

## The Use of Virtual Reality in Geo-Education

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Nurzhanat Shakirova (✉)

Abai Kazakh National Pedagogical University, Almaty,  
Republic of Kazakhstan  
shakirn\_123@mail.ru

Nidal Al Said

Ajman University, Ajman, United Arab Emirates

Svetlana Konyushenko

Immanuel Kant Baltic Federal University, Kaliningrad,  
Russian Federation

**Abstract**—The paper discussed the technological capabilities of virtual reality (VR) in education as a highly developed form of computer modeling. In order to study the impact of VR technology on the quality of e-learning, an experiment was conducted during an online Physical Geography course.

The current research involved 60 third-year students from the Abai Kazakh National Pedagogical University, Immanuel Kant Baltic Federal University, and Aldar University College. The respondents were divided into two groups—the first group underwent training through distance learning in the Moodle e-learning system, while the educational process of the second group was supplemented with technological capabilities of the latest VR services (Google Earth, Apple Maps, My Way VR, The VR Museum of Fine Art). During the study, students' subjective assessment of the training was performed according to the basic, expected, and desirable criteria. The examination was carried out in two stages - before and after the course. At the first stage of the assessment, the use of VR corresponded to the desired quality of the educational product. However, after finishing the course and acquiring virtual experience, the students' desired criteria were transferred to the expected ones.

This indicated a high degree of adaptability of VR technology in education as well as an increase in the respondents' requirements for the quality of subsequent academic training. Given this, a significant impact of immersive technology's evolution on the demands on the e-learning quality can be noted.

**Keywords**—Augmented reality (AR), cross-reality (XR), e-learning quality, immersive technologies, mixed reality (MR), STEM-education, virtual reality (VR).

## **1 Introduction**

### **1.1 Emerging technologies in STEM education**

The global transformation of the educational paradigm, caused by the development of digital technologies, creation of labor, research, and educational groups in the digital space, as well as free access to educational resources, scientific research, digital games and virtual libraries, continues to be the reason for systemic changes in the educational environment [1].

Recent technological advances have led universities to introduce innovative teaching methods and approaches that apply immersive technologies. The digital interaction of students and teachers, based on Learning Management Systems (Moodle, RedClass, and the like), produces new claims for ensuring the high quality of education. Furthermore, the development of multimedia and computer technologies opens up broad prospects for using digital learning to increase educational motivation and training effectiveness [2].

In modern educational space, STEM is spreading and developing as an innovative form of learning activity organization. The concept of STEM education is associated with virtual, augmented, mixed, and cross reality. Their possibilities reveal new trajectories of practically-oriented educational activities aimed at obtaining modern knowledge and practical skills [3].

The present-day society is characterized by the process of continuous transformation due to the globalization and rapid development of digital technologies. Therefore, the implementation of STEM education across the globe is crucial to meet the needs of a labor market of 21st-century [4] that requests for science, technology, engineering, and mathematics information literacy. In this context, there is an increasing demand for training personnel who can apply theoretical knowledge and scientific methods to understand and transform the objective reality. People should be able to adopt advanced technological solutions in professional activities, synergistically use mathematical and creative modeling, effectively interact with virtual information resources and the world itself.

In an educational context, geography has the potential to play a significant role in advancing the objectives of STEM, paying particular attention to critical and creative thinking [5]. STEM and humanities complement one another, providing an understanding of the context in which science gains its significance [6]. In the ever-evolving technology-focused world, humanities contribute to the preservation of balance. In this environment, rather than anywhere else, geography makes its unique contribution to STEM, encompassing the physical, social, and human sciences.

New interactive technologies in terms of smart mobile devices and accompanied applications are widely integrated into the educational methodology, raising numerous initiatives for their implementation and adaptation to the STEM education model [7]. Studying geography at schools and universities requires students to work with virtual technologies that can show connections between subjects, demonstrate holistic interpretations about the place and spatial patterns, and make predictions about future environmental events [5]. The synergy of digital technologies and innovative thinking

has created the opportunity for education through various learning activities. Thus, for example, robotics can be introduced into the educational practice to study mathematical and natural sciences [8].

## **1.2 VR, AR, and MR in education**

Virtual reality (VR) is a highly developed form of computer simulation that allows the user to interact with the artificially created world through sensor devices. VR is usually associated with video games and media resources. However, it has more extensive application capabilities due to significant advances in its technology. In this regard, VR is becoming more accessible and widely used in education. VR opens up a fundamentally new level of interaction with the digital world, allowing the user to experience and interact with a computer-generated environment. In contrast to the traditional user interfaces, VR places the one inside an experience through the Head-Mounted Display (HMD). This immersive environment can be similar to the real world, or it can be fantastical, creating an experience that is not possible in ordinary circumstances.

Unlike VR, which immerses users in a completely artificial environment like a video game, augmented reality (AR) is an interactive experience of a real-world environment where the objects are enhanced by computer-generated perceptual information. The overlaid sensory data can be constructive (i.e., additive to the natural environment) or destructive (i.e., masking of the natural environment) and are seamlessly interwoven with the physical world so that it is perceived as an immersive aspect of the real situation [1].

Mixed reality (MR) is a combination of physical and virtual worlds. MR gives an opportunity not only to integrate virtual objects into the real world but also to interact with them. In this case, a user is fully immersed in the virtual environment while the real world is blocked out.

Cross reality (XR) functionally combines virtual, augmented, and mixed reality. It enhances the capabilities of all three technologies to expand the boundaries of the physical space-time continuum for working with human perception. XR technologies form the transition from “full real” to “full virtual”.

## **1.3 Research objectives**

Based on current trends in global education and the evolutionary technological processes in the digital world, this work was aimed at studying the impact of VR technology on the qualitative assessment of online education. In this regard, the research objectives were defined as follows:

- 1) Analyze the technological capabilities of VR in the field of education
- 2) Determine criteria for an efficient and high-quality educational process
- 3) Examine the impact of VR, AR, and MR technologies on the students’ expectations from the course

- 4) Compare the results of the training quality assessment according to the basic, expected, and desirable criteria
- 5) Develop the quality pyramid of the e-learning course to predict improvement of education quality
- 6) Evaluate the knowledge and skills acquired through the use of VR services during the STEM education program on the example of Physical Geography course
- 7) Estimate the overall satisfaction of students towards performed training

## 2 Methods

### 2.1 Research design and sampling

The research design was determined by the specifics of the studied issue. The study was based on the Moodle online platform to examine the impact of VR technologies on education quality during the Physical Geography course. The experiment lasted from September 2019 to December 2019. It involved 60 third-year students from the Abai Kazakh National Pedagogical University (Kazakhstan), Immanuel Kant Baltic Federal University (Russian Federation), and Aldar University College (United Arab Emirates) (Table 1).

**Table 1.** Population of the sample

Group	Number of students	Age	Gender	Faculty/specialty	University
1	30	20-24	15 M 15 F	Geography/Geography	Immanuel Kant Baltic Federal University (9 students) Abai Kazakh National Pedagogical University (14 students) Aldar University College (5 students)
2	30	20-24	17 M 13 F	Geography/Geography	Immanuel Kant Baltic Federal University (10 students) Abai Kazakh National Pedagogical University (15 students) Aldar University College (5 students)

### 2.2 Experiment

All the respondents were distributed into two groups. The first group underwent training in the Moodle system, based on Zuma's developments [10]. The educational process of the second group was supplemented with the technological capabilities of the following VR services:

1. Google Earth VR was used with the HTC Vive helmet and allowed studying geographical objects of anthropogenic and natural origin in the form of three-dimensional reality. The Google Earth VR program provided automatical downloading of images and data necessary for the educational program [11].

2. Apple Maps, with a Flyover mode, enabled exploring the world in 3D. With this application, a student could visit more than 250 cities around the world [12].
3. My Way VR offered a virtual journey through different countries, continents, and cultures.
4. The VR Museum of Fine Art allowed visiting museums in VR mode [13].

During the Physical Geography course, the second group of students gained virtual experience in studying the geography of tourist destinations through the use of the Google Earth VR program. Respondents were able to travel to any location in the world in real-time with the help of individual VR controllers. Students were also given an opportunity to study natural phenomena, global climate processes, and world tourist resources in 3 VR-modes: 360-degree view, fly, and teleportation. Using the Google Earth Studio service, 3D videos of the Earth's surface, based on 3D maps and data on climatic changes, tsunamis, storms, and droughts, were created and analyzed. Through the Street View mobile application, respondents acquired skills in building tourist routes. A virtual journey through different countries, continents, and cultures was performed with the help of My Way VR. By using the VR Museum of Fine Art, the participants attended virtual museums, saw famous sculptures and paintings.

### **2.3 Research limitations**

According to the purpose of the current paper, partial assessment of the qualitative characteristics of an e-learning product was made. It was necessary for analyzing students' motivation and strategy while selecting a particular study course. The evaluation, based only on the subjective opinion of a student, cannot provide a complete understanding of the educational process's quality and effectiveness. Thus, expert assessments should also be taken into account to form a better e-learning product.

### **2.4 Statistical analysis**

Statistical analysis of data was conducted using Statistica software (version 5.0). The obtained results were considered reliable, with an error of up to 3%.

### **2.5 Ethical issues**

All experiment participants were informed about their role in the examination, as well as research goals and specifics. Each student signed a written agreement regarding consent to participate in the study and the use of survey data. For all the involved, the highest possible confidentiality was granted.

### 3 Results

#### 3.1 Assessment of the educational product: Pre-test results

Modern digital technologies, based on virtual reality, form the main criteria of an efficient and high-quality educational process, oriented on practice and productivity. A survey on the students' expectations about the course was carried out by classifying the assessment of online education quality into basic, expected, and desired (Table 2).

**Table 2.** Pre-test assessment results

Criteria	Basic	Expected	Desired
Modern e-learning platform	x		
Structured teaching material	x		
Optimized and high-quality educational content	x		
Compliance with world educational standards	x		
Compliance with the employers' requirements	x		
Setting deadlines for tasks	x		
Text, graphic, audio, and video content	x		
Real-time monitoring	x		
Objective and clear knowledge assessment system	x		
Computer testing of knowledge quality	x		
Student rating system	x		
International educational groups		x	
Personality-oriented approach to learning		x	
Ability to organize the educational process freely and independently		x	
Use of modern means of group communication		x	
Mobile technologies integration		x	
Adaptive approach to education - learning through practice			x
Cooperation on projects initiated by the real economy			x
Interaction with virtual educational environment adjusted to the educational program			x
Learning through the interactive computer experience in the professional environment			x
Gamification of learning based on intellectual incentives			x
Implementation of VR/AR/MR technologies			x
Professional activity imitation			x
Educational projects in a digital learning environment			x

\* Developed by the authors

Students associated the basic quality of the training course with an efficient and modern organization of teaching process, based on the processing capabilities of e-learning platforms. The provision of education with basic quality can be possible due to the implementation of a modern e-learning platform, structured teaching material, optimized and high-quality educational content; compliance with world educational standards and the employers' requirements; setting deadlines for tasks; implementation of text, graphic, audio, and video content; real-time monitoring; objective and

clear knowledge assessment system; computer testing of acquired skills and information; and student rating system.

The expected quality of the educational course was connected with additional contents of the educational process or the use of modern pedagogical and communication techniques. It can be realized through the creation of international educational groups; personality-oriented approach to learning; development of an individual educational trajectory; provision of an ability to organize the educational process freely and independently; application of modern means of group communication; and mobile technologies integration.

The desired quality of the online course can be achieved by including advanced digital technology and the ability to acquire modern and relevant knowledge. It can be ensured through the implementation of an adaptive approach to education; cooperation on projects initiated by the real economy; interaction with a virtual educational environment adjusted to the educational program; learning through the interactive computer experience in the professional environment; game-based education; application of VR/AR/MR technologies; professional activity imitation; and implementation of educational projects in the digital learning environment.

Comparing the results of the subjective educational evaluation performed by students before the Physical Geography course, it can be concluded that the use of VR technology was associated with the desired quality of the educational product.

### 3.2 Assessment of the educational product: Post-test results

After completing the Moodle Physical Geography course, a survey among the second group's participants was carried out again. Its results demonstrated the transfer of the desired criteria to the expected, indicating high adaptive capacities of VR technology in educational processes. Besides, the obtained data revealed an increase in requirements for the quality of subsequent educational courses among students who acquired virtual experience (Table 3).

**Table 3.** Post-test assessment results

Criteria	Basic	Expected	Desired
Modern e-learning platform	x		
Structured teaching material	x		
Optimized and high-quality educational content	x		
Compliance with world educational standards	x		
Compliance with the employers' requirements	x		
Setting deadlines for tasks	x		
Text, graphic, audio, and video content	x		
Real-time monitoring	x		
Objective and clear knowledge assessment system	x		
Computer testing of knowledge quality	x		
Student rating system	x		
International educational groups	x		
Personality-oriented approach to learning	x		
Ability to organize the educational process freely and independently	x		

Use of modern means of group communication	x		
Mobile technologies integration	x		
Adaptive approach to education - learning through practice		x	
Cooperation on projects initiated by the real economy		x	
Interaction with virtual educational environment adjusted to the educational program		x	
Learning through the interactive computer experience in the professional environment		x	
Gamification of learning based on intellectual incentives		x	
Implementation of VR/AR/MR technologies		x	
Professional activity imitation		x	
Educational projects in a digital learning environment		x	

\* Developed by the authors

### 3.3 Quality pyramid of the e-learning course: Predictions about the VR technology evolution

Based on the analysis of changes in the expectations about the e-learning among students undergoing training with VR technologies, a significant impact of the immersive technologies' evolution on the requirements for online education can be predicted (Fig. 1).

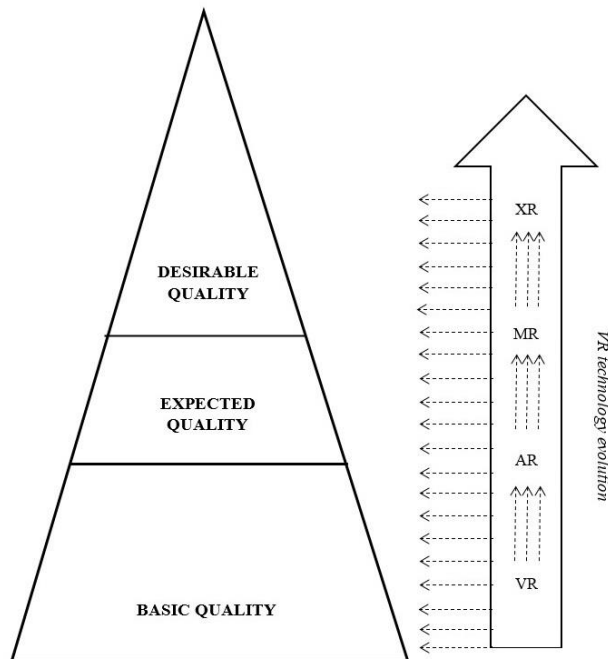


Fig. 1. Quality pyramid of the e-learning course

\* Developed by the authors



At the end of the course, students of two experimental groups were asked to evaluate the knowledge obtained during online Physical Geography course as well as the level of satisfaction of their educational needs according to the following options:

1. Professional knowledge
2. Professional skills and abilities
3. Satisfaction of *basic* education quality criteria
4. Satisfaction of *expected* education quality criteria
5. Satisfaction of *desired* education quality criteria

Self-assessment results showed that respondents who used VR, AR, and MR during the course achieved better learning results than those who did not benefit from the mentioned virtual technologies. Consequently, it can be stated that the use of VR during geography training may provide students with more effective preparation.

## 4 Discussion

The use of innovative digital software in the framework of STEM education has many barriers. Among them the high cost of equipment for organizing the educational space, the need for additional competencies of the teaching staff [9], and the use of students' personal devices to ensure successful group interaction [14]. The current article outlined changes in students' assessment of the educational product in the process of the Physical Geography course before and after the application of virtual technologies. Within the paper, the interpretation of basic, expected, and desirable quality of online education was given based on students' expectations from the course. The findings of the present research are consistent with the works of Aristin et al. [15], and Stojšić et al. [16].

One more study, similar to the present, was performed in Turkey. Its authors examined the potential of AR technology for geography training and confirmed the assumption that AR remains a useful tool for teaching geography, especially geomorphology topics [17]. However, not only this area can take advantage of AR technology implementation. Many scholars note that applications developed with AR can also be beneficial for mathematics and visual thinking [18].

A strong opposition exists between the information visualization community (Infovis), which criticizes the use of 3D, and the scientific visualization community (Scivis), which proves the importance of 3D capabilities during the examination of structures and processes. In turn, geographic visualization (Geovis) stands between the Infovis and Scivis communities. It is widely noted that in geographic information science, most visuospatial analyses were sufficiently conducted in 2D or 2.5D, including analyses related to terrain and many urban phenomena [19].

Recently, the emergence of information technologies, such as virtual cities, digital globes, and virtual explorations, open a new horizon for learning geography. For example, Geospatial VR offers realistic 3D learning environments and provides immersive, engaging, and interactive activities to build a professional experience [20]. Modern virtual technologies have the potential for scientific research in many fields. These

days, virtual geographic environments (VGEs), characterized by support for geodata management, geosimulation, geointeraction, and geocollaboration, play an important role in geographic research [21].

## **5 Conclusion**

The research findings confirmed that VR helps to reach the desired quality of the educational product and opens up new opportunities for mastering practical skills. Within the experimental study, VR technology implementation allowed a better understanding of the complex concepts and contributed to gaining experience in the chosen professional field. The paper's outcomes exposed that modern digital technologies based on VR can create the foundation for effective and high-quality training with an orientation on practice and productivity.

Students' subjective assessment of the quality of the educational process according to the basic, expected, desirable criteria was performed in two stages - before and after introducing VR. In the first stage, the use of VR was associated with the desired quality of the educational product. However, after completing the training program and gaining experience with virtual technologies, the students' desired criteria were transferred to the expected ones. This designates the adaptability of virtual technologies and confirms that learners with VR experience have higher requirements for training than others. Hence, a significant impact of immersive technologies on e-learning quality can be predicted.

## **6 Recommendations and Further Research**

The experimental study results affirmed a high degree of adaptability of VR technology to the educational process. Moreover, the present paper revealed an increase in requirements for the quality of subsequent educational courses among students who have experienced VR technology. This fact may indicate a notable impact of the evolution of immersive technologies on the standards of distance learning.

The proposed quality pyramid formed a primary understanding of modern trends in e-learning and provided an insight into the future improvement of digital education. This pyramid will become the basis for subsequent scientific work on the development of a comprehensive methodology for ensuring the high quality of an online educational product.

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## 9 Authors

**Nurzhanat Shakirova** is a Master of Geographic Sciences, 3-rd year doctoral student of the Department of Geography, Ecology and Tourism, Abai Kazakh National Pedagogical University, Almaty, Republic of Kazakhstan.

**Al Said Nidal** is a PhD. He is Assistant Professor of the College of Mass Communication, Ajman University, Ajman, United Arab Emirates.

**Svetlana Konyushenko** is a Doctor of Education, Professor, Immanuel Kant Baltic Federal University, Kaliningrad, Russian Federation.

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