# Virtual Reality in Medical Education during the COVID-19 Pandemic; A Systematic Review

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## Abstract

**Introduction:** With the outbreak of the COVID-19 disease and the virtualization of education, many challenges were created in the field of medical education. Many of these challenges were turned into opportunities with the help of new technologies such as virtual reality. The purpose of this research was to investigate the applications of virtual reality in medical education in the era of COVID-19.

**Methods:** We aimed to investigate new technologies' applications in medical education during the COVID-19 pandemic. Original English articles were browsed in online databases of PubMed, Embase, Scopus, and Web of Scienceas of November 24, 2022. Data of eligible publications were extracted following screening/ selection in two steps and applying inclusion/ exclusion criteria. This systematic review follows PRISMA checklist and Newcastle-Ottawa Scale (NOS) bias assessment tool.

**Results:** Based on the included articles, Microsoft HoloLense2 and Meta Oculus devices were used extensively in medical training studies. In some of the studies, the results demonstrated that the use of these technologies resulted in high levels of engagement, was suitable for training purposes, and decreased the risk of medical learning practicums. Moreover, some studies observed improvement in training compared to traditional training systems.

**Conclusion:** Extended reality use including Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR) concepts in teaching activities and practical procedures can improve the overall educational process, while also increasing engagement, motivation, and understanding of key concepts of participants, especially medical students.


## 1. Introduction

On March 11, 2020, the World Health Organization (WHO) declared the outbreak of the novel coronavirus (COVID-19) as a pandemic (1, 2). At first, to control the spread of the virus, it was recommended that people stay at home and observe social distancing, which has had a significant impact on people's normal life (3, 4). Healthcare is one of the sectors most affected by the adverse effects of the COVID-19 pandemic (5). The adverse effects of the COVID-19 pandemic, including the prolongation of social distancing and staying at home, caused problems in clinical practice in hospitals (6, 7) and medical education programs (8–10).

The extensive development of technology has affected various sectors, including medical education, which due to the epidemic of COVID-19 is necessary to adapt to new life trends, such as the limitation of face-to-face activities, and it should be noted that this limitation affects learning activities, especially in medical education affects and challenges medical education professionals (11, 12). These conditions require the replacement of new educational methods in learning activities. Virtual reality (VR) is one of these alternative methods. VR is a technology that allows the real-time exploration and manipulation of artificial or computer-generated natural 3D multimedia worlds (13). In addition, VR represents the development of strong information and communication technology that has led to the improvement of the clinical education process (14–18).

VR can be an effective tool for pediatric training residents in behavioral health and skills because it empowers the educational community to focus on the curriculum despite the COVID-19 pandemic (19). The use of VR-mediated simulation in knee arthroplasty training is also supported. This approach can enhance the training of surgical trainees by improving knowledge to perform efficient total knee arthroplasty procedures (20). The correct use of personal protective equipment (PPE) in health care in the field of prevention of COVID-19 among employees was also one of the other benefits of using VR (21). In the field of gaming, VR games can control the functional and cognitive outcomes of a person and increase their ability to take care of their health (22). There have been studies in the field of using VR to rehabilitate people with various disorders throughout the COVID-19 pandemic (23–25). Therefore, according to the studies conducted in the field of virtual reality, its applications can be considered important for education and medical care. Therefore, we aim to systematically review technology in medical education during COVID-19.

## 2. Methods

In this review, we systematically explore current literature studying new technologies in medical education during the COVID-19 pandemic. This study conforms to measures of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. In addition, we utilized the Newcastle-Ottawa Scale (NOS) bias assessment tool to clear up probable biases.

# 2.1. Data sources

Online sources of PubMed, Embase, Scopus, and Web of Science were searched for determined keywords and their following combinations. We harvested original English publications until November 24, 2022.

1. "COVID-19" OR "SARS-CoV-2" OR "SARS-COV2" OR "coronavirus disease 2019" OR "severe acute respiratory syndrome coronavirus 2" [Title/ Abstract]
2. "Medical" [Title/ Abstract]
3. "Education" [Title/ Abstract]
4. "Technology" [Title/ Abstract]
5. [A] AND [B] AND [C] AND [D]

## 2.2. Study selection

By application of screening and selection in two separate steps, we figured out the literature of interest. Preliminarily two members assessed the titles and abstracts of the articles and sorted through them for the second step of selection. The second step which happened to be more in-depth was carried out by the other four members. They got through the full texts of these preliminarily screened papers and advanced to pulling out the required data for the study. We also determined the following inclusion/exclusion criteria to select the studies of interest:

1. Inclusion items: Originality of the articles, being in English language, passing peer review step before being endorsed for publication, and studies addressing technology applications in medical education during the course of the COVID-19 pandemic
2. Exclusion items: Full text lacking publications, investigations short of published data, duplicated articles, case series and reports, letters and editorials, and conference abstracts.

## 2.3. Data extraction

Extraction of the requisites of the study was implemented once the second step of the selection process was fulfilled. Four researchers carried out this extraction by meticulously getting through the full texts. Table 2 depicts the extracted data. An extra investigation of included papers and pulled-out data was exerted by other researchers to clear up possible left duplications of papers and data.

## 2.4. Quality and bias risk assessment

To ensure the quality of this systematic review adheres to the measures of the PRISMA checklist, we also minimized the bias risk by benefiting from the Newcastle-Ottawa Scale (NOS). Three items of this tool including selection, comparability, and exposure/outcome are scored maximum values of 4, 2, and 3 respectively. Table 1 shows these values allocated to each study. Lastly, these values were added to one another in column five and a maximum score of nine would be achieved for each study included in the project.

Table 1
Newcastle-Ottawa Scale (NOS) bias risk assessment of the study

| First author | Selection (out of 4) | Comparability (out of 2) | Exposure/Outcome (out of 3) | Total (out of 9) |
|---|---|---|---|---|
| Laksha Bala (26) | *** | *** | *** | 9 |
| Rachel Herbst (27) | ** | *** | ** | 7 |
| Martin Boros (28) | *** | *** | ** | 8 |
| Radek Kolecki(29) | **** | ** | *** | 9 |
| Christian Zammit (30) | *** | ** | *** | 8 |
| Maryam Alawadhi (31) | **** | ** | *** | 9 |
| Muhammad Ivan Muntahir (32) | ** | ** | *** | 7 |
| Rukhnoor Malik (33) | **** | ** | *** | 9 |
| Andrew J. Hall (34) | ** | *** | *** | 8 |
| Saman Behmadi (35) | **** | ** | *** | 9 |
| Tsekhmister Yaroslav Volodymyrovych (36) | ** | *** | *** | 8 |
| Jeffery Baker (37) | ** | *** | ** | 7 |
| Paul Zikas (38) | **** | ** | *** | 9 |

## 3. Results

After searching the databases, 2172 articles were obtained (PubMed = 483, Embase = 637, Scopus = 531, and Web of Science = 521). After initial review, 712 duplicate references were removed and 1460 articles were screened after removing duplicate articles, and after two stages of screen including title and abstract screen and full text screen, finally 13 articles met the inclusion criteria (Fig. 1). Based on the findings of the present research, in most of the reviewed studies (46.1%) the application of virtual reality in general medicine was mentioned. Percentage of included studies that addressed field of education using VR is demonstrated in Fig. 2.

We investigated the main findings of the included resources along with the purpose of the study, target population, type of technology, type of device, and field of education. A description of the findings reported in the eligible studies is shown in Table 2.

A total of 13 studies during the COVID-19 outbreak included 1407 participants, of which 1167 (82.9%) were medical students, 120 (8.5%) were healthcare workers (HCW), 44 (3.1%) were emergency staff, 20 were residents (1.4%), 5 (0.3%) were surgical scrub nurses and 4 (0.2%) were consultant knee surgeons.

During the COVID-19 outbreak, 6 (46.1%) studies have been used VR as head-mounted displays (HMD), followed by MR with 4 (30.7%) studies, 2 (15.3%) studies used AR, and one study did not mention the type of technology. HoloLense2™ was the most common HMD utilized by 6 (46.1%) studies for all types of technology (VR, MR, and AR), and Oculus Quest 2™ was another device used in 3 (23.1%) studies for VR technology. Also, one study used Vuzix™ smart glasses for AR technology, and 4 (30.7%) studies did not mention the name of a specific device (Fig. 3).

MR and VR were mostly used for training in the fields of a general physician with a total of 3 (23.1%) studies, AR/MR in anatomy with 3 (23.1%) studies, followed by AR/VR in emergency medicine with a total of 2 (15.3%) studies, MR/VR in practical procedures with 2 (15.3%) studies, and VR in the orthopedics, pediatric, and health at work each with one study.

Education with VR were perceived as enjoyable, with high satisfaction and improved knowledge, and filled the gap in the current medical education. Also, in Ukrainian situation helped academic continuity in medical education. Education with MR was found to be effective, enjoyable, faster, efficient, and with high engagement. AR-based studies reported this technology-enhanced spatial relations and helped students better understand key concepts.

Most of the papers were published in high-income countries (HICs) (39), 7 articles (61.5%) were from Europe, which the UK with 4 articles had the most papers, 2 (15.3%) studies were from the United States (US), and one article from UAE. Low- and middle-income countries (LMICs) (40) published 3 papers which were from Indonesia, Iran, and Ukraine.

Table 2
Description of the findings reported in the eligible studies

| ID | First Author | Country | Study design | The aim of study | Target population (N) | Type of technology | Type of device | Field of education | Main results |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Laksha Bala (41) | UK | Qualitative | Teaching ward rounds via remote access | 11 (medical students) | MR | HoloLense2 | General physician | A unanimous consensus was reached among students that the use of this technology was enjoyable and provided access to teaching that would otherwise be unavailable. |
| 2 | Rachel Herbst (42) | USA | mixed-method (qualitative and quantitative) | Using VR-based behavioral health anticipatory guidance to educate pediatric residents | 14 (pediatric residency) | VR | - | Pediatric | According to preliminary data, VR may serve as an important tool for teaching pediatric residents behavioral health anticipatory guidance, which fills a gap in current medical education. |
| 3 | Martin Boros (28) | Czech Republic | Qualitative | Develop an OHS training system for multiple segments of the workforce. | 120 (Safety and healthcare workers) | VR | Oculus Quest 2 | Safety and health at work (OHS) | A total of 117 participants expressed satisfaction with the use of VR technology. |
| 4 | Radek Kolecki(29) | Poland | quantitative | Assess the attitude toward these new technologies and whether the use of MR technology can contribute to the improvement of medical education | 258 = 211 medical students + 47 academic faculty | MR | HoloLense2 | Anatomy | According to 70% of students and 60% of academic faculty, MR-supplemented education is more beneficial than classical instruction. |
| 5 | Christian Zammit (30) | UK | quantitative | Assessment of the impact of AR in the dissection theater through a validated survey | 130 (medical students) | AR | HoloLense2 | Anatomy | This study suggests that the use of AR technology enhances spatial relations, accelerates detailed material assimilation, and contributes to a better understanding of key concepts when utilized. Additionally, the majority of participants consider AR to be a valuable learning tool. |

VR: Virtual Reality, AR: Augmented Reality, MR: Mixed Reality, UK: United Kingdom, USA: United States of America, UAE: United Arab Emirates

| ID | First Author | Country | Study design | The aim of study | Target population (N) | Type of technology | Type of device | Field of education | Main results |
|---|---|---|---|---|---|---|---|---|---|
| 6 | Maryam Alawadhi (31) | UAE | | An investigation of how United Arab Emirates students perceive metaverse systems in medical training. | 435 (medical students) | - | - | General physician | Learning and teaching will be transformed as a result of the technology, which is likely to replace the internet. |
| 7 | Muhammad Ivan Muntahir (32) | Indonesia | Qualitative | developing the simulation of infusion installation based on web XR and VR applications | 30 (medical students) | VR + WebXR | Oculus Quest 2 + Magic Leap 1 + HoloLense2 | Practical procedure | The overall satisfaction of VR application was higher than the WebXR. Additionally, these technologies decreased the risk of medical learning practicums. |
| 8 | Rukhnoor Malik(43) | UK | quantitative | Study looked at how HoloLens2 can enhance traditional remote case-based teaching. | 73 (medical students) | MR | HoloLens2 | Anatomy | As a result of teaching with HoloLens2, students reported that the experience was enjoyable, the concept demonstrations were effective, and the engagement was high. |
| 9 | Andrew J. Hall (34) | UK | mixed-method (qualitative and quantitative) | Assessing the effectiveness of virtual reality-mediated simulation and a multi-modality 'Bootcamp' in teaching total knee arthroplasty (TKA) to orthopedic surgical trainees. | 15 = (6 surgical trainees + 5 surgical scrub nurses + 4 consultant knee surgeons.) | VR | Oculus | Orthopedics | A VR-mediated simulation could enhance the training of surgical trainees and scrub team members by improving their understanding of the surgical process map. |
| 10 | Saman Behmadi (35) | Iran | quantitative | A comparison of virtual-based and lecture-based medical education in teaching emergency medical students. | 44 (Emergency medicine staff) | VR | - | Emergency medicine | VR is a promising method for improving undergraduate emergency students' knowledge, according to the results of this study. |

VR: Virtual Reality, AR: Augmented Reality, MR: Mixed Reality, UK: United Kingdom, USA: United States of America, UAE: United Arab Emirates

| ID | First Author | Country | Study design | The aim of study | Target population (N) | Type of technology | Type of device | Field of education | Main results |
|---|---|---|---|---|---|---|---|---|---|
| 11 | Tsekhmister Yaroslav Volodymyrovych (44) | Ukraine | Qualitative | A study of the virtual reality technology and online learning system at Bogomolets National Medical University, Ukraine during the COVID-19 pandemic | 226 medical students | VR | - | General physician | Online teaching and virtual reality technology are crucial for academic continuity in Ukrainian medical education.<br><br>65.79% of students agreed with the user-friendly interface for VR and online teaching system. 64.03% of students agreed that VR and online teaching system compensated the suspension of in-person medical education. |
| 12 | Jeffery Baker (37) | USA | Qualitative | An investigation of the feasibility and usability of smart glasses in medical education. | 22 medical students | AR | Vuzix smart glasses | Emergency medicine | In the emergency department, smart glass technology can expose preclinical medical students to clinical medicine. |
| 13 | Paul Zikas (38) | Greece | quantitative | Developing a medical virtual reality simulation model for COVID-19 Swab Testing and Proper handling of personal protective equipment | 29 students | MR | HoloLense2 | Practical procedure | Compared to traditional training, the designed VR model offers a faster and more efficient method of cooperative, gamified, remote training for healthcare professionals. |

VR: Virtual Reality, AR: Augmented Reality, MR: Mixed Reality, UK: United Kingdom, USA: United States of America, UAE: United Arab Emirates

## 4. Discussion

After public health emergency of international concern" on January 30, 2020. in 2020 by WHO. (45) universities and academic institutes tried to decrease face-to-face education to avoid transmission of COVID-19, even in obstetrics, physicians decreased in-person visits and appointments as much as possible for this purpose (46). The COVID-19 pandemic has made the need for technology-based learning more than ever needed (28, 44). Students' educational needs and expectations have been dramatically changed as they grow up in environments where technology is an essential part of everyday life. Consequently, students are looking for more relevant learning experiences using educational methods and approaches, which are more engaging, realistic, and motivating (38, 47). A range of study designs was used, and unlike previous literature (48, 49) in which quantitative methods were dominant, in our study quantitative and qualitative methods with five studies were equal. Additionally, two studies used mixed-method (qualitative and quantitative). Our review with 13 studies had 1167 (82.9% of total participants) medical students which is showing the increasing trend of applying HMDs to medical education during the COVID-19 outbreak compared to a similar review which had 573 (59.9% of total participants) medical students in 27 studies (49).

## 4.1 Applications

## 4.1.1 Theory

All of the included studies used VR for distance learning due to the COVID-19 outbreak. A majority of the applications were designed to simulate real-world learning experiences, the participant's physical location was either an academic center or a hospital setting. Distance learning can allow participants to access the learning materials and resources including digital learning resources encompassing video, audio, text, animations, and images of a relevant course or class, and some studies have found that students prefer it to traditional educational methods (29, 44). Additionally, a meta-analysis showed that there is a statistically significant difference in exam pass rates between medical students undertaking VR-based education, higher pass rates, and traditional method (50).

### 4.1.2 Skills

Using extended reality can improve participants' skills, which are fundamental to some fields, and help them develop their practical skills, social interaction, problem-solving emergencies, and experiencing different scenarios, which are essential in dealing with nowadays' extensive problems (47). One of the new problems which had a massive effect on educational systems was COVID-19 (30, 37). COVID-19 forced universities and academic centers to develop online methods such as webinars, online classrooms, serious games, and gamifications to further engage students and teachers. But, in training practical skills VR is a stand- out choice even in specialty fields such as orthopedics and surgery (34, 51). A meta-analysis that compared VR-mediated with traditional methods showed that in two subgroups of postgraduate and hospital residents, VR group had a significantly higher pass rate than a traditional group which may suggest VR can help the acquisition of complex skills and specialized knowledge (50). Social interaction and communication as well as empathy are necessary for patient care. A study of this systematic review presented that not only diagnostic and therapeutic skills can be trained, but also attitudes and behaviors (42).

## 4.2 Motivation

In VR applications users should frequently do some sort of input/interaction which this process encourages active engagement; this is preferable to simple passive learning (29, 42). Collaboration and learning in groups to solve VR-based problems is a common motivator. More importantly, the ability for users or students to explore the virtual environments either alone or with the help of other classmates or instructors not only increases motivation but also increases the enjoyment (41, 43).

## 4.3 Type of technology

All three types of extended realities through engaging and experiencing different aspects of the related field that are created in safe and hybrid environments, which support observing and guiding can bring several benefits and opportunities (47, 52). VR is the most common device due to its availability, and ease of use, and can provide a variety of tools and options in different fields from behavioral science (42) to orthopedics surgery (34) in a virtual environment. On the other hand, MR and AR can combine the digital world with real life and can be used mostly in anatomy (30, 43) to different fields like ward rounds (41), and emergency simulations (37).

## 4.4 Field of education

As mentioned in a related systematic review of 40 studies, the virtual reality HMD literature mostly focuses on surgical procedures, procedural skills, and anatomy (48). Additionally, in a similar scoping review out of 114 included papers 69 (60.5%) were about surgical VR simulators, which indicates a small number of educational areas account for the vast majority of educational virtual reality implementations (53). Conversely, in a review from 2010 to 2017 out 35 health- related domains, 17 studies were related to general medical topics, 10 to surgical procedures, and 3 to physical education (54). In our review due to narrowed timeline, the most common fields were general physician and anatomy with three papers each, followed by emergency medicine and practical procedures with two studies each, and only one study was about orthopedic surgery.

## 4.5 Effectiveness

Our final results refer to the usefulness and effectiveness of the VR system which was implemented in its educational context including design, costs, usability, and users' feedback. Particularly, when used for medical students, following proper educational strategies, using experienced mentors, and extensive content with a wide variety of features, VR-based education can arguably be the method of choice for teaching during COVID-19 limitations (38, 51). Positive outcomes, benefits for medical students, and professors, facilitation of the content transition, and improvement of the educational process, with VR-enhanced learning, are some of the most mentioned conclusions in the entered studies (29, 35, 42, 43) Furthermore, increased students' engagement/participation, enjoyment, motivation, and focus were also frequently observed (28, 32, 41, 43).

#### Limitations

The number of included studies was low due to the focus of this systematic review which was carefully narrowed to specifically investigate the field of medical education during the COVID-19 outbreak. Also, there is a clear lack of studies from LMICs because of the high costs. For example, the HoloLens2™ is a commercially available HMD that currently costs $3500 per headset. Almost all participants in the most of included studies were volunteers and familiar with using VR which required little amount of technology training. The majority of studies described the process of implementing VR-based education but did not discuss the concept behind these procedures and strategies. Additionally, studies had a lack of objective indicators, such as the pass rate or exam scores compared to a control group, which can effectively reduce bias.

## Conclusions

The majority of studies entered in this systematic review considered VR-based education better than traditional teaching methods. Most VR-based educations have been reported as an engaging, enjoyable, motivational tool for students, and residents which improved their knowledge acquisition and

practical skills. VR-based education is still a novel technology, slowly developing its effectiveness and usefulness for medical education. Surgery and anatomy fields are relatively well-known, but it is not clear whether and how other medical fields and educational stages may benefit. We believe that VR will exceed its current limitations, may most likely break the barriers of formal traditional education, and will foster and improve high-quality teaching and training, anywhere and at any time which requires further technological advancements. However, there are still some gaps in VR-based education which remain to be filled. Also, the shifting of skills after VR-based education to the real-world clinical setting needs further investigation. Furthermore, practical procedures, particularly specialized knowledge such as surgery, require highly careful and complex software design.

### Recommendations for future work

The applications of VR in medical education are currently mainly skewed toward those for simulations and training purposes, such as anatomy, surgery, and practical procedures. Therefore, more work is required to evaluate widespread generalizable applications to VR-based education. We also recommend to studies use an objective indicator such as the pass rate or exam scores compared to a control group, which can effectively reduce bias.

## Declarations

*-Ethics approval and consent to participate:* Not applicable

*-Consent to publication:* Not applicable

- *Availability of data and material:* The authors stated that all information provided in this article could be shared. If someone wants to request the data from this study, should be contacted with corresponding author (Samaneh Mohammadi).

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## Figures

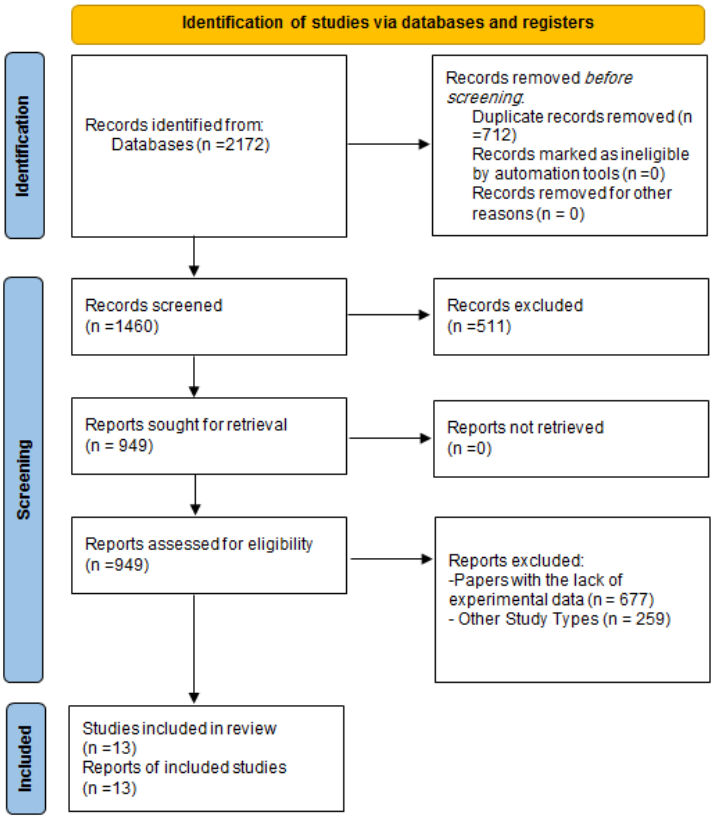


**Figure 1**

PRISMA 2020 flow diagram of study retrieval process

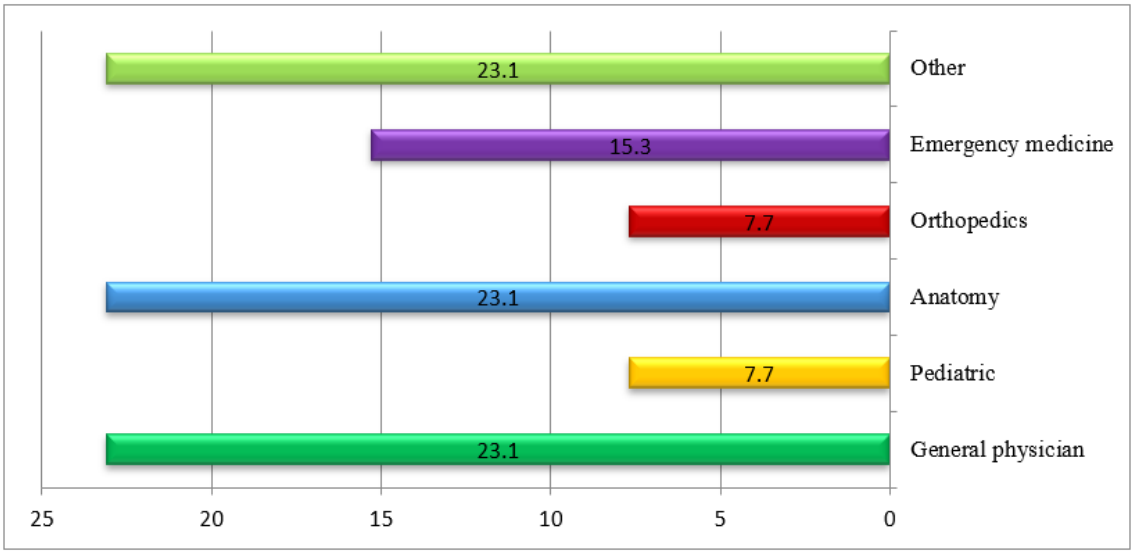


**Figure 2**

Percentage of included studies that addressed field of education using VR

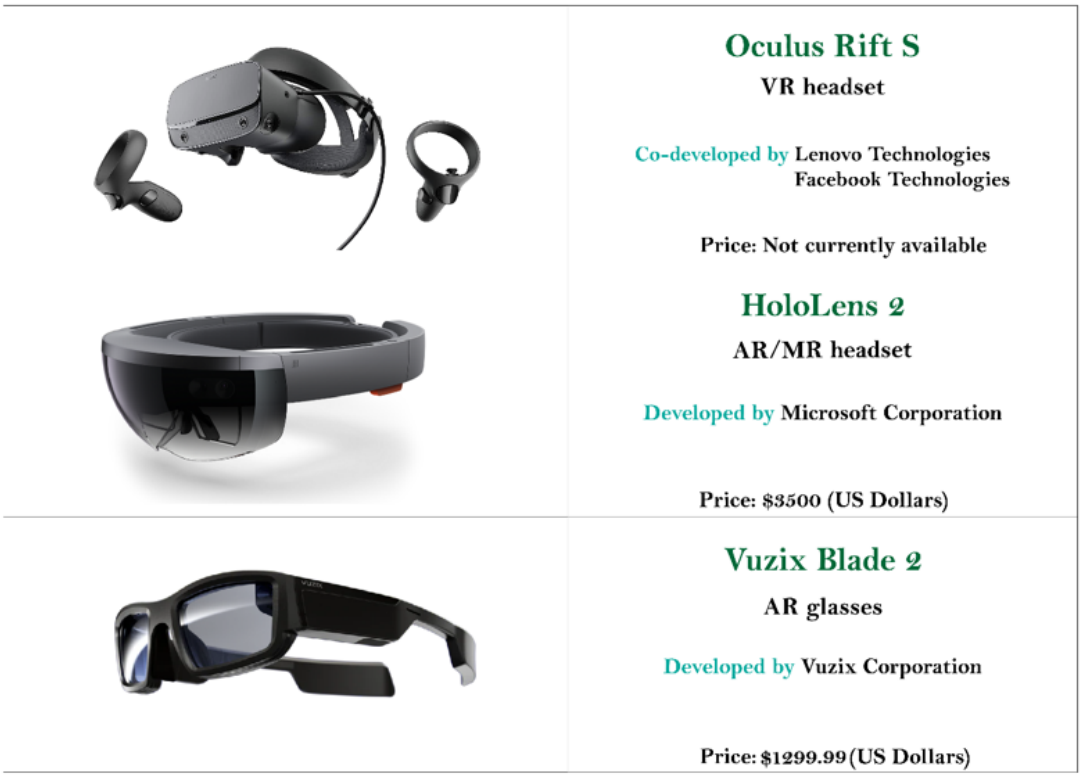


**Figure 3**

Types of head-mounted display (HMD) and glasses