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Virtual and augmented reality technologies as Innovative tools in education.

Nadezhda Sivrikova [1,] South Ural State Humanitarian Pedagogical University, Department of Social Work, Pedagogy and Psychology, Chelyabinsk Oblast, Russia

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Abstract

The process of introducing digital technologies into education has received a strong impetus, which is no longer possible to stop. Therefore, it is now important to analyze scientific research on innovations related to the introduction of new technologies into education. This work examines the experience of introducing virtual and augmented reality technologies into education. An analysis of 31 literature reviews on the experience of introducing VR and AR technologies into education showed that VR allows the formation of complex specific skills without risks; VR has a large motivational impact associated with immersion and real-time presence effects; there are differences in attitudes to VR technology in education related to age. The results of numerous studies are summarized and systematized in sections. Based on the findings, the most important factors that could potentially hinder the adoption and application of immersive technologies in education are funding, health, and accessibility, or lack thereof, in both developed and developing countries.

Keywords: Augmented reality; education; technology; virtual reality.

***** ADDRESS FOR CORRESPONDENCE: Nadezhda Sivrikova, South Ural State Humanitarian Pedagogical University, Department of Social Work, Pedagogy and Psychology, Chelyabinsk Oblast, Russia.
E-mail address: bobronv@cspu.ru

1. Introduction

The new challenges facing society require the development of new digital technologies and their active implementation (Budd et al., 2020). This was confirmed by the experience of the pandemic Covid-19. In 2020, several countries decided to organize distance education in schools and universities to prevent the spread of coronavirus. In Russia, this experience showed that a modern school has sufficient resources for such a step. However, the technological level of the Russian school is inferior to many developed countries. This is particularly evident in the application of virtual and augmented reality technologies in education. Therefore, this work will consider the world experience of introducing these technologies into education.

Virtual reality (VR) and augmented reality (AR) already have a fairly large history of development. Daniel Vickers created the first VR headset in 1970 (Elmqaddem, 2019). However, the high cost prevented the widespread introduction of VR into human practice. The term Virtual Reality itself was proposed in the United States in the 1980s, and the term Augmented Reality appeared in the 1990s (Elmqaddem, 2019). At that time, these technologies were expensive and not convenient enough, which prevented their implementation in practice. Only since 2012, technological and commercial improvements have made this interesting for mass use. The following factors contributed to this: increasing the availability and capacity of computers and smartphones, facilitating access to the Internet, developing a variety of content in virtual environments, and improving the quality of computer images and videos. The possibilities that VR technology offers now were technically impossible a few years ago.

The increase in the use of VR in education is reflected in the exponential increase in the number of publications on this topic in peer-reviewed scientific publications (Aznar Díaz, Romero Rodríguez, & Rodríguez García, 2012; Campos Soto, Ramos Navas-Parejo, & Moreno Guerrero, 2019; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). The researchers aim to summarize the accumulated data in the form of systematic literature reviews and meta-analyses of empirical data. At the moment, dozens of reviews and systematic comparisons of virtual and augmented reality applications for education have been carried out. These studies focus on publications published until 2019 inclusive. It should be noted that researchers have different goals and use different strategies for data search and analysis. Some scientists analyze the bibliometric parameters of publications (Aznar Díaz et al., 2012; Campos Soto et al., 2019; Radianti et al., 2020), and other researchers summarize the content of the articles (Radianti et al., 2020) or view each article as a case (Zender, Knoth, Fischer, & Lucke, 2019).

The field of view of researchers includes works that consider different types of education. For example, Merchant et al. (2014) analyze the use of virtual games and virtual environments for learning in secondary and higher education. Jensen & Konradsen, (2018) focus on the use of head displays (HMD) in higher education. Alam et al., (2019) consider using AR technology in primary school.

1.1. Purpose of study

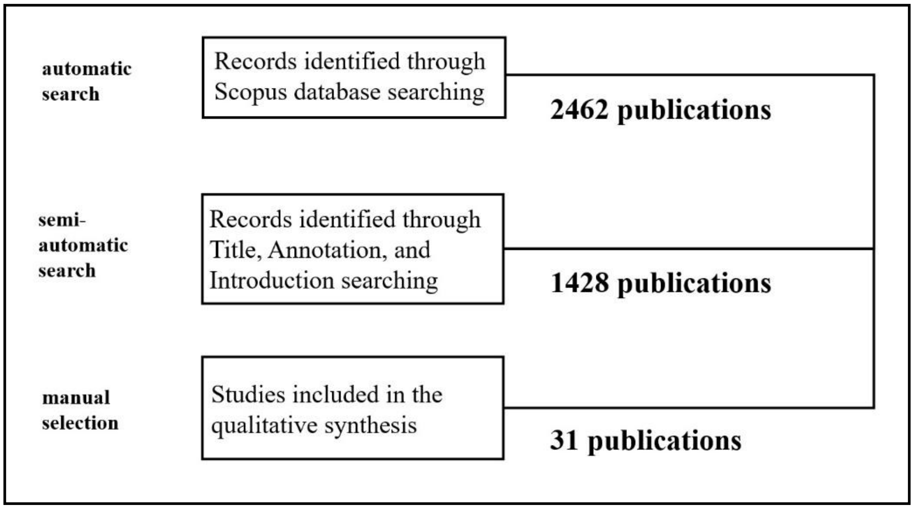
To have a complete picture of the possibilities of applying VR and AR in education, it is necessary to summarize the results obtained by different researchers. In addition, such a review will identify areas for further systematic reviews of the literature on the issue. The purpose of this research was to study the experience of applying VR and AR technologies in education.

2. Materials and Methods

To achieve this goal, an analysis of the reviews on this topic presented in the Scopus database from 2018 to 2020 was carried out. The search for publications included the following steps: automatic search, semi-automatic search, and manual selection (Fig. 1).

Figure 1

The article selection process for this study



Automatic search in Scopus was performed according to the following settings: (TITLE-ABS-KEY (virtual AND augmented AND reality) AND PUBYEAR > 2017 AND PUBYEAR < 2021) AND (education OR training OR learning) AND (LIMIT-TO (PUBSTAGE, "final")). As a result, 2,462 articles were found. Next, publications that contained the words «review» or «meta-analysis» in the title and/or in the annotation were selected from the common data array. There were 1428 of them. The manual selection involved: reading titles and annotations, reading text, and further eliminating irrelevant publications. As a result, 31 publications were selected for further work (table 1). 6 works were published in 2018, 15 works were published in 2019 and 10 works were published in 2020. 3.2% of publications were a chapter in the book, 74.3% were articles in journals, and 22.5% were articles in conference collections.

In this work, we tried to clarify the following aspects of introducing VR and AR technologies into education: classification of technologies used, main applications, educational content, assessment of training results, implementation conditions, and use prospects.

3. Results

*3.1. **Classification of VR and AR technologies in educational projects***

The authors use different grounds for classifying innovative technologies using virtual environments and their elements. VR and AR are immersive technologies, that is, methods of training user engagement based in a virtual environment to such an extent that communication with the surrounding reality is temporarily lost and there is a sense of "presence" in the task environment. Different technologies differ in immersion capabilities - the perception of physical presence in the non-physical world (Radianti et al., 2020). Differences exist in the level of interactivity of technologies, that is, the user's ability to interact with VR too. Presence, interactivity, and immersion are key components of VR (Mäkinen, Haavisto, Havola, & Koivisto, 2020). Because most researchers believe that stronger immersion has a positive effect on learning outcomes (Jensen & Konradsen, 2018), this characteristic should be discussed in detail as a basis for classifying immersive technologies.

Table 1

Systematic reviews of publications on the use of VR and AR technologies in education

authors	publication period	N	type of education	variables to be analyzed

Alam et al. (2019)	2004-2018	33	Primary school	Application of AR to primary education using individual "topic cards" for different topics
Ali et al. (2019)	2007-2017	148	All	Mixed reality technologies and subcategories applied to collaborative learning environments
Arici et al. (2019)	2013-2019	62	All	Research trends and bibliometry of articles related to the use of AR in natural science education
Billingsley et al. (2019)	no time constraint	8	Professional	Increased training opportunities for educators
Calabuig-Moreno (2020)	1900–2019	22	All	VR and AR in Physical Education
Chavez and Bayona (2018)	1999-2017	30	Professional	VR Characteristics, Learning Impact
di Lanzo (2020)	2015-2019	17	Professional	Leveraging Virtual Environments in Engineering Education
Diao and Shih (2019)	up to 2019	21	Professional	AR application trends in architecture and construction training
Durrani and Pita (2019)	2012-2018	38	All	Effectiveness of VR and AR in different educational contexts
Elmqaddem (2019)	no time constraint	12	All	Achievements and perspectives of VR and AR in education
Feng et al. (2018)	no time constraint	15	All	Learn how to evacuate from a closed building with VR
Gudoniene and Rutkauskiene (2019)	2014-2017	11	Higher education	Benefits of VR and AR Technologies for Education
Jensen and Konradsen (2018)	2005-2018	30	All	Using AR to improve the skills of children and adolescents with autism
Kamińska et al. (2019)	no time constraint	150	-	Options for using AR glasses in education
Khowaja et al. (2020)	Before 2019	555	All	Bibliometrics of publications on the use of AR in education
Kortekamp et al. (2020)	2006-2017	29	All	Application of VR, AR, and MR technologies in educational environments
López Belmonte et al. (2019)	up to 2019	26	All	Using VR in Health Education
Maas & Hughes (2020)	2000-2018	40	Higher education	Problems Encountered Using VR and AR Technologies in Distance Learning
Mäkinen et al. (2020)	1998-2018	57	Preschool	Possibilities of using AR in education
Ntaba and Jantjies (2019)	up to 2016	85	All	Education-oriented VR and AR research directions
Oranç and Küntay (2019)	2016-2018	38	Higher education	Design elements, learning theories, training content, applications of VR immersive technologies
Queiroz et al. (2018)	no time constraint	15	All	Learn how to evacuate from a closed building with VR
Radianti et al. (2020)	2014-2017	11	Higher education	Benefits of VR and AR Technologies for Education
Raju and Joshith (2020)	no time constraint	100	All	AR English Learning Technology
Sheik-Ali et al. (2019)	После 2009	11	Professional	Effectiveness of VR/AR in surgical education
Suh and Prophet (2018)	201-2017	54	All	Application of immersive technologies in various fields, including education
Uruthiralingam and Rea (2020)	2007-2020	87	Professional	VR and AR on studying anatomy
Wang et al. (2018)	1997-2017	66	Professional	Building and Architecture Training with VR and AR

Williams and Gilbert (2020)	2008-2018	70	Special	Educating children with autism
Zender et al. (2019)	no time constraint	6	Higher education	Potential and challenges in using VR as a tool for research and education
Zheng et al. (2019)	2010-2017	33	All	Using 3D virtual environments to learn a foreign language

The term AR combines technologies in which virtual objects are introduced into the real environment in real-time using special devices. This technology allows you to enhance the acoustic and tactile sensations of the user, superimposing digital information on elements of the real world. Special gadgets are used to provide AR: Head-Mounted Display, Smart Glasses, Head-up Display, Contact lenses, Handheld display, and Pinch Gloves (Raju & Joshith, 2020). This technology can be implemented based on common digital devices: computers, tablets, iPod touch, Microsoft Kinect, Fitbit smartwatch, Tangibles AR toys, Google Glass, and Interactive floor (Khowaja et al., 2020).

The term VR refers to technologies that create an interactive virtual environment designed to simulate real-world experiences (Suh & Prophet, 2018).VR can divide into Immersive and Non-immersive/desktop reality in the continuum - of virtuality (Suh & Prophet, 2018). Non-immersive VR – this is a technology that relies on displaying virtual content through a computer screen without additional equipment that enhances the immersion sensation. Immersive VR is a technology that involves deep immersion in a virtual environment through more complex systems, such as head-end displays (Feng, González, Amor, Lovreglio, & Cabrera-Guerrero, 2018; Mäkinen et al., 2020).

These systems block visual signals from the user's physical environment to create a more controlled, restricted environment. Some of them can collect and use data from the user. For example, head and eye movement, and heart rate (Suh & Prophet, 2018). Some authors distinguish semi-immersive VR systems. They are an improved version of desktop VR systems, as they provide a greater degree of immersion, for example, by tracking the movement of the eyes and head (Mäkinen et al., 2020).

Radianti et al., (2020) devoted their work to the analysis of VR technology in higher education. The authors divided them into 3 groups: mobile VR, high-end HMDs, and Enhanced VR. At the same time, high-class helmets are most often used, such as Oculus Rift or HTC Vive. 20% of the studies they studied were based on the use of low-budget mobile VR, for example, using smartphones and Google Cardboard. Equipment for improved VR is used only in rare cases in higher education. The authors note that the researchers do not report the equipment used to create VR in single papers.

Another type of immersive technology that is addressed in the reviews is mixed reality (MR). It is a combination of AR and VR that allows you to physically interact with virtual objects in the real world (Maas & Hughes, 2020). More detailed classifications of technologies are used for selected areas of education. For example, Wang et al. (2018) believed that VR and related technologies for construction and design training can be divided into 5 main types. There are Desktop-based VR, Immersive VR, 3D game-based VR, BIM-based VR, and Augmented Reality.

Williams & Gilbert, (2020) studied technologies that are used to educate children and adolescents with autism. They divided them into the following groups: Affective Computing, Virtual Reality, Augmented Reality, Gaze-contingent Computing, Brain-Computer Interface, and Other (motion sensing, or something wearable without direct biosensors, yet is intended to influence wearer physiology or expression). Thus, current reviews of the use of VR and related technologies in education affect a wide range of hardware and software that allows you to achieve different levels of immersion.

*3.2. **Main areas of application of VR technologies in education***

While some reviews under consideration focused on the narrow scope of VR and/or AR technologies (Arici, Yildirim, Caliklar, & Yilmaz, 2019; Calabuig-Moreno, González-Serrano, Fombona, & García-Tascón, 2020; Diao & Shih, 2019; Feng et al., 2018; Lanzo et al., 2020; Wang et al., 2018), others consider education in different contexts (Durrani & Pita, 2019) or education as one of many applications of VR (Gudoniene & Rutkauskiene, 2019; Suh & Prophet, 2018). The most attention of researchers is attracted by those areas of professional training where immersive technologies are the most popular in professional activities. Therefore, several systematic reviews have already been devoted to training in the field of construction and architecture (Diao & Shih, 2019; Lanzo et al., 2020; Wang et al., 2018) or medicine and health care (Mäkinen et al., 2020; Sheik-Ali, Edgcombe, & Paton, 2019; Uruthiralingam & Rea, 2020). Researchers note that the use of VR technologies in these areas of professional activity is most intensive, which requires future specialists to know in these areas. For our part, we want to note that the technologies in question are quite widely represented in the field of special education. We found 2 reviews (covering a total of 100 publications) focusing on the use of VR or AR technologies in educating children with autism (Khowaja et al., 2020; Williams & Gilbert, 2020).

The results of other systematic reviews support the idea that the most popular applications of VR and/or AR technologies are: engineering, healthcare, computer science, science (for example, astronomy, natural science), and general-purpose educational tools (Kamińska et al., 2019; Radianti et al., 2020). The field of view of researchers whose work has been considered rarely includes examples of training in humanitarian fields, for example, psychology, history, etc. Little attention is paid to VR analysis in non-formal education.

3.2.1. level

Inequalities are noted in the spread of innovative virtual technologies at various levels of education. 35.4% of the publications we reviewed focused on studies of the use of VR and/or AR in higher vocational education. 45.2% - did not introduce restrictions on the level of education (Table 1). 1-2 systematic reviews were conducted on primary and preschool levels (Alam et al., 2019; Oranç & Küntay, 2019).

A review presented by Maas and Hughes (2020)found that experience in using AR was presented in articles looking at all levels of learning, including in higher education. However, most often, the articles describe the experience of using AR in elementary and middle grades. Articles on the use of this technology in high school and at university are much less common. Among the publications considered by the authors, the experience of using VR only in high school is described. MR technologies are presented in publications looking at high school and high school.

3.2.2. Extracurricular education

Researchers note that there are many gaps in research into the application of VR and AR in preschool education and the non-formal education system. For example, Queiroz et al. (2018) showed that among the studies presented by Brazilian scientific groups, only one of 85 studies focused on corporate education and several on early childhood education. This seems a big omission since the age of children joining digital devices has decreased significantly recently (Sivrikova et al., 2020). Oranç and Küntay (2019) claim that a well-designed AR application can support early childhood education. It draws children's attention to learning material and encourages them to reflect on the content, establishes an unusual learning environment, and reduces the representative disparity between the context in which children learn new information and the context in which they must apply what they have learned.

3.2.3. Special education

VR and AR open up new learning opportunities for children with developmental disabilities. Williams & Gilbert, (2020) analyzed 70 publications on wearable technologies and identified 8 targets for their use in educating children with autism: monitoring physiological signals to expand existing behavioral interventions, training in emotion recognition and learning about the features of autism, training in social skills - smart glasses as a prosthesis of social etiquette, professional rehabilitation, and adaptation in society, regulation or mitigation of sensory experience, feedback on the state of the autonomic nervous system for the development of self-regulation, self-expression, the formation of metacognitive strategies.

Khowaja et al., (2020) grouped the studies they considered according to the types of skills that were formed in children with autism by AR: Attention Management; Brush teeth; Cooking; Facial expressions and emotions; Handling Plants; Literacy; Navigation; Pretending to Play; Social communication skills. Researchers believe that immersive technologies can make life and learning easier for children with developmental disabilities. It should be recognized that the scope of their application can go beyond working with children with autism significantly. Such technologies would be especially useful in the organization of remote forms of education for children with musculoskeletal disorders. Modern technologies allow such children to attend virtual classes together with other students. However, not a single overview of work on this topic was included in the field of our search. In general, limiting interest in reviewing studies of the use of VR and AR in the education of children with developmental disabilities to autism spectrum disorders alone seems unduly narrow.

3.2.4. School education

Often, literature reviews on the application of VR and AR technologies include publications on schooling. At the same time, researchers note that modern technologies are used in teaching different subjects. For example, AR technology is used in the field of art, foreign language, library education, mathematics, and science. Moreover, more works are devoted to training in the field of science (Maas & Hughes, 2020). Modern applications allow a student to study the basics of electricity (point charges and static electricity, electrical conductivity and electromagnetism), to form argumentation skills in the field of environmental sciences, to form ideas about the universe, solar system, water cycle, bacteria, aquatic plants, and food chains. Research on the use of VR and AR in art training concerns dramatic play, early art education, and motivation in the field of visual art. Some studies focus on the use of VR and AR to introduce students to the use of the library. AR allows students to facilitate the study of algebra and geometry.

Using virtual environments, the process of learning a foreign language, and creating reading skills is facilitated. Researchers cite convincing evidence that the use of 3D virtual environments (3DVEs) in the process of teaching a foreign language increases overall language literacy and language efficiency. Much attention is paid to how VR and AR technologies contribute to the formation of specific linguistic skills through the introduction of forms such as listening (Levak & Son, 2017), speaking (Lan, Kan, Sung, & Chang, 2016), and writing (Wang, 2017) n the learning process.

VR technologies are used to improve non-language knowledge and skills of students when learning a foreign language. These include the development of communicative skills or sociocultural interactions; increased critical thinking of students, their cognitive achievements, and joint learning skills. Researchers discuss how learning experiences through a virtual environment can affect the acquisition of cultural knowledge, positive attitudes towards targeted culture, and cross-cultural adaptation (Zheng et al., 2019).

Researchers note that the school uses mainly virtual environments using desktop equipment, although in some cases more complex systems are used. There are no examples of using immersive VR using a non-computer-generated virtual environment, such as, for example, 360-degree images or video. This is noteworthy because many cite the benefits of using immersion in a virtual environment with 360-degree images or videos to develop empathy and better understanding (Maas & Hughes, 2020).

In the works devoted to schooling, the negative effects of VR and AR in the lesson are considered. In particular, it is indicated that the immersive experience of being in a simulated reality overshadows the acquisition of cognitive skills (Zheng et al., 2019). In this regard, it is assumed that it is better to use the virtual experience of low immersion (without HMD) to stimulate the understanding and memorization of the material. But this advantage is limited by several factors, the main of which is the degree of familiarity of students with VR technology and the tendency to cybernetics.

3.2.5. Higher and professional education

An analysis of the bibliometric performance of publications on the use of AR in higher education showed that this technology is considered innovative and has several advantages (López Belmonte, Moreno-Guerrero, López Núñez, & Pozo Sánchez, 2019). VR is used to train future doctors, psychologists, IT specialists, trade, industry, and mining. It provides an opportunity to expose students to dangerous simulated situations without exposing them to real danger.

The use of VR in medical universities is because computer technology allows interactive training and the development of various skills related to medical professions without the risk of harming the patient. Students can combine theoretical knowledge with practice, acquire non-technical skills and receive computer feedback on their actions (Mäkinen et al., 2020). The work of Sheik-Ali et al. (2019) showed that VR/AR may be useful for enhancing practical skills as well as surgical knowledge, at least in the short term. The authors were able to find limited evidence suggesting that VR/AR may have positive learning advantages in improving the rate of acquisition of surgical skills, surgeons' ability to multitask, ability to perform the procedure accurately, and hand-eye coordination. The advent of VR technology offers a faster, safer, and less expensive way to train surgeons. The software, which can be surprisingly realistic, allows the student to practice a wide range of surgical procedures, repeating each with several different conditions until the student is ready for traditional surgical practices. This reduces the risks to patients and the need for the expensive use of animals in training. Introducing at least some of the described improvements in learning, without the use of digital technologies, would require much more time and effort from teachers and students. With limited effort, the new digital technology makes training surgeons much more interesting and effective (Gudoniene & Rutkauskiene, 2019).

Ntaba & Jantjies (2019) found several uses of AR and VR in higher education. But they believe that these technologies are more productive when used in courses that require the development of practical skills. They emphasize that AR and VR should not be used as a substitute for traditional training, but as a complement to it. The authors cite evidence that AR and VR contributed to student involvement in learning, better assimilation of course content, and better development of practical skills. AR and VR have demonstrated several benefits that can help expand the distance learning experience (Ntaba & Jantjies, 2019).

Chavez & Bayona (2018) found that more than 50% of the articles they reviewed confirmed that the use of VR and AR technology in higher education leads to the following positive effects: improving learning outcomes; gaining practical experience close to reality; internal motivation to explore new topics; Increasing the level of interest in learning compared to traditional academic learning, acquiring new or improving existing skills.

3.2.6. Learning content

An important aspect of the analysis of the use of VR and AR technologies in education is the study of the type of specific types of educational content that are presented in applications developed for this purpose.

A systematic review of the scientific literature by Radianti et al. (2020), showed that in higher education, applications designed to form are most often used:

- Procedural and practical knowledge (33%), for example, filling out a report or extinguishing a fire;

- Declarative knowledge (25%), for example, the study of the names of planets or scientific concepts;

- Analytical and problem-solving skills (12%), e.g. patient diagnosis or programming;

- Ability of students to work in a team, soft skills (10%);

- Capacity for foreign languages (2%);

- Behaviors and useful habits (6%).

Kaminska et al. (2019) proposed a taxonomy of VR applications based on the results and goals of training. They used three categories closely related to the level of immersion in VR: 1) understanding and memorization; 2) use of knowledge in a typical situation; 3) the use of knowledge in an atypical situation. According to the author's taxonomy, the first type of VR platform is used to represent knowledge in a specific field of science and helps to obtain theoretical knowledge (terms, dates, facts, rules, theories, etc.). This requires the least immersive environment, such as a wall projection with special glasses or a tablet touchscreen. Such technologies are represented by visualizations of 3D, training in behavior in dangerous situations, as well as virtual travel (into space, on historical events).

The second type of VR application is used to teach practical skills. This kind of application requires a deeper immersive feeling and control. It requires special external sensors such as Kinect or MYO Gesture Control Armband, sensor gloves, or special costumes. The latest type of VR application is designed to teach you how to use your knowledge and skills to solve problems. They are mainly used in the professional training of doctors and engineers, architects. By interacting with 3D models of real objects, students can understand their design, principles of functioning, the essence of physical phenomena, etc.

Developing practical and cognitive skills is a priority in the use of VR and AR technologies. Therefore, researchers analyze in detail the features of the formation of certain types of skills: cognitive, psychomotor, and affective. When analyzing educational content presented in VR and AR applications, it must be borne in mind that all cognitive skills evaluated in the studies relate to low-level cognitive skills according to Bloom's classification. They are characterized by remembering or understanding the facts. No study examined the use of VR or AR to teach higher-level cognitive skills (Jensen & Konradsen, 2018).

Many studies examining the acquisition of psychomotor skills show the effectiveness of VR in improving students' skills to work on a simulator. Only the same studies examine the transfer of training results on the simulator to the real environment. For example, this is shown in studies of the use of surgical simulators using special devices worn on the hands. These simulators can slowly increase complexity and allow you to model the situation very close to the real world. In cases where psychomotor skills are associated with head movements, such as visual scanning or observational skills, modern technology offers high simulator accuracy. For a variety of other psychomotor skills that require physical interaction with specific objects and environments, in general, effective acquisition of psychomotor skills with HMD will not be possible until peripheral technologies are significantly improved to incorporate user body movements into the simulation.

Affective skills, such as psychomotor skills, require repetition to achieve skill, and a successful VR simulator for affective skills must be very interactive. Many affective skills are related to interpersonal skills, and here the ability of technology to create plausible simulations of a virtual human or social situation is crucial. Although this topic is hardly explored in the studies presented, the acquisition of affective skills seems to be a good place to use VR and AR. Training simulators for affective skills are less dependent on immersive peripherals that incorporate bodily motions into the simulation, and more dependent on the simulation's ability to induce an emotional response in the learner. If the emotional response can be generated by exposure to sound and image in the VR, then this can be used in training.

VR technology is already being used to treat phobias and to teach stress management. As artificial intelligence improves, more affective skills will appear that can be taught virtually.

4. Discussion

The most important factors that could potentially hinder the adoption and application of immersive technologies in education are funding, health, and accessibility, or lack thereof, in both developed and developing countries (Ntaba & Jantjies, 2019). However, recent advances in mobile computing and performance have increased the allocation of resources for the development of mobile VR and AR systems. This has made digital technologies more accessible to the general public. The transfer of national training systems to a remote format, which happened in Russia in the spring of 2020 in connection with the prevention of the spread of Covid-19, was another factor that contributed to the intensive introduction of digital technologies in education. This may force society to turn to the latest developments in the field, in particular, AR and VR technologies. In this regard, it is important to note that studies that used AR and VR in education were not conducted in isolation settings.

It is important to understand that expanding traditional education practices through the use of AR and VR should be seen as a tool to enrich teaching and learning, rather than as a complete substitute for traditional learning. This is due to the limitations of technology in matters of comprehensive personal development. The latter is impossible without inclusion in the interpersonal interaction system according to the cultural and historical theory of the development of L.S. Vygotsky. The teacher's personality plays a huge role in the education process, especially in its early stages.

In addition, the desire to make full use of the learning results in the context of immersion with the help of VR and AR should be subject to the condition of practical expediency. The virtual learning environment must be consistent with the practice and results of the course. The technologies shall be modifiable to match the course results and not require a change in the course according to the AR and VR restrictions. This is most pronounced in the need to find a balance between the attractiveness of technology for the younger generation, the degree of immersion in the virtual world on the one hand, and the need to concentrate on educational tasks on the other. As part of the solution to this condition, the competition will unfold between VR and AR technologies. Smartphone-based AR applications allow users to navigate their physical environment, looking at their augmented world through a mobile device. And VR applications allow the user to interact with objects of virtual space in conditions that are as close to reality as possible.

An important condition for implementing AR and VR in the learning process is ensuring the physical comfort of students. Jensen & Konradsen (2018) showed that 8 of the 21 studies that came to their attention addressed the problem of physical discomfort and cybersickness. They state that the frequency of cybersickness and symptoms vary from very rare to present in almost every student. In some cases, symptoms of cybersickness forced study participants to drop out of experiments. Studies show that cyber disease negatively affects students' attitudes to VR technology and is associated with lower learning outcomes. It was also found that the onset of symptoms of the cyber disease depends on the playing experience of students (for example, the experience of playing 3D) and age (older people more often note symptoms of cyber disease).

Another condition for the introduction of new technologies in education is the readiness of teachers for such changes. Studies show that not all teachers own new technologies at the proper level (Sivrikova, Roslyakova, Sokolova, & Moiseeva, 2019). Other teachers may be overly reliant on technological advances, resulting in a lack of interaction between teacher and student. A human teacher is also a natural filter and moderator of information received by students, necessary for assessing the reliability and relevance of the data obtained. Moreover, focusing too much on digital educational solutions can distort the balance between learning hard and soft skills, to the great advantage of the former, while the latter remains very important in the modern workplace. Although we may be tempted to replace all old-fashioned solutions with modern digital ones, there must be a balance between modern solutions and human interaction, mentorship, and the relationship between teacher and student.

Another condition for the introduction of new technologies in education is the readiness of teachers for such changes. Studies show that not all teachers own new technologies at the proper level. VR and AR are likely to become an integral part of education. They are already actively used at different levels of training. The most intensive implementation of these technologies will occur in the training of those activities that are directly related to the use of virtual space. Future applications of VR and AR in education are limitless and will allow efficient and efficient preparation for activities in difficult conditions.

Scientists have proved that content obtained through the experience of VR and AR is remembered more than the experience without augmented reality (Gudoniene & Rutkauskiene, 2019). However, VR objects for formation are highly dependent on the technical aspects of mobile devices, their operating environment, and their limitations. VR and AR technologies allow students to interact, providing social communication even in isolation. They introduce a new type of automated applications and increase the efficiency and attractiveness of the learning environment for students (Weng, Bee, Yew, & Hsia, 2017). As powerful educational tools, VR and AP can lead to shorter learning and learning times. However, to achieve this goal, it is necessary to identify the right scenarios and develop appropriate learning experiences in a virtual environment. The use of VR and AP will be useful not only in formal education but also in non-formal education.

5. Conclusion

The education system has been developing for centuries. It has always adapted to the available technologies and the needs of students. Now we are on the verge of another development, and the responsibility for its adoption and preparation rests with scientists, teachers, and teachers. The generation that sat behind desks now has been online all its life. The digital world is as important and immersive as the real one. These children are digital Aboriginal people born in the world of mobile phones, the ubiquitous Internet, and immediate access to much of the desired information or data, be it music, video, or content. Generation Z education is a task that requires a completely different approach to maximizing efficiency and engagement.

There are numerous proven advantages of using AR and VR technologies in education. First of all, they provide outstanding visualization that cannot be obtained in a traditional class. They reflect a world in which younger generations feel comfortable. They are inclusive and enable everyone, regardless of status, financial status, and disability, to participate in the education process. They provide virtually unlimited access to information, books, or articles. They allow you to survive and rehearse action algorithms in the most difficult situations without a threat to health. Modern technologies used in the classroom increase engagement, and stimulate collaboration, and participation. It is used for highly effective mixed learning, promoting self-learning and individual desire for knowledge.

Although the use of modern technologies in the educational environment is profitable, it is not without risks and dangers. One of the main issues was the lack of flexibility. During traditional classes, students can ask questions, receive answers, and participate in this discussion. Using a virtual reality headset with certain software, students must follow the rules and cannot do anything other than what they must do. Thus, the analysis of systematic reviews and meta-analyses of publications on the use of VR and AR in education made it possible to draw the following conclusions: modern education intensively introduces digital technologies; VR theory for educational applications is underdeveloped; scientists have accumulated basic experimental material for the development of VR/AR for different types of formation;

Currently, there are virtually no mechanisms for sharing best practices in the application of VR and AR in both education and related fields; researchers present arguments for including VR and AR in curricula; the risks involved are also recognized. Promising areas for systematic reviews are publications on the use of AR and VR in non-formal education and the education of preschool children.

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