacher, a technical programmer, and an educational architect; (iv) production of the experience; (v) train teachers to apply AR solutions within their teaching methodology; (vi) and finally implement the use of the experience with students [13].

Moreover, the application of AR was studied to help students to understand the feasibility of this technology for meaningful learning, to recognize the response of students to knowledge of the human body with AR, and as teaching material to improve analytical skills for the human body. The study was applied in March 2022 in elementary school children; however, this AR tool can be applied to high school and university students. Unity and Vuforia were used, with QR markers to distinguish the areas. The results were evaluated through a questionnaire, and the conclusions were favorable, mentioning that this technology can be a useful tool for learning [30].

It is important to comment that the main benefits of AREd depend on the number of specialized professionals. This can be noted from AREd growth at any school level, increasing student enthusiasm for learning, as well as the assimilation of contents. However, the main difficulties for AREd in institutions are financial challenges, the necessity of personnel professionalization, and the lack of specific methodologies to simplify the use of this technology [14].

Table 3 shows the problems or difficulties with AR applications (-), benefits or positive experiences in the implementation (*), an intermediate point where even though there were issues, it was possible to find solutions (+), or articles that did not show information about the branch suggested (/).

3.1.2. Industry

Industry AR (IAR) has revolutionized complex manufacturing processes and activities, security methods, personnel training, testing applications to avoid failures in procedures, and AR technical manuals, among other areas. Even though AR tools in the industry are useful, it is still considered to be at an early stage with the lack of battery durability, AR tools overheating [15], and more ergonomic devices, better configurations, and improvements in light variation [31] are required. The following 12 articles refer to specific examples of AR applications in manufacturing fields.

Navatia, an important shipbuilding company developed and evaluated an IAR system based on a fog computing architecture. The most remarkable outcome of the study is the assessment of AR frameworks, such as ARToolKit and Vuforia, as well as markers on smartphones, tablets, and smart glasses. The evaluation facilitated the determination of the performance of IAR in a shipyard within a ship under construction and the election of the best hardware and software to be used in the practice. Although the technology today is functional, there should be an improvement in the marker systems due to the change in lighting [32].

Table 3. The main AR characteristics found in the articles for education.

Education					
Databases	**Articles**	**Learning**	**Adoption**	**Implementation**	**Motivation**
IEEE Xplore	Augmented reality and virtual reality for learning: An examination using an extended technology acceptance model [25].	*	*	/	/
	Knowing your student: Targeted teaching decision support through asymmetric mixed reality collaborative learning [21].	*	-	/	/
	Adoption of virtual and augmented reality for mathematics education: A scoping review [13]	*	*	-	*
Science Direct	Improving stroke education with augmented reality: A randomized control trial [23].	*	/	/	*
	Virtual and augmented reality for the biological microscope in experiment education [26].	*	/	/	/
	Augmented reality for the hands-on studying of the human body for elementary school students [30].	*	/	/	*
Google Academic	The impact of an augmented reality application on the learning motivation of students [24].	*	*	/	*
	Application of augmented reality technologies for the preparation of specialists of a new technological era [14].	/	/	-	/
Taylor & Francis	Interaction analysis of teachers and students in inquiry class learning based on augmented reality by iFIAS and LSA [22].	*	*	/	/
	Augmented reality sandboxes: Children's play and storytelling with mirror worlds [27].	*	/	/	*
Springer	Improving the learning of mechanics through augmented reality [28].	*	/	/	/
	Evaluation of the ARTutor augmented reality educational platform in tertiary education [29].	/	/	/	*

A follow-up of the previous study of IAR in the Navatia shipbuilding factory was made to improve the IAR application where it is proposed the combination with cloudlets and fog computing to reduce latencies caused by elements in the cloud and rendering. The IAR tool helped to locate products inside the workshops with placed tags and sensors among other practices. The answer is still not optimal, but there is a clear advance in the subject, and it refers to the need for cloudlets in case of real-time use [33].

In the aviation industry, appropriate maintenance practices with AR tools project realistic scenarios. The elements taken in this study are AR and additive manufacturing, where the purpose was to be able to provide preventive and corrective maintenance as required, making a comparison with traditional practices. It obtained good results, but as in the shipbuilding IAR practices, it came out with the same defects in the perception of light for the markers in the area where they were applied [34].

A maintenance AR system was also developed for fast-track repair procedures in the context of industry 4.0. It was implemented in smartphones, where the elements were detected, and instructions were given for the repair or support of the service for the machinery. In this case, an air conditioning compressor was used as a sample. More than 20 experts evaluated the maturity of the product, noting that support can be effective, especially in reducing the time by 30% [35].

The performance of AR in the food industry remains significantly low. This document defines AR, its benefits and challenges, and proposes a framework for the implementation of AR in the food industry. It points out the importance of interactive menus within restaurants, and it also mentions the need for fast operation and the ability to be able to take advantage of the best options within the wide range that this technology offers, since it is very new, in addition to considering its role in increasingly smaller, cheaper, and more robust devices [36].

IAR still struggles with various challenges mainly caused by technical limitations, security problems, or industry-specific restrictions. The implementation of an open-source AR remote helped to carry out an examination to compare it with a printed manual. The study aimed to know which method uses less time and errors. The result obtained showed that AR helps to reduce defects in processes with 13% failure compared to 53% from paper, and the time in the execution of the activity was reduced by 3 s. Even though the differences in time were not significant, the instructions tasks were much easier to follow, and the reduction in mistakes made it totally worth it [15].

Talking about the construction industry, there was acceptance of a building information model (BIM) and AR integration. The research was based on the Technology Acceptance Model 3 (TAM3). The scope was narrowed to four developing countries (Malaysia, Egypt, Saudi Arabia, and Turkey), and a survey was developed and distributed to construction professionals in those places for data collection purposes. Exploratory factor analysis (EFA) was used to develop the TAM, and regression analysis was performed to validate it. The TAM3 showed that users' control over BIM–AR and the perception of simplicity in use have the greatest influence on the effectiveness of the system. The results of this study can be used to evaluate the acceptance of BIM–AR integration in the context of the construction industry, and the TAM3 can be applied for the improvement of a new BIM–AR that can be used in developing countries [12].

Exceeding traditional paper manuals, there was a study to compare three different disassembly sequences seeking to achieve the best performance, after which a simulation was carried out with IAR where the best assembler is taken as a model. Looking at the AR simulation, it could be noted how the chosen layout showed a flexible approach for mounting and dismounting (i.e., three axes with all individual elements and end covers for each, which would also allow for a parallel dismounting approach). Piece interference was checked for each sequence [31].

There was an enhancement made in the planning and integration process for the required data and production systems that are user-oriented and partially automated. This was made thanks to a machinery maintenance system through AR that simulates scenarios with models implemented in a CAD procedure, a production data management system (PDM), a manufacturing execution system (MES), and CNC [37].

Additionally, an AR system was analyzed where different tasks could be assisted remotely with experts in the area supporting the operators within the industry to have a better performance. The results of the study allowed us to observe that AR can supplant the experts in activities that are within an already established process, increasing work-time efficiency, and eliminating the deaths generated by communication problems or waiting for a response from experts. Nevertheless, it is important to consider that the tests were carried out accompanied by the assistant and that they were not contemplated in extraordinary situations [38].

Moreover, an IAR proposed methodology was compared with three disassembly sequences using a hybrid approach between genetic algorithms and state space search. This information was presented in AR to allow viewers a better understanding of the methodology and to simulate the effect in the real world. AR demonstrated that research methodologies can be represented, showed how 3D models behave in real spaces, and finally, showed the importance of research work in the fields of industry [31].

In the last article, there were automatic trackers for automotive AR applications based on CNN (convolutional neural network) enhanced by implementing 299 $\times$ 299 pixel images in RGB format. However, depth was lost, but it could be improved in RGB-D formats. With this practice, it was intended to implement the results of methodologies for decision making, seeking optimization, and raising the importance of using models for problem solving and AR as an exemplification sample. The AR experience can be improved by generating a specialized network architecture for pose estimation or the optimization of network hyperparameters. Likewise, it was shown that although it was difficult to train personnel in the use of AR in specific cases if the problems are predictable and planned, these are optimal, allowing human efforts and adjustment calibrations to be eliminated [9].

To have a graphic summary of AR in industry, we made a review in Table 4, which shows problems or difficulties with AR applications (-), benefits or positive experiences described (*), an intermediate point where even though there were issues, it was possible to find solutions (+), or articles that did not show information about the branch suggested (/).

3.1.3. Marketing

Augmented reality marketing (ARM) is a term adopted to express the use of AR in innovative marketing strategies. In this study, we have 12 articles where ARM was applied to have a more dynamic and meaningful approach to customer preferences [16], a practical tool for client decision making [39,40], and a company's instrument that ensures certainty on the products offered to increase its profits and maintain brand awareness and client loyalty [40–42].

For example, in tourism and hospitality ARM is key to interacting with the clients and customizing the product. In the article "Spatial Augmented Reality-Based Customer Satisfaction Enhancement and Monitoring System" [42] there was an implementation where it was possible to observe the gestures of restaurant clients to obtain feedback on the meals, prices, and services. This is convenient for smart restaurants to offer their clients a greater experience and better prices on their next visit [42]. A similar example of ARM implementation is lived in Inamo restaurant located in London [43], where it is possible to have AR in water-proof tables, capable of projecting interactive menus, games, chef cameras, and independent payment. The engagement with clients achieved thanks to ARM is unique and attractive for new generations [43].

Additionally, there are applications in companies such as Lego, which combined its products with some images in AR, making them more appealing to clients by offering added value with an engaging and innovative AR feature [40]. Similarly, a new interactive game called Pokémon Go was declared as one of the most viral AR games in 2016, evaluated for new forms of marketing since people have a new way to get involved emotionally with each other in real and virtual places. Kai-Shuan Shen proposed a study to be taken as an opportunity to have new marketing strategies using the characteristics of communication and users' psychological attachment to these kinds of games [16].

ARM applied in premium brands gives a personalized and luxurious experience to the user by employing high-definition 3D images capable of stimulating the consumer's positive decision before buying the product. Some examples of brands using AR are Chanel, Tiffany, and Swarovski [39].

Table 4. The main AR characteristics found in the articles for industry.

Industry				
Databases	**Articles**	**Illumination**	**Latencies**	**Instructions and Labels**
IEEE Xplore	A practical evaluation of commercial industrial augmented reality systems in an Industry 4.0 shipyard [32].	-	+	/
	A review of industrial augmented reality systems for the Industry 4.0 shipyard [33].	-	/	*
	C.DOT—convolutional deep object tracker for augmented reality based purely on synthetic data [9].	*	/	*
Science Direct	Food 4.0: Implementation of augmented reality systems in the food industry [36].	/	-	*
	Creating an open-source augmented reality remote support tool for industry: Challenges and learning [15].	/	/	*
Google Academic	Maintenance in aeronautics in an Industry 4.0 context: The role of augmented reality and additive manufacturing [34].	-	/	*
	Technology acceptance model for augmented reality and building information modeling integration in the construction industry [12].	/	/	*
	MARMA: A mobile augmented Reality maintenance assistant for fast-track repair procedures in the context of Industry 4.0 [35].	/	/	*
Taylor & Francis	Disassembly sequence planning validated thru augmented reality for a speed reducer [31].	/	/	*
Springer	The efficient integration processing of production data into augmented reality-based maintenance of machine tools [37].	/	/	*
	Improving AR-powered remote assistance: a new approach aimed to foster operator's autonomy and optimize the use of skilled resources [38].	/	/	*

ARM makes brand equity possible by giving the client the chance to experiment with the quality of the product in a short time and the comfort of their homes [39]. For instance, IKEA and Amazon give the option of placing furniture or objects in customers' living spaces, making them feel comfortable with the recommendations received to empower their decision before buying [44].

Additionally, there is an AR implementation study of the Sephora app and L'Oreal's virtual mirror where clients can try on makeup digitally with simulated physical control, creating engagement with the brand and an entertaining and relaxing experience [45]. Both studies made were useful to make clear that AR apps for shopping can have a contrast between utilitarian and hedonic features. In the case of Sephora's AR app, the experience of the client was very entertaining, which meant that for that market, the hedonic value was too important rather than the usefulness characteristic to buy new products [45,46]. In summary, for both experiments, the AR-service augmentation can be beneficial for a company to save money (e.g., sampling or returning products) and to give customers a comfortable interaction as well as a positive feeling while buying products that can be placed in spaces or tried on such as cosmetics, accessories, decoration, furniture, or clothing [46].

It is believed that AR can substitute some physical products if the clients become used to being in contact with realistic and sophisticated AR content, this will generate a new era of AR transformation where common and cheap places will become well designed and fancy spots with complex holographic objects and decorations. Among the products more accepted for substitution for AR holograms are post-it notes, clocks, signs, posters, and calendars, but it does not mean that in the future there will be more objects to be accepted and changed for AR products, according to a study made by Philipp A. Rauschnabel. The important relevance of AR in marketing products is that companies today should make an analysis of disruptive technologies, such as the use of AR, that can make their businesses grow [47].

A purchase experience of a lamp with AR in Amazon was analyzed through two studies with 238 students divided into 118 using AR and 120 users with traditional purchase experiences. The objective was to obtain affective responses toward the product as well as enjoyment and inspiration through the Amazon app. The necessary data for empirical research was obtained based on the variants: (1) the differences in intensity of affective responses between AR and non-AR, (2) the interplay between affective and cognitive responses in shaping behavioral outcomes, and (3) the moderating role of client-specific factors (familiarity and AR product of the customers). Considering the product and the knowledge about the affective responses, the result is that the AR does not directly depend on the purchase result, that is, the AR increases enjoyment, although it does not support the purchase factor. On the other hand, the impact of the brand improved the inspiration thanks to AR; it also served as a driver and the brand attitude in the purchase intention. However, user interaction with AR and the product did not improve brand enjoyment. Likewise, AR can increase the relationship with the brand [48].

A study of ARM mobile apps discusses an integrative review and semi-inductive approach to the existing mobile apps market, clarifying and amplifying experiences, digital orientation, and customer value through journeys seeing competitive advantage in 471 studies across a study range of two decades. The research resulted in a positive decision-making process being characterized by the pre-adoption stage of AR, where it depends on the benefit that the consumer perceives from the applications and the individual characteristics, while these trigger positive experiences and journeys for customers if the added value is relevant within the purchase [10].

Talking about disadvantages, it is important to mention that ARM is still in the infancy stage because there has been little study into the benefits that can be obtained from it [40]. Additionally, even though ARM can give an enterprise a real perspective on clients' preferences because of the personal information gathered [39], it can be invasive and risky with no laws yet applied to ensure that people's privacy is not going to be exposed [40,41]. Some applications may have their own security strategies [42], but still, there is a lot to do to regulate the ethical issues of AR applications that extract and track clients' data. Another difficulty of ARM is to build better quality 3D images that represent the products portrayed making a negative perception of the brand, nevertheless, if the application is well oriented as in the case of the Sephora AR app, clients can forgive technology imperfections as it fulfills their necessities and motivations [45].

ARM works better for younger consumers since older generations have more rooted habits of consumption; it is a concern that age can be a watershed for the acceptance of the technology while talking about AR implementation on any product or AR retailing application [47].

Finally, Table 5 shows problems or difficulties with AR applications (-), benefits or positive experiences (*), an intermediate point where even though there were issues, it was possible to find solutions (+), or articles that did not show information about the branch suggested (/).

Table 5. The main AR characteristics found in the articles for marketing.

		Marketing							
Databases	**Articles**	**Visualization**	**Cost**	**Decision Making**	**Object Substitution**	**Interaction**	**Strategic Innovation**	**Cybersecurity Risk**	**Comprehension by the User**
IEEE Xplore	Spatial augmented reality-based customer satisfaction enhancement and monitoring system [42].	+	*	-	*	/	/	/	/
	E-marketing via augmented reality: A case study in the tourism and hospitality industry [43].	/	/	/	*	/	*	/	-
Science Direct	Setting the future of digital and social media marketing research: Perspectives and research propositions [40].	/	/	/	/	/	*	-	/
	Augmented reality is eating the real world! The substitution of physical products by holograms [47].	-	*	/	*	/	*	/	-
Google Academic	Augmented reality marketing: A technology-enabled approach to situated customer experience [41].	/	/	*	*	/	*	-	/
	We ARe at home: How augmented reality reshapes mobile marketing and consumer-brand [45].	-	*	*	*	*	/	/	*
	Strategic approaches to augmented reality deployment by luxury brands [39].	-	/	*	*	/	*	/	/
	Beyond the gimmick: How affective responses drive brand attitudes and intentions in augmented reality marketing [48].	/	-	-	/	*	*	/	/
Taylor & Francis									

Table 5. *Cont.*

		Marketing							
Databases	**Articles**	**Visualization**	**Cost**	**Decision Making**	**Object Substitution**	**Interaction**	**Strategic Innovation**	**Cybersecurity Risk**	**Comprehension by the User**
Springer	Measuring the appeal of mobility-augmented reality games, based on the innovative models of interaction: A case study [16].	/	/	/	/	/	*	/	-
	Seeing eye to eye: Social augmented reality and shared decision making in the marketplace [44].	/	/	*	/	*	*	/	-
	Augmenting the eye of the beholder: Exploring the strategic potential of augmented reality to enhance online service experiences [46].	-	*	*	*	*	*	/	/
	Marketing research on mobile apps: Past, present and future [10].	*	-	*	*	*	*	/	/

3.1.4. Medicine

AR in medicine is potentially useful in scenarios where doctors need extra help to virtually observe organs in places where it is not possible to do so. During the research of AR medicine, it was possible to analyze articles relating to plastic surgeries, medical treatments where movements and eye perception are important to implement, medical procedures such as laparoscopies, and psychological therapies among other operations that were successfully implemented with certain improvements to manage in the future.

First, studies using AR and VR were carried out to induce anxiety as a possible treatment for claustrophobic patients. The tests were applied to 34 randomly selected participants, where the variables considered were skin behavior and heart rate through a subjective anxiety scale; the data were taken at the end of each activity. The VR and AR systems effectively induced anxiety, and although no significant differences were found between which system was better to simulate these scenarios, it was considered that the AR had a slightly higher score [49].

The following article pointed out the importance of AR for medical personnel training in thoracoscopic surgeries. The necessity of AR in this procedure originated from the difficulty in specializing in or improving surgical processes and enhancing surgeons' skills. For the study, it was necessary to replicate scenarios through 3D models in the concept of the visual and reproduction of physical models, pressure gauges, and sensations for the kinesthetic aspect, demonstrating that the simulator is useful for improving the practices of experimented surgeons and beginners. The AR-based video-assisted thoracoscopic system developed in this study was effective and can be used as a training device to aid in the development of thoracoscopic skills for surgeons that are in their initial stages [17].

Additionally, another of the studies analyzed a presented problem corresponding to visuospatial deficiency manifested at the end of cardiovascular accidents in patients. In this case, visual scanning training is used for rehabilitation, making it very intensive and less attractive for patients. Nevertheless, AR helps facilitate treatment by increasing natural interactions with the environment [50].

An AR tool for the monoscopic projection of the liver on a phantom surface in a 3D model is proposed, allowing the simulation of syringe insertion into the liver, thereby reducing the number of errors made from 50% to 30%. Although it was effective, it still has problems to be solved, for example, the user must pay attention to avoid the occlusion of the phantom edge of the camera. In addition, single-marker head tracking makes the system sensitive to yaw/pitch/roll rotations of the head, and significant rotations can lead to inaccuracy and distortion in the projected image [51].

Talking about medical diagnostics guidelines, a print run with 40 volunteers based on 30 fictitious descriptions of the patient was developed, where AR smart glasses and a tablet were compared. The precision in decision making was recorded and the results between both devices were contrasted. Significantly faster overall triage time was achieved with the tablet PC (median 12.8 s, IQR 9.4–17.7, 95% CI 14.1–14.9) compared with smart glasses (median 17.5 s, IQR 13.2–22.8, 95% CI: 18.4–19.2; $p = 0.001$). Taking into account the difference in triage time between both devices, the additional time needed with the smart glasses could be significantly reduced over the course of the tests (21.5 s, IQR 16.5–27.3, 95% CI: 21.6–23.2) in the first run, 17.4 s (IQR 13–22.4, 95% CI: 17.6-18.9) in the second run, and 14.9 s (IQR 11.7–18.6, 95% CI: 15.2–16.3) in the third run ($p = 0.001$). Regarding the accuracy of guideline decisions, there were no significant differences between the two devices [52].

Another way of being able to work with AR in medicine is in laparoscopy, where the study analyzed applies two methodologies in the implementation of AR. The first study gave unfavorable experiences because the model was left out of the field of vision, generating disgust and complexity for users. On the other hand, the second examination seemed to be promising since it allowed greater control in these aspects even though the problem persisted [53].

Evaluating the accuracy based on points with AR in laparoscopic liver resection surgery was another study presented to determine the points of operation or need for attention with signaling through digital images. Although the research could be achieved, it is still necessary to improve the precision, since it is difficult to observe the exact point of the damage and variations in the movement. In any case, it can be functional to measure the dimension of the lesion site [54].

AR is also used to improve surgeons' understanding of anatomy and pathology, where it improves planning, intraoperative guidance, and better patient care. This study explains how 3D anatomical models are created and deployed in AR for Microsoft HoloLens devices in urologic oncology to guide the surgery. Obtaining the result of successful implementation, allowing the specific cancer models to be seen determining the dominant tumors with the key anatomic structures, preparing the surgeon for complex surgical cases, and describing, to the patient, their state. AR is making great progress in the medical field, and it is expected that these uses can be implemented in the future since it allows visual support to be obtained as a guide and feedback in real time [55].

Another similar AR implementation was made in research about the context of kidney cancer, showing the impact of the use of AR and 3D printed models for patients' instruction in their medical status, medical treatments, surgery procedures, and advances in their conditions. AR allows detection as well as the visualization of tumor size, enabling the doctor to make identifications with greater agility, which is important for decision making [56].

Moreover, an AR system was analyzed which was created to support surgeons and a test was carried out for craniomaxillofacial surgeries using a lightweight and portable device potentially useful for keeping the natural view of the operating room. For the examination, the researchers used a pair of stereo-rig cameras and a mini projector; these items helped to make a comparison between a custom-made VST HMD (Video see-through, head-mounted device) and a normal AR projection. The correct calibration was the key to the accuracy of the device and lighting was not a variable, but it was important to consider in future studies because it might vary in a common operating room. Unfortunately, both AR methods had a certain lack of accuracy; however, they are still in the range of acceptance to be used [57].

One of the articles showed AR implementation for the teaching of physiology and anatomy, key to the brain and mechanisms underlying dementia, where the feasibility of its implementation was evaluated. Comparisons were made with 24 students divided into two groups (12 in each group), one that used AR and the other with traditional models based on brochures with the same information. With AR it was possible to view the data with a cube facing the camera of a tablet, representing a 3D model of the brain, and receiving narrated information. The results were obtained through a 15-item multiple-choice questionnaire (MCQ) with similar information in both cases and nonsignificant variation; however, AR was perceived as highly useful for learning and understanding dementia [58].

The last article was based on the use of AR during the period of the COVID-19 pandemic to find places contaminated with COVID and thus be able to prevent the spread. Likewise, through AR, the graphical representation of the type of virus was achieved and how it can be treated. This study emphasizes that in medicine, AR has supported physiotherapy, psychotherapy, anxiety, stress, and pain management treatments, in addition to supporting surgical operations [11].

In Table 6, it is possible to see the important terms that highlight the characteristics of AR in medicine, which are simulation, entertainment, visuals, learning, rehabilitation, and precision. Described are the problems or difficulties with AR applications (-), benefits or positive experiences (*), an intermediate point where even though there were issues, it was possible to find solutions (+), or articles that did not show information about the branch suggested (/).

Table 6. The main AR characteristics found in the articles for medicine.

		Medicine					
Databases	**Articles**	**Simulation**	**Training**	**Visualization**	**Learning**	**Rehabilitation**	**Precision**
IEEE Xplore	Effects of virtual reality and augmented reality on induced anxiety [49].	*	/	/	/	/	/
	Projected augmented reality to drive osteotomy surgery: Implementation and comparison with video see-through technology [57].	/	/	-	*	/	/
Science Direct	Augmented reality-based visual-haptic modeling for thoracoscopic surgery training systems [17].	/	*	/	/	/	/
	The design choices for the development of an augmented reality game for people with visuospatial neglect [50].	/	/	/	/	*	/
	Chapter 4—Augmented reality, virtual reality, and new age technologies demand escalates amid COVID-19 [11].	*	*	*	/	-	/
Google Academic	Medical augmented reality visualizer for surgical training and education in medicine [51].	/	/	-	/	/	*
	Augmented reality for guideline presentation in medicine: Randomized crossover simulation trial for technically assisted decision making [52].	/	/	/	/	/	*
	Providing dementia education with augmented reality: a health sciences and medicine feasibility pilot study [58].	*	*	*	-	-	/
Taylor & Francis	Augmented reality for guideline presentation in medicine: Randomized crossover augmented reality registration [53].	/	/	-	/	/	/
	Influence of sampling accuracy on augmented reality for laparoscopic image-guided surgery [54].	/	/	-	/	/	*
Springer	Patient-specific 3D printed and augmented reality kidney and prostate cancer models: Impact on patient education [56].	*	/	/	*	/	/
	A workflow to generate patient-specific three-dimensional augmented reality models from medical imaging data and example applications in urologic oncology [55].	*	/	/	*	/	/

3.1.5. Entertainment

AR in the industry of entertainment (ARE) can be applied in almost any area; it can be seen mostly in games, music, sports, and videos, among others. The great part of ARE is that the user is not the observer anymore but the principal actor, which is why ARE is such an engaging feature that can become an added value component in any entertainment area. Even though AR has been proven in many fields of entertainment, in the last open access articles found, there is material dedicated to sports, educational games, and games for medical purposes, the last one being successfully applied mostly for disabilities.

The mixed reality head-mounted (MRHM) game was made for attention deficit hyperactivity disorder (ADHD) in children not older than 10 years old. ADHD is a cause of poor motivation and low self-esteem, among other cognitive problems in small children [59]. In this case, the AR game was made for face recognition based on the theory that ADHD children elude eye contact, which is necessary for face recognition [60]. The AR game was demonstrated to be useful as a treatment to improve attention and impulsivity [61].

Another similar AR game was applied for children to enhance the visual perception that caused a delay in their normal development as children. In this study, 60 children between the ages of 6 and 10 were evaluated with an AR game based on kinesthetic activities that allowed children to follow different and systematic activities. This was useful for children to improve their adaptative behaviors and abilities that had to do with visual perception. The important element of the game was that the therapist could adapt the AR application according to the necessities and context of the child [62].

A third example of AR entertainment used for medical treatment purposes is in improving motor problems in patients that suffer from Parkinson's or a stroke. In this study, the potential of AR was explored to assess the speed and goal orientation of movements within the individually determined interaction space, the adaptation of hand opening to objects of different sizes, and obstacle avoidance. In the study, healthy individuals participated (N = 10) as well as individuals suffering from two highly prevalent neurological conditions (N = 10 Parkinson's disease patients and N = 10 stroke patients). Three games were successfully tested for AR assessment, where Parkinson's disease patients moved more slowly than controls and needed more time to complete the task, meanwhile, there were no differences found between stroke patients and controls. The usability of the AR system was successful, with a natural interaction adapted to the patient [63].

AR in music entertainment can be represented in an AR game adapted for dance training. In this study, there was a comparison between AR and VR-based games where there was a 3D character named Alberto Rodríguez who danced Latin music and helped users to practice their Latin dance steps. Both games (VR and AR) were tested for 18 adult participants and some characteristics considered were performance, accuracy, usability, effort used, user frustration, and how demanding was the game. The results were that VR was more successfully applied in performance, accuracy, and responsiveness, while AR had some defects in visualization and orientation [64].

In another study, there was an AR project to analyze the effects of gamified AR in public places through an application called ARQuiz, which consisted of a questionnaire displayed with question marks in AR in a museum. The study was conducted through a survey and face-to-face interviews with 231 volunteers, the analysis variables were the usefulness and enjoyment of the application, the satisfaction with the presentation, and the test. The friendliness perception and user behavior on the ride were also examined before and after exposure. The results were gratifying, improving user appreciation and understanding. However, the application intrusiveness had to be reduced [65].

An AR prototype and a vibrotactile feedback jacket allowed greater interaction with video games through vibrations. There were 14 actuators used to vary the type and intensity of vibration according to the game scenario, generating an immersive experience. Unity 3D, C# language Oculus DK2 system, and Arduino were employed. The results obtained were satisfactory, although in some conditions the rate of frames per second (FPS) was reduced up to 32%; the study is pending tests on users and measuring satisfaction [66].

A study made in the year 2020 by Lopez and Jean evaluates the use of marker-less mobile AR-like technology to implement a multiplayer game scenario that can be used to improve socialization, communication skills, and emotional intelligence in elementary school children. It also makes a comparison between competitive play and collaborative play. The results obtained were that both game modes are intrinsically satisfying for children and generated positive emotions such as enthusiasm, and collaboration having a greater impact on emotional affection, social interaction, and interest [18].

PlanetarySystemGO is a mobile AR system for educational and entertainment purposes based on the location of the celestial bodies and the planetary systems of the universe, with an added web application to interact with a mobile phone. It is also useful in person, online, or as a system of teaching curricular content, where the application was evaluated and gave positive results in motivation and learning; however, training for the management of RA in teachers is still one of the main struggles [67].

AR in sports entertainment plays an important role in seeking to improve the viewer experience with a novel combination of existing image processing techniques, artificial vision, and machine learning in stadiums or normal sports fields. This EAR System application gives the viewer information about players and the match, and although there were current problems to recognize each player, in this examination, researchers tried to eliminate blurring, lighting problems, or obstacles to recognizing the players, achieving an improvement of 95.18% and 90.75%, respectively. In the end, in a low light range of 52.12% to 94.22%, the app successfully achieved the desired enhancement [68].

One of the articles was related to a combination of techniques, which are AR modeling and already existing game engines to improve a realistic AR environment. All this is made to enhance some design problems in AR games such as realistic 3D images, shading, occlusion, overlaps, lighting, and perception, among other important special effects for AR game characters in real environments. The GREP platform, as well as the Unity platform, were the technologies implemented to create the features needed, and they were tested in two AR games applied in an auditorium from Madrid, where more than 100 people played at the same time. Thanks to this study it was found that the combination of both tools was feasible to fulfill the necessities of improvement in realistic scenarios for AR games. Researchers do not discard the possibility of this implementation in other areas where it is necessary to improve AR realistic effects in environments [69].

A study of AR in sports broadcasting was carried out concerning the viewer experience to identify the key characteristics, as well as their advantages and disadvantages. This study was carried out with 30 participants who knew and at the same time understood the sport. Qualitative data were obtained through a structured interview where four characteristics were found and AR turned out to be an informative, novel, lively, and a telepresence tool. The drawbacks were the distraction and the lack of authenticity [70].

Finally, another example where entertainment in AR was highlighted was in a systematic review using keywords and medical terms associated with VR/AR, rehabilitation, and musculoskeletal disorders. The selected articles were evaluated through standards for reporting implementation studies, where the most used tools for development were Kinect as an input tool (55%), studies that describe the techniques used to analyze movements (75%), and tools that were developed in Unity (50%) [71].

In summary, we found six characteristics of AR applied to entertainment (Table 7), which are interest, rehabilitation, training, visualization, learning, and latencies. The characteristics are shown as problems or difficulties with AR applications (-), benefits or positive experiences (*), an intermediate point where even though there were issues, it was possible to find solutions (+), or articles that did not show information about the branch suggested (/).

Table 7. The main AR characteristics found in the articles for entertainment.

Entertainment							
Databases	**Articles**	**Interest**	**Rehabilitation**	**Training**	**Visualization**	**Learning**	**Latencies**
IEEE Xplore	Eye-contact game using mixed reality for the treatment of children with attention deficit hyperactivity disorder [61].	*	*	*	/	/	/
	Effectiveness of kinesthetic game-based training system in children with visual–perceptual dysfunction [62].	/	/	*	+	/	/
	Near-contact person-to-3D character dance training: comparing AR and VR for interactive entertainment [64].	/	/	/	-	-	/
	Effects of gamified augmented reality in public spaces [64].	/	/	*	-	/	/
Science Direct	Development of augmented reality serious games with a vibrotactile feedback jacket [66].	/	/	/	*	/	+
	EmoFindAR: Evaluation of a mobile multiplayer augmented reality game for primary school children [18].	*	/	/	/	/	/
Google Academic	EAR: Enhanced augmented reality system for sports entertainment applications [68].	*	/	/	-	/	/
	An interactive information system that supports an augmented reality game in the context of game-based learning [67].	*	/	/	/	*	/
	Augmented reality in sports event videos: A qualitative study on viewer experience [70].	*	-	-	*	-	-
Taylor & Francis							
Springer	Designing and implementing interactive and realistic augmented reality experiences [69].	*	/	/	-	/	/
	Patient-tailored augmented reality games for assessing upper extremity motor impairments in Parkinson's disease and stroke [63].	/	/	*	/	/	/
	Technical aspects of virtual augmented reality-based rehabilitation systems for musculoskeletal disorders of the lower limbs: a systematic review [71].	*	*	-	*	-	/

4. Discussion of the Results

Throughout the content analysis of the articles, we need to go back to the aim of this study, which is to identify challenges, technical problems, and benefits of applying AR within the five areas selected.

Firstly, we have identified that AR used as an educational tool is a prevalent topic which easy to find in any of the chosen databases; this is because helping students to become actively involved in their classes is a concern for any educational institution. The benefit of AR in the classroom is the production of dynamic environments [72] where motivation and interaction are the main features [73]. Within this study, we observed some AR applications in educational games that were successfully applied and tested for children of different ages and school levels [74]. AR has shown along the way that it is a tool with a positive impact within schools or training areas where characteristics of inspiration for learning, satisfaction, and confidence are prominent [14,21,22,25,27,29]. Finally, we discovered that AR was useful in understanding abstract concepts difficult to manage with normal classroom tools in subjects such as physics [24,27].

Talking about AR challenges in this area, we could find that when authors made tests to prove if AR was effective in learning, unfortunately, they discovered that even though the understanding was good, the improvements in knowledge retention were minimal [26,27], so it is still necessary to keep working on making AR for meaningful learning. Another task to be solved is the lack of professionalization in teachers because before using AR tools it is necessary to train school personnel, as well as to have easy AR application methodologies and manuals to make AR easy to manage at school. Besides that, educational institutions must invest in technological infrastructure [14,22]. Despite the difficulties that emerged, there are still studies that considered possible solutions, but still with no promising results [24]. The technical problems in the studies of AR in education were mostly the lack of robust infrastructure to support the AR systems.

AR is commonly applied in industry. It is noticed that aviation, industrial and automotive plants are fields with more AR implementation [75]. It is important to highlight that a large percentage of its use refers to the mechanical area, justifying the data by its usage in areas such as automotive, training, and military industries, among other aspects of general mechanical operations. Moreover, technical processes in industries constantly need to be monitored and this is where AR shows us that it is the ideal tool to reduce errors and production times [15,31,35,36,38] as well as train staff with manuals and machinery tools labeling [12,34,37].

Nevertheless, in the technical problems found, we noticed that it is necessary to implement optimal processes by selecting the appropriate programming frameworks [32] to reduce latencies along with the difficulty of lighting and precision [32–34]. In the same way, it is essential to look for ergonomic, specialized, and easy-to-use hardware involved in ARI to eradicate the user's lack of comfort [33]. The challenge of AR in this area is the creation of new manual content to make functions that manage and develop industrial processes within the industry [38].

An innovative way of reaching new clients in marketing is the use of AR in the delivery of promotional messages personalized with greater precision, working through geolocation and individualized adaptation to create confidence and the intention to purchase [76]. The interaction with products thanks to AR is dynamic in making the decision to purchase [77]. Companies are taking advantage of the information gathered thanks to the use of AR applications in marketing and in creating customer profiles to follow-up [78].

Within ARM, we can say that AR has been successfully applied to some products and brands to help clients to have certainty and better decision making in their shopping options [44], generally those products can be placed in AR-fused spaces such as furniture, pictures, decoration objects, stores or even restaurants [42,43]. There are also products that through AR applications can be tried on clients' bodies such as jewelry, clothes, or makeup [39,42,46]. Many brands have started to penetrate the AR fields to save money, increase positioning [40], and obtain information for customer tracking [42]. Some studies even promoted marketers to look for innovative strategies to gain space in the competitive area of business development [16].

On the other hand, there are certain challenges for AR in marketing. The first one is that there is the perception that AR is still in an immature stage because its adoption in this area does not go as fast as other technologies [40]. Furthermore, there is an important concern in security protection for clients' personal data with no laws regulating or solving this problem [39]. Therefore, there is a critical interest in how this technology can gather information from clients' likes and dislikes, gestures, and even body movements that can be used to manipulate decision making in the clients [39]. Finally, AR needs technical improvements in visualization with more realistic and high-quality graphics [47] so that users do not lose interest in the final product because it has features that AR still cannot emulate [40,41,45].

AR has improved medicine in many ways, for example, in three-dimensional (3D) models to analyze the anatomy of patients in surgery [79], medical training, supplying elements that are difficult to visualize within the patient's body [80], computer-assisted surgeries with three-dimensional images, and computed tomography with X-rays and treatments for patients [81]. In this study, we found that AR has also been involved in the successful simulation of scenarios [49,52–54,57], with a great improvement in medical training [17,51,53–56], important benefits for rehabilitation [15], and surgeries and medical treatments.

Among the technical problems found, some studies pointed to the complexity of working with AR when light and projection can hinder the accuracy of AR performance, as well as ergonomic devices that can work freely in an operating room [51,52,54,57]. Talking about the challenges in this area, we can say that, different from using AR for doctors' training and decision making [52,56] before surgeries, the task to be solved is to use AR technology in real-time surgical procedures, which is difficult when there are technical issues such as internet connectivity.

Not only with AR but also with VR and now through the metaverse, significant advantages for medicine can be potentially suggested, such as the possibility of creating international databases for disease diagnoses, maintaining connections with doctors from all over the world through virtual rooms, and avatars that will allow training, monitoring, therapies, and remote treatments for patients [82]. Additionally, today there is an increase in metaverse investment that will permit further research and development that will innovate surgical and medical procedures. However, research should be given relevance, especially in spinal column surgeries, so that these new technologies do not remain as "Vaporware" (vague future software interactions) [83].

Psychology and psychiatry are also fields where AR and VR are having exponential strength, being auxiliary tools that improve mental and physical health. The recent study in this field guides future researchers to do new health studies across the metaverse [84].

Finally, AR entertainment is implemented in sports [68], in games that help reduce the effects of mental diseases, and in video-gaming interaction mainly through cellphones, Pokémon Go being one of the most popular examples of videogames based on the application of AR [85]. Additionally, AR tools have increased the experience in entertainment-supporting areas such as education [62,65,86], improving interaction experiences in users [66,68], for the projection of elements according to their location [18,67], and games for rehab [59,61,86]. Although these elements are defined, there are still technical problems to solve such as visualization, latencies, orientation, and technical lighting defects [64–66,68,69].

5. Recommendations for AR Implementation

In this section we make recommendations considering the main challenges that AR faces for its successful implementation. The main problems encountered were visualization, illumination, precision, latencies, learning, cybersecurity risks, and comprehension by the user.

The first piece of advice is for visualization problems; in this case, there should be deeper research and tests on the use and study of elements such as digital cameras, infrared cameras, as well as geolocation features to provide extra information about the markers and the digital images projected.

Additionally, in the case of illumination problems in AR, there should be the creation of new mathematical methodologies to predict images with drastic changes in illumination and shadows that will allow incremental precision.

In the second problem, which is latencies, we propose deeper research on the use of an intermediary system between the cloud/server and final user to keep the models updated and working locally so that the 3D models are shown in a shorter time.

Furthermore, AR in learning processes, in many cases presented great motivation but with no meaningful knowledge compared to traditional education or training methods. Hence, for future research, we consider that the step forward for AR is the metaverse with more possibilities for user immersion.

Regarding the cybersecurity risks that AR faces, it is necessary to create new laws that can protect users' data, and exploring the implementation of AR in the blockchain is also recommended.

Finally, one of the important challenges encountered was the problem of AR comprehension. There should be more research focused on strategies for user experience models to understand patterns of simplicity for successful AR use.

Limitations

Among the limitations in the development of this article was the lack of financial resources to access research in paid articles.

6. Conclusions

In conclusion, with the study made, we can say that AR, nowadays, plays an important role as an innovative technology in the areas of medicine, education, industry, entertainment, and marketing. AR applications are successfully functional mostly in motivation for training and the transmission of knowledge; it works as a tool to give unique, dynamic, and interactive experiences to users, making them feel related to new products, comfortable with decisions, and supported while performing activities that require deeper attention such as surgeries or managing industrial machinery.

Additionally, there are significant tasks to consider in AR applications. We can say that so far in all the areas studied, AR has technical problems to be solved such as latencies, visualization, perception, lack of ergonomic devices, especially for industry and medicine, location and precision failures, and lighting occlusions.

In the case of challenges, it is necessary to have strategic plans to overcome the deficiency in AR training for personnel, reinforce the investment in infrastructure resources needed for AR implementation as well as laws that regulate the information gathered thanks to AR tools. Unfortunately, all of the negative elements complicate the full adoption of this technology in the fields studied and give the idea that AR is not a mature technology ready to explode.

Finally, contributing to future research on the successful implementation of AR in specific areas, we provided a summary of AR projects in the last six years, highlighting the last negative and positive features, and with this, we provide a starting point for those who are interested in the further research or development of this technology.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13052766/s1, Table S1: Summary of AR literature Review; Table S2: Titles selected for AR study in Education; Table S3: Titles selected for AR study in Industry; Table S4: Titles selected for AR study in Marketing; Table S5: Titles selected for AR study in Medicine; Table S6: Titles selected for AR study in Entertainment.

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