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Immersive technologies as an innovative tool to increase academic success and motivation in higher education

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The latest techniques and technologies significantly improve the academic performance, engagement, and motivation of students. VR and AR open up numerous opportunities for the educational system. The purpose is to evaluate the effectiveness of using immersive technologies as a tool to increase the level of academic success, involvement, and motivation among students. The research involved a total number of 180 students in two higher educational institutions. This study presupposed using a previously elaborated program for further use in the experimental group. This program was introduced into the study program within the participating universities. The study included three tests to collect the data under the Motivation and Engagement Scale, as well as European Credit Transfer and Accumulation System. The experimental group provided positive indicators during statistical data analysis; thus, it demonstrates the effectiveness of the studied methods. Although the engagement and motivation of students from the experimental group increased, there were no differences in academic achievements between the groups. Therefore, it cannot be argued that immersive technologies have a direct impact on grades, which are the main indicator of success in learning. The new experimental data obtained in this study and the analysis of previous modern experimental studies allowed us to draw relevant conclusions about the expediency and high efficiency of immersive education technologies for teaching university students.

KEYWORDS

augmented reality (AR), European Credit Transfer and Accumulation System, higher education, immersive technologies, students, the motivation and engagement scale, virtual reality (VR)

1. Introduction

Computer multimedia environments are interactive systems or software that combine various media elements, such as text, image, sound, and video, to create a multimedia experience for users (Mutlu-Bayraktar et al., 2019). Immersive technologies are computer systems or devices that allow users to fully immerse themselves in a virtual or augmented environment. These technologies contribute to an immersive experience. The latter implies that users feel like they are in a different world or environment (Stanney et al., 2020).

Immersive technology is an umbrella term for technologies that blur the line between the physical and digital worlds. It refers to technology that enables users to interact, thereby creating a certain immersion. These technologies include augmented (AR), virtual (VR), and mixed (MR) realities. AR and VR are the most used types of these technologies (Emmelkamp and Meyerbröker, 2021).

Extreme professions are jobs or occupations associated with a high level of risk, physical and psychological challenges, or problem-solving in dangerous conditions (Gad et al., 2022; Le Roy et al., 2023). Complex systems are systems consisting of numerous interconnected elements or components that exhibit collective certain behavior or properties. The latter cannot be explained or provided by understanding the individual components (Proctor and Van Zandt, 2018).

AR technologies allow users to acquire skills based on experience, minimizing costs and risks (Zhao et al., 2019). It is generally recognized that immersive technologies enable users to conduct tasks that cannot be performed in physical reality (Nussipova et al., 2019). In particular, animal testing or patient rights usually encounter questions of ethical issues in the field of biology, medical research, and education. It demonstrates that conventional education, in these situations, can be morally questionable.

Immersive technologies, such as virtual reality (VR) and augmented reality (AR), are increasingly used in higher education in Russia and Kazakhstan. For example, the National Research Nuclear University MEPhI in Russia uses VR to teach students about nuclear safety. Students use VR headsets to simulate a nuclear power plant, where they can learn about various safety procedures and emergency response methods (Abdraimova et al., 2020).

Nevertheless, these countries have to deal with some problems and challenges related to the introduction of immersive technologies in higher education. The primary challenge is the financial costs of purchasing and maintaining the necessary hardware and software. Most higher education institutions have a limited budget, which can limit access to immersive technologies (Blyth, 2018). The training of teachers and personnel to effectively use immersive technologies is another problem. It is crucial to train teaching staff to use the technologies in the educational process and create appropriate educational materials. In this case, it will be possible to implement these technologies more successfully (Suleimenov and Tasbulatova, 2018).

In addition, immersive technologies in higher education foster active and engaging learning of students. These technologies help visualize complex concepts, create interactive simulations, and allow students to master practical skills in a controlled environment (Karakozov et al., 2020).

Immersive technologies, such as virtual reality (VR) and augmented reality (AR), have gained even more interest after the coronavirus pandemic. The pandemic crisis has led to a significant transformation in the field of learning and development (Darawsheh et al., 2023). At the same time, immersive technologies have proved to be useful tools for ensuring the continuity of learning and improving the quality of education (Rutledge et al., 2020).

The rapid progress of digital technologies opens up new opportunities for using AR tools in educational contexts (Dick, 2021). Immersive learning tools have obvious potential and educational benefits (Nussipova et al., 2019). Nevertheless, there are several unresolved problems associated with these tools. Firstly, the impact of this technology on mental and physical health, as well as user safety issues, receives insufficient scientific attention (Dick, 2021). Since AR tools are still a relatively new and rapidly evolving technology, the evidence base of the immersive technology benefits is incomplete. In particular, the information on the impact of AR tools on improving learning outcomes among students is limited. Consequently, this issue necessitates further research to understand the features of this training mode. That is why we assume that the use of immersive technologies for higher education institutions in Russia and Kazakhstan can significantly improve the learning process and the individual elements of its success.

2. Literature review

Multimedia modeling is the process of creating or developing models for the analysis, design, synthesis, or reproduction of multimedia systems and content (Kumari et al., 2018). Dynamic visualization is the process of creating or reproducing visual representations of data or concepts that gradually change. It shows the progress, development, or changes occurring in the data or system over time (Beck et al., 2017) nowadays, everyone can use AR due to the transformation and accessibility of modern technologies (Kornilov, 2019). In these terms, multimedia modeling and dynamic visualization are quite popular (Reinke et al., 2021).

Researchers have studied the effectiveness and potential of training based on AR technologies in various fields (Nussipova et al., 2019; Dick, 2021). And educational institutions have introduced immersive learning into their study programs. These include, the preparation of specialists in the armed forces and aviation (Slater and Sanchez-Vives, 2016), medicine (Thompson et al., 2020), architecture (Sopher et al., 2019), design and engineering (Drigas et al., 2022), programming and mathematics (Di Cecca et al., 2016) and within courses on the construction safety and its maintenance (Li et al., 2018) presupposes using virtual reality (VR) training programs. The following facilities demonstrate the best examples of immersive technologies implementation in the learning systems (in this case, we mean relevant examples of the effectiveness of certain immersive technologies based on the analyzed articles):

- The AR/VR studio in Harvard Innovation Labs (Nussipova et al., 2019),
- The Colorado State University VR lab, which is designed to improve the quality of education and improve the professional skills among students of technical and humanities fields through immersive simulations,
- Courses based on immersive learning and the XR laboratory of The University of Michigan (Dick, 2021),
- The Smithsonian Institution, which offers a repository of three-dimensional models with open access, allows users to explore items from the collections of the Smithsonian Museums in their physical environment through immersive technologies (Dick, 2021),
- The Department of Journalism, Center for Emerging Media Design and Development, Ball State University, Muncie, Indiana,
- The Department of Media and Information, Faculty of Communications, Michigan State University, East Lansing, Michigan,

- Clinical and Translational Science Institute, University of Rochester, Rochester, New York (Huang et al., 2019).

Tchaikovsky and Izotova (2020) also note the possibility to expand inclusive education through immersive learning technology. Beyond their ability to improve standard learning systems, VR tools can significantly contribute to integrating students with disabilities into the learning process and professional activities.

Some researchers identify several unique VR capabilities, such as immersion in the simulated environment, multimodal interaction, concretization of imagination, embodiment, and empathy (Pellas et al., 2021). VR increases empathy. It provides grounds for the embodied presence of the users (Pellas et al., 2021). Studying the impact of virtual and AR technologies on education, some researchers (Qushem et al., 2021) have revealed various benefits related to knowledge acquisition, commitment, motivation, and academic performance. This alternative educational approach has an additional value due to the high accuracy of the representation of three-dimensional virtual objects and the opportunity offered to students to model the operations and procedures of abstract concepts (Christopoulos et al., 2018; Qushem et al., 2021).

Immersive experience improves the memorization of complex or abstract topics based on intangible concepts (Dick, 2021). Such an experience increases motivation and engagement improvement, as well as obtaining emotional satisfaction (Morimoto and Ponton, 2021).

The involvement of students in educational activities is the most important requirement for effective student learning (Khan et al., 2017). AR/VR technologies also offer promising tools for student engagement, both offline and online (Dick, 2021). Some researchers emphasize that interaction with three-dimensional visualization causes positive emotional experiences that lead to improved learning outcomes and increased level of motivation (Reinke et al., 2021). Such emotional events can lead to better memorization (Parong and Mayer, 2018; Reinke et al., 2021), and positive emotional experiences usually result in improved academic performance. Furthermore, positive emotions resulting from using AR can strengthen the internal motivation to learn.

Educational immersive tools have a huge potential for training students of different ages and specialties (Huang et al., 2019; Dick, 2021). One of the previous studies analyzed the percentage distribution of educational AR/VR research by fields of education presented by Malaysian Online Journal of Educational Technology 2018 (Volume 6 – Issue 2) (Sirakaya and Alsancak Sirakaya, 2018). Accordingly, biology (19.8%) has the highest ranking, and its scientific topics include many specific concepts (Liou and Chang, 2018; Sirakaya and Alsancak Sirakaya, 2018). Engineering (12.8%) and medical education (11.6%) are other popular areas of research (Sirakaya and Alsancak Sirakaya, 2018). Three-dimensional technologies can contribute to developing visual and spatial literacy, as well as promoting creative thinking among biology students (Acuña and Melón, 2022). For example, students who studied with the practical use of AR/VR demonstrated higher results compared to students under the conventional program. Consequently, those students received immersive experience of specific biological processes, such as spatial orientation, vision formation in animals, the digestive process, and anatomical structure (Liou and Chang, 2018). Immersive experience offered by VR applications contributes to higher engagement and better learning outcomes among students (Makransky and Petersen, 2019; Morimoto and Ponton, 2021).

Some researchers indicate that immersive technologies can improve the learning environment and enlarge educational systems (Dick, 2021). Immersive technologies serve as valuable tools for expanding the training appliances. Furthermore, virtual learning allows teachers to sharpen their skills through teaching simulated virtual students (Abdallah and Musah, 2021).

Moreover, immersive technologies allow users to study in any learning mode and interact with teachers and colleagues in real-time using common virtual elements. Accordingly, students, teachers, and specialists in various fields express increased enthusiasm for using AR technologies as educational tools within their training (Dick, 2021).

Many researchers confirm that immersive technologies have great potential to support learning and teaching (Emmelkamp and Meyerbröker, 2021). Nevertheless, technological, pedagogical, and educational issues still require further study (Schaffernak et al., 2020).

The following issues are among the most significant ones related to AR development (Sirakaya and Alsancak Sirakaya, 2018). Firstly, teachers experience a lack of sufficient information for preparing AR materials. Secondly, compared to conventional lessons, AR/VR-enabled lessons require more time for preparation (Acuña and Melón, 2022). Consequently, it is crucial to train teachers who can provide an immersive educational experience, successfully integrating this technology as a standard environment (Ijaz et al., 2017).

In addition, despite the many advantages of this learning mode and the positive results of education through AR, higher education institutions have moderately been introducing this way of training into the study programs. Most of the immersive technology interventions described in previous studies are limited to professional development, such as process modeling or narrow-profile training. Consequently, most researchers overlook this issue in the context of educational programs in higher educational institutions (Pellas et al., 2021). Thus, it requires additional research which should focus on promoting AR training.

2.1. Importance of research

The main motivation for conducting this study lies in the desire to obtain new experimental data on the impact of immersive technologies and relevant applications on training specialists in various fields. In particular, it regards training specialists in complex industries and extreme situations. Moreover, such a learning mode presupposes intensifying the immersion into the simulated environment. The present research has practical significance as it demonstrates the effectiveness of introducing immersive technologies into study programs within higher educational institutions. The scientific value of the present study lies in outlining the key concepts of "immersive technologies" and "virtual reality," as well as describing their features within training specialists in various fields.

2.2. Setting goals

The purpose of this research is to study and describe the existing immersive technologies, theoretically substantiate their use, and experimentally evaluate the situation with their implementation in study programs within higher educational institutions. The objectives of the present research are to:

1. Study and describe the existing educational immersive technologies,
2. Identify the level of professional competence (academic performance, involvement, and motivation for studying among students) by monitoring and assessing two groups: the control group (students who received training under the conventional program) and the experimental group (students who studied through immersive technologies),
3. Conduct a comparative analysis of the level of professional competence in both groups by analyzing the dynamics of indicators before and after the implementation of the modified course program based on immersive educational technologies.

3. Methods and materials

3.1. Participants (sample)

Students from the following higher educational institutions participated in this study: Sechenov University and Silkway International University. The choice of these universities was because they were among the most outstanding and innovative in their countries. The study involved first-, second-, and third-year students. All subjects were selected through a questionnaire, where they indicated whether they were ready to participate in the research and whether they would like to study in an experimental group. The questionnaire contained questions related to consent to data processing; that is, the expected sample size was maximum, given the number of students with the required majors. Despite that, these students demonstrated high proficiency in using modern technologies. Thus, it significantly contributed to the present research (Atanga et al., 2020). The study involved 180 students divided into two groups based on the training approach. Each group comprised 90 students. All respondents were students of 1st to 3rd year who were majoring in Psychology and Biology. In the experimental group, the average age was 21.8 years (SD = 13); in the control group, it was 21.6 (SD = 9). They were chosen and assigned to groups randomly (Table 1).

Based on the total number of medical students from these universities, the permissible sampling error does not exceed $p = 4.53$.

TABLE 1 Distribution of respondents by age (%) and year of study (%).

Criteria	Respondents % (*N*)		
	Experimental group	Control group	Total
Male	51.1 (46)	52.2 (47)	51.6 (93)
Female	48.9 (44)	47.8 (43)	48.4 (87)
First-year students	34.5 (31)	33.3 (30)	33.9 (61)
Second-year students	32.2 (29)	35.5 (32)	33.9 (61)
Third-year students	33.3 (30)	31.2 (28)	32.2 (58)

Thus, the sample is sufficiently representative for the study.

3.2. Research design

The study included three stages: preparatory, practical, and summarizing The first stage evaluated the study participants regarding their professional competence (academic success, involvement, and motivation). At this stage, the researchers determined the experiment strategy and formed the groups. It is important to note that the control group studied under the conventional program, while the experimental group received training under the modified program using immersive technologies.

The first stage assessed the academic success of students. Accordingly, students were evaluated regarding their academic performance in Biology and Vocational pedagogy. It was significant to identify the level of their professional knowledge and skills.

Both groups were also tested with the Motivation and Engagement Scale (MES) test to identify their level of motivation and involvement (Liem and Martin, 2012). The authors of MES offer several approaches for conducting the test. It was relevant to use Option 3 in the present study, which presupposes testing university students.

The second stage entailed introducing immersive technologies into the biology course for an experimental group. The implementation of immersive technologies presupposed using AR tools within Biology and Vocational Pedagogy training during one academic semester. The course program complied with the conventional program of the selected disciplines at the university for third-year students. Consequently, the research lasted six months, with a total complexity of 2 academic hours per week, a total of 18 lessons.

The present study necessitated external support for the effective implementation of immersive technologies into study programs. Accordingly, two Kazan companies GD Forge and Zarnitsa-Innovations provided their support. These companies work with creating VR and AR technologies. GD Forge develops and creates programs and games using VR and AR. They helped with the introduction of relevant programs within training in the following disciplines: Biology, Preschool Education, Primary Education, and Russian Language. Zarnitsa-Innovations is a company that trains specialists using VR and AR technologies in mathematics. Students who participated in the study installed special applications (programs available for installation and use without additional devices) on their mobile phones that allowed them to work with AR technology at home. GD Forge and Zarnitsa-Innovations also provided additional devices needed for immediate use.

The external support of two Kazan companies, GD Forge and Zarnitsa-Innovations, was important for the effective implementation of immersive technologies in educational programs. These companies specialize in the development and use of virtual and augmented reality (VR and AR). GD Forge focuses on creating programs and games using VR and AR. They facilitated the introduction of relevant programs in such academic disciplines as Biology, Preschool Education, Primary Education, and the Russian language. Zarnitsa-Innovations trains specialists in mathematics using VR and AR technologies. The study participants installed special applications on their mobile phones. The applications allowed them to work with AR technology at home. In addition, the companies provided additional devices necessary for the immediate use of technology.

At the end of the experimental period, students were assessed regarding their level of involvement and motivation using the MES test. The results were compared with their academic performance.

TABLE 2 Comparison of academic performance before the intervention in both groups.

Levels	Experimental group % (*N*)	Control group % (*N*)
A	10 (9)	11.1 (10)
B	20 (18)	20 (18)
C	44.4 (40)	45.5 (41)
D	25.6 (23)	23.3 (21)

The data obtained under the study and their further analysis contributed to forming corresponding conclusions. Finally, the third stage presupposed analyzing and generalizing the results of experimental data and reaching theoretical and practical conclusions. The study was conducted from October 2022 to February 2023. The survey took place online via Google Forms.

3.3. Instruments

Students underwent the evaluation of their academic success according to their semester grades. The evaluation procedure presupposed the use of the ECTS (European Credit Transfer and Accumulation System) Scale system. Accordingly, students who got A had excellent results, B – good, C – average, D – satisfactory, E – sufficient, FX – unsatisfactory, and F – fail.

Both groups were also tested with the MES test to collect data on the level of motivation and involvement among students under study (Liem and Martin, 2012).

The MES package includes a motivation and engagement Profile Sheet for each user (provided in PDF format), and an online data collection and scoring service ("Norming") function. Students spent 60 min taking the MES test.

Student Profile Sheet, after processing, provides an estimation for each of the motivation factors from A to D. Scoring Service presupposes estimating the selected criteria by a 100-point scale where 100 indicates a high coefficient of motivation and engagement. Accordingly, students with scores of 100–66 got an A (high), 65–35 was a B (average), and less than 35 was a D (low). This online service provides processed data of individual results of respondents together with mean indicators (M) of group results in a single file.

3.4. Data analysis

The objectives of the present study presupposed assessing the academic performance of students and their level of involvement, motivation, and memorization. The data obtained during the experiment were subjected to statistical processing using the following computer programs: Microsoft Excel spreadsheets and an online calculator.[1] This study also necessitated conducting a comparative descriptive analysis. The quantitative analysis presupposed using the Student's t-test for independent samples. Reliability for experimental data is given at $p<0.05$ (95%). The used tools made it possible to obtain accurate results and reasonable conclusions.

1 https://math.semestr.ru/group/group_manual.php

3.5. Research limitations

Several previous studies on the practical implementation of immersive technologies into education and vocational training indicate that respondents experienced health and safety problems, as well as physical and visual discomfort (Cheng, 2022). The regular testing of university students has also become a favorable factor in this context. The time spent on VR and simulation is also important for the safety of users. Therefore, the present research considered this factor within the practical part of the study.

3.6. Ethics approval

The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The research was approved by the local ethics committees of I.M. Sechenov First Moscow State Medical University (Protocol no. 638 dated 02/02/2022). Informed consent was signed by participants.

4. Results

The methods used at the organizational and preparatory stage of the present study allowed identifying the level of involvement and motivation, comparing the results of academic success and memorization among study participants of both groups. Since the first stage obtained and processed the test and academic performance results, it was possible to draw relevant conclusions. Consequently, it is important to mention that students received no E (sufficient), FX (unsatisfactory), and F (fail) grades, so the statistical summaries of the study do not reflect these indicators. The present study used the ECTS/MES Scale system, where A corresponds to a high level, B is average, C is sufficient, and D is low. Accordingly, Table 2 displays the academic performance of study participants in both groups before the experiment.

After the intervention, students in both groups underwent an assessment of their academic performance in the selected course of Biology. Table 3 shows the results of the effectiveness of immersive technologies in this context.

According to the data obtained, the final assessment in the experimental group displayed an increase in the indicators of high and medium levels while sufficient and low levels significantly decreased. Moreover, the control group showed similar results. Differences in indicators of students in both groups were insignificant before the intervention. Statistical processing of the data on student assessment determined the level of academic performance of study participants. Quantitative and qualitative processing of average grades contributed to identifying that most students demonstrated sufficient and low results before the intervention. In the experimental group, these indicators amounted to 70%, and 40 and 23 participants (N) formed the indicators ratio of sufficient and low level, respectively. In the control group, these indicators comprised 68.9%, and the ratio of respondents (N) was 41 and 21, respectively (Table 2). The final assessment and its comparison provided the following results. The number of students in the experimental group with high and average academic performance increased by 23.3%, which corresponds to 13.3/40% (N = 12/36). In the control group, the dynamics indicator was +2.2%/+7.8%, and the final result was 13.3/27.8% (N = 12/25). In terms of sufficient and low results of academic success in the experimental group, there is a decline of more than 13.3% compared with the control group (Table 3). Table 4 presents the results of comparing MES (Positive Motivation, Positive Engagement, Negative Motivation, Negative Engagement) in both groups before the intervention.

Accordingly, Table 5 presents the results of comparing MES indicators (Positive Motivation, Positive Engagement, Negative Motivation, Negative Engagement) in both groups after the intervention. The results demonstrate the effectiveness of using immersive technologies within study programs.

Furthermore, the mean values of the experimental group students have more significant dynamics, while the control group has less progressive results. The comparative analysis of the obtained data demonstrated that the mean indicator of Positive Motivation among students in the experimental group increased to 68.8 (which corresponds to a high level), and in the control group this indicator increased to 62.7 (which corresponds to the average level). Since the value of p is below 0.05 ($p = 0.035$), this result has a statistical difference. The mean indicator of Positive Engagement among experimental group students increased to 70.1, and the control group experienced an increase only to 46.2. The value of p is below 0.05 ($p = 0.031$), so the differences between the indicators are also significant. The mean indicators of Negative Motivation among the study participants equated to 32.4 in the experimental group and 35.1 in the control group. However, the results are statistically insignificant as the value of p is over 0.05 ($p = 0.668$). The mean indicator of Negative Engagement among students is 30.6 in the experimental group and 36.2 in the control group. This result is also statistically insignificant ($p = 0.37$) for the study (Table 5).

However, there was a significant improvement in the experimental group compared to the control group in terms of positive motivation and engagement. It raises additional discussions. Although the students showed a positive trend, this result did not lead to an improvement in their grades. This fact questions the real impact of positive motivation and engagement in academic performance. It is also important to consider other possible influential factors, such as personality differences, teaching methods, and the use of immersive technologies, as well as the learning context.

Before the intervention, the respondents in both groups had almost identical results. The statistical differences were not significant ($p < 0.05$). The analysis and results of the data obtained from both tests led to the next stage of the present study. This stage presupposed identifying the specifics of immersive technologies for teaching and professional training in higher educational institutions.

The results of the study showed an increase in engagement and motivation in the experimental group. Nevertheless, there was no difference in academic achievement between the groups. It follows that the use of immersive technologies does not have a direct impact on academic scores, which are the main focus of educational institutions.

In addition, the authors note that for this study, it was "crucial" to consider well-being, health, and mental contraindications. At the same time, these aspects were not directly investigated. This statement means that there is no direct evidence or conclusions about the impact of immersive technologies on these aspects.

Academic achievements are the main criterion for success in many educational environments. Therefore, given these circumstances, the obtained results fail to confirm the effectiveness of immersion technologies. Additional research directly studying these aspects may be useful for a more objective assessment of the effectiveness of immersive technologies in teaching.

5. Discussion

Immersive technologies are a powerful and promising educational tool due to their unique features and capabilities that distinguish them

TABLE 3 Comparison of academic performance after the intervention in both groups.

Levels	Experimental group % (*N*)	Control group % (*N*)
A	11.1 (10)	11.1 (10)
B	23.3 (21)	25.6 (23)
C	41.1 (37)	40 (36)
D	25.5 (23)	23.3 (21)

TABLE 4 Comparison of the MES in both groups before the intervention.

Scales	Experimental group *n* = 90 M (SD)	Control group *n* = 90 M (SD)	*t*	*p*
Positive motivation	42.7 (5.61)	43.1 (5.66)	0.96	0.064
Positive engagement	46.1 (6.06)	45.8 (6.02)	0.972	0.061
Negative motivation	39.6 (5.20)	39.4 (5.18)	0.978	0.063
Negative engagement	38.3 (5.03)	37.9 (4.98)	0.843	0.059

$p < 0.5$; t is a Student's t-test; M is a mean value; SD is a standard deviation.

TABLE 5 Comparison of the MES in both groups after the intervention.

Scales	Experimental group *n* = 90 M (SD)	Control group *n* = 90 M (SD)	*t*	*p*
Positive motivation	68.8 (9.04)	45.8 (6.02)	2.12	0.035
Positive engagement	70.1 (9.29)	46.2 (6.07)	2.16	0.031
Negative motivation	32.4 (4.26)	35.1 (4.61)	0.43	0.668
Negative engagement	30.6 (4.02)	36.2 (4.77)	0.9	0.37

$p < 0.05$; t is a Student's t-test; M is a mean value; SD is a standard deviation.

from other IT applications. The integration of AR tools affects various fields of human activity. Researchers regard the great potential of this technology in terms of training, transforming pedagogical technologies, and creating ambitious integrated learning systems. The immersive approach, which involves using progressive techniques implemented in fundamentally new conditions, has a key role in this context (Kornilov, 2019).

The present research presupposed conducting a control assessment among study participants in both groups regarding their level of involvement and motivation using the MES test and comparing the results of their academic performance. Comparing the assessment results obtained before and after the intervention demonstrated the positive dynamics in the learning environment using immersive technologies. Academic performance and the level of motivation and involvement of students in the control group did not significantly change after the experimental period.

Consequently, the results obtained during the research indicate the effectiveness of using immersive technologies in the field of education. The positive dynamics of mean indicators, a high level of academic performance, involvement, and motivation in studying the selected subject among experimental group students after the intervention demonstrate immersive technologies' effectiveness. Thus, it is expedient to use immersive technologies in a modern educational environment to increase student training effectiveness by immersion in a multimedia environment. The conclusions of the present research comply with the study results provided by Johnston et al. (2018). The latter describes the results of the immersive learning introduction into the course program in cell biology. In particular, it regards the comparison of the academic performance within the relevant exam. Students who experienced the I-VR scored 5% more on the corresponding exam question (Cell Biology) compared to the rest of the exam questions. Those students who studied under the conventional program and did not experience I-VR scored 35% less on the same question.

The findings are consistent with a study conducted by Johnston et al. (2018) in the field of immersive learning. Their study compared the scores on the Cell Biology exam between students who used immersive virtual reality (I-VR) and those who completed a regular curriculum. According to the results, the I-VR students demonstrated a significant improvement.

Furthermore, some researchers conducted a study that lasted for several years (Ijaz et al., 2017). It was a pilot project initiated by the University of Sydney regarding the use of immersive VR technology in undergraduate and postgraduate studies. This study discussed the approach used to implement immersive VR for training specialists, the various stages of planning and applying innovative technologies, and conducting practical exercises. The project was divided into four stages. Minor motion sickness and problems with wearing glasses were among the expected issues that the study participants could undergo.

Thus, this study did not show a significant improvement in overall academic performance. Nonetheless, it is impossible to neglect the multifaceted benefits of immersive technologies that go beyond exam grades. Immersive technologies create a special learning environment that attracts students to a multimedia experience, contributing to deeper understanding and exploratory learning.

Researchers that studied immersive technologies as a means to foster procedural skills have demonstrated a clear advantage of those tools over traditional methods. For example, some researchers proved that engineering students assembled household appliances faster in the process of virtual functional analysis in VR (Ijaz et al., 2017), and medical students were more accurate in the practice of tying knots when using VR technology as a training tool (Morimoto and Ponton, 2021). Other researchers have paid attention to the study of immersion training as an educational tool for firefighting training in the operating room for medical and surgical purposes (Alvarez, 2021). The study showed that 70% of those who used VR training could successfully perform the aforementioned procedure in the correct order. Their result was 50% higher than in the control group, who had access only to presentations and reading materials.

Moreover, immersive technologies provide impressive grounds for further implementation in various forms of education. In Sri Lanka, researchers focused on examining Massive Open Online Courses (MOOCs) with VR support and the learning experience of students in comparison with conventional video-based MOOC training (Hewawalpita et al., 2018). The results and feedback from respondents indicate the high effectiveness of using VR content. The possibility of using AR tools during online learning was also in the study focus of some researchers (Pandey et al., 2022). Several studies emphasize the availability of technologies, unlimited exchange of resources, and flexibility in training and collaboration (Pandey et al., 2022).

Another study highlights the results of a cross-study regarding the positive impact of immersive technologies on students' academic success (Allcoat and von Mühlenen, 2018). Researchers affirmed that VR gives an advantage over learning from videos or textbooks when questions require memorization but do not relate to understanding the material. The authors suggest that the unfamiliarity and novelty of the multimedia environment may have contributed to the lack of obvious advantage in the latter area.

Nevertheless, several studies have not confirmed the obvious advantages of using immersive technologies compared to traditional pedagogical methods. In particular, the study of Moro et al. (2017) presupposed comparing the impact of AR tools with VR and 2D desktop videos on students studying natural science. The results did not show a clear advantage of learning based on AR when comparing the difference and significance of learning outcomes between selected environments. Similarly, another study proved that immersive tools are no more effective than online textbooks for teaching neuroanatomy (Stepan et al., 2017). Moreover, some researchers observed that students who used VR in a biology course received lower scores than those who studied using PowerPoint (Parong and Mayer, 2018).

The consistency of the studies mentioned in the above context with those considered in this study is that they also confirm the benefits of immersive technologies for learning. Researchers have identified the positive impact of immersive technologies on the development of procedural skills in various fields. For instance, studies conducted by Ijaz et al. (2017) and Morimoto and Ponton (2021) showed that engineering and medical students who used VR technologies demonstrated better results in working with equipment and surgical skills compared to traditional teaching methods.

The studies mentioned by Alvarez (2021), Hewawalpita et al. (2018), and Pandey et al. (2022) confirm the potential of immersive technologies in various forms of education. They highlight the effectiveness of VR and AR technologies in remote learning. The researchers also emphasized the availability of technologies, the exchange of resources, and the flexibility of training and cooperation.

Another study paid attention to the gender factor in the use of VR technologies during studying molecular biology in educational institutions in Singapore (Tan and Waugh, 2013). These researchers noticed a positive effect on the academic performance among male students compared to female students. The authors concluded that gender is an important factor in the design and versatility of the immersive VR experience. Despite that, their conclusions do not comply with the present study results, which did not reveal the influence of gender on the learning process using AR technologies.

Another study focused on identifying areas of the potential use of AR in pilot educational programs. Since the number of men prevails in many areas (in particular, complex industries and extreme professions), researchers considered gender preferences during this study (Schaffernak et al., 2020). The pilot training program used in that study presupposed the use of AR technology. Most respondents agreed that AR is an effective technology for theoretical and practical training. In addition, both gender groups demonstrated similar preferences for various immersive technologies. Research results have demonstrated that men are usually better at processing visual–spatial information, whereas women are better at processing verbal information. This research showed that there were no gender differences in three-dimensional tasks. Moreover, such differences decreased after training through two-dimensional tasks of visual–spatial mental rotation (Schaffernak et al., 2020). Another study confirmed the aforementioned results (Koglbauer, 2017). In this case, the researchers evaluated the training program based on professional simulators. As a result, they did not find any gender differences in terms of situational awareness and task performance, which included processing both visual–spatial and verbal information. The issues raised, inconsistencies, and contradictions (Allcoat and von Mühlenen, 2018; Parong and Mayer, 2018) became the motivating factors for the present research.

Thus, based on the set hypotheses, the study showed minor changes in the academic performance of both groups: the students moved from C to B level. Consequently, the results confirmed the hypothesis about the influence of immersive technologies on the level of professional competence. Given the limited number of participants and the influence of other factors, it is impossible to draw unambiguous conclusions about the impact of immersive technologies on grades. The first research objective required methodological and theoretical analysis. The other two were tested experimentally.

6. Conclusion

VR and AR open numerous opportunities for the educational system. Consequently, they can play an important role in fulfilling the tasks of this system and improve its quality. Immersive technologies can create more engaging, effective, and equitable learning environment. The growing interest of researchers in the field of education in identifying the hidden advantages and opportunities of AR and multimedia environments signals the beginning of a new era. Accordingly, it necessitates developing the relevant training and modifying the curricula to ensure long-term sustainability with an emphasis on the training accuracy.

The present research demonstrated the effectiveness of using immersive technologies in higher educational institutions. The dynamics of the study participants in the experimental group is significant since the initial results of high and average academic success increased from 30 to 53.3% (+23.3%), and high and low levels of engagement and motivation also increased by 21%. The academic performance results in the control group are less dynamic. The high and average level increased from 31.1 to 41.1% (+10%), and the values of high and average levels of motivation also increased only by 10%.

Thus, these results prove that academic performance, engagement level, and motivation among students in the experimental group significantly increased compared to the control group. It indicates the effectiveness of the practical implementation of immersive technologies into the system of training in complex industries and within the preparation of specialists for extreme professions.

Although the involvement and motivation of students from the experimental group have increased, the experiment did not reveal differences in academic achievements between the groups. Therefore, it cannot be argued that immersive technologies have a direct impact on grades, which are the main indicator of success in learning. In addition, the study did not directly examine aspects of well-being, health, and mental contraindications. Nevertheless, these factors were identified as crucial. To obtain more objective conclusions, there is a need for additional studies that will directly address these issues.

The new experimental data obtained under the present research and the analysis of previous modern experimental studies contributed to drawing relevant conclusions regarding the expediency and high efficiency of using the educational immersive technologies for training university students. The study findings offer valuable information and useful insights that can help practitioners in further decision-making and future actions in education. The examples presented in this research open the way for further studies and projects at both theoretical and practical levels. Future researchers may focus their attention on research into factors that increase student motivation through interactive learning.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The research was approved by the local ethics committees of I.M. Sechenov First Moscow State Medical University (Protocol no. 638 dated from 02/02/2022). The patients/participants provided their written informed consent to participate in this study.

Author contributions

ES: conceptualization, validation, investigation, data curation, writing – original draft, visualization, and writing – review & editing. EY: methodology, formal analysis, investigation, data curation, visualization, and writing – review & editing. GB: conceptualization, methodology, resources, writing – original draft, and writing – review & editing. FR: validation, formal analysis, resources, writing – original draft, and writing – review & editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abdallah, A. K., and Musah, M. B. (2021). Effects of teacher licensing on educators' professionalism: UAE case in local perception. *Heliyon* 7:e08348. doi: 10.1016/j.heliyon.2021.e08348

Abdraimova, E. T., Shoibekova, S. A., and Zhorabaev, K. B. (2020). Immersive technologies in a higher school in the modern digital reality. *EurasianUnionScientists* 1, 49–52. doi: 10.31618/esu.2413-9335.2020.1.79.1030

Acuña, A., and Melón, M. (2022). "Virtual learning environment for immersive teaching of the operation of high-risk equipment in architecture and industrial design workshops" in *In DS 117: Proceedings of the 24th international conference on engineering and product design education (E&PDE 2022)* (London: London South Bank University), 1–6.

Allcoat, D., and von Mühlenen, A. (2018). Learning in virtual reality: effects on performance, emotion and engagement. *Res. Learn. Technol.* 26:2140. doi: 10.25304/rlt.v26.2140

Alvarez, K. S. (2021). Using virtual simulations in online laboratory instruction and active learning exercises as a response to instructional challenges during COVID-19. *J. Microbiol. Biol. Educ.* 22, ev22i1–ev22i2503. doi: 10.1128/jmbe.v22i1.2503

Atanga, C., Jones, B. A., Krueger, L. E., and Lu, S. (2020). Teachers of students with learning disabilities: assistive technology knowledge, perceptions, interests, and barriers. *J. Spec. Educ. Technol.* 35, 236–248. doi: 10.1177/0162643419864858

Beck, F., Burch, M., Diehl, S., and Weiskopf, D. (2017). A taxonomy and survey of dynamic graph visualization. *Comput. Graph. Forum* 36, 133–159. doi: 10.1111/cgf.12791

Blyth, C. (2018). Immersive technologies and language learning. *Foreign Lang. Ann.* 51, 225–232. doi: 10.1111/flan.12327

Cheng, K.-H. (2022). Teachers' perceptions of exploiting immersive virtual field trips for learning in primary education. *J. Res. Technol. Educ.* 54, 438–455. doi: 10.1080/15391523.2021.1876576

Christopoulos, A., Conrad, M., and Shukla, M. (2018). Increasing student engagement through virtual interactions: how? *Virtual Real.* 22, 353–369. doi: 10.1007/s10055-017-0330-3

Darawsheh, S. R., Al-Shaar, A. S., Alshurideh, M., Alomari, N. A., Elsayed, A. M., Abdallah, A. K., et al. (2023). "The relation between creative leadership and crisis management among faculty members at imam Abdulrahman bin Faisal University in light of the Corona pandemic from the perspective of department heads" in *The effect of information technology on business and marketing intelligence systems* (Cham: Springer International Publishing), 1503–1514.

Di Cecca, C., Ciuffini, A. F., Ferrise, F., Mapelli, C., and Gruttadauria, A. (2016). Study about the augmented reality adoption in the maintenance in steelmaking area. *Metall. Ital.* 7, 11–16.

Dick, E.V. (2021). *The promise of immersive learning*. Information Technology and Innovation Foundation. United States

Drigas, A., Mitsea, E., and Skianis, C. (2022). Virtual reality and metacognition training techniques for learning disabilities. *Sustainability* 14:10170. doi: 10.3390/su141610170

Emmelkamp, P. M., and Meyerbröker, K. (2021). Virtual reality therapy in mental health. *Annu. Rev. Clin. Psychol.* 17, 495–519. doi: 10.1146/annurev-clinpsy-081219-115923

Gad, S., Nazarova, T., Rzanova, S., and Makar, S. (2022). Social workers' job satisfaction in public institutions. *SA J. Hum. Resour. Manag.* 20:a2127. doi: 10.4102/sajhrm.v20i0.2127

Hewawalpita, S., Herath, S., Perera, I., and Meedeniya, D. (2018). Effective learning content offering in MOOCs with virtual reality-an exploratory study on learner experience. *J. Univers. Comput Sci.* 4, 129–148.

Huang, K.-T., Ball, C., Francis, J., and Ratan, R. A. (2019). Augmented versus virtual reality in education: an exploratory study examining science knowledge retention when using augmented reality/virtual reality mobile applications. *Cyberpsychol. Behav. Soc. Netw.* 22, 105–110. doi: 10.1089/cyber.2018.0150

Ijaz, K., Marks, B., Gibbens, P., Thomas, J., and Hartley, T. (2017). "The immersive learning laboratory: employing virtual reality technology in teaching" in *In 28th annual conference of the Australasian Association for Engineering Education (AAEE 2017)*. eds. N. Huda, D. Inglis, N. Tse and G. Town (Sydney: Australasian Association for Engineering Education), 974–981.

Johnston, A. P., Rae, J., Ariotti, N., Bailey, B., Lilja, A., Webb, R., et al. (2018). Journey to the Centre of the cell: virtual reality immersion into scientific data. *Traffic* 19, 105–110. doi: 10.1111/tra.12538

Karakozov, S. D., Ryzhova, N. I., and Koroleva, N. Y. (2020). Virtual reality: the genesis of the concept and trends of use in education. *Comput. Sci. Educ.* 10, 6–16. doi: 10.32517/0234-0453-2020-35-10-6-16

Khan, A., Egbue, O., Palkie, B., and Madden, J. (2017). Active learning: engaging students to maximize learning in an online course. *Electron. J. e-Learn.* 15, 107–115.

Koglbauer, I. V. (2017). Forschungsmethoden in der Verbindung Gender und Technik: Research Methods Linking Gender and Technology. *Psychologie in Österreich* 37:354.

Kornilov, Y. V. (2019). An immersive approach in education. *Azimuth of Sci. Res: Pedagogy Psychol.* 8, 174–178.

Kumari, A., Tanwar, S., Tyagi, S., Kumar, N., Maasberg, M., and Choo, K. K. R. (2018). Multimedia big data computing and internet of things applications: a taxonomy and process model. *J. Netw. Comput. Appl.* 124, 169–195. doi: 10.1016/j.jnca.2018.09.014

Le Roy, B., Martin-Krumm, C., Pinol, N., Dutheil, F., and Trousselard, M. (2023). Human challenges to adaptation to extreme professional environments: a systematic review. *Neurosci. Biobehav. Rev.* 146:105054. doi: 10.1016/j.neubiorev.2023.105054

Li, X., Yi, W., Chi, H. L., Wang, X., and Chan, A. P. (2018). A critical review of virtual and augmented reality (VR/AR) applications in construction safety. *Autom. Constr.* 86, 150–162. doi: 10.1016/j.autcon.2017.11.003

Liem, G. A., and Martin, A. J. (2012). The motivation and engagement scale: theoretical framework, psychometric properties, and applied yields. *Aust. Psychol.* 47, 3–13. doi: 10.1111/j.1742-9544.2011.00049.x

Liou, W. K., and Chang, C. Y. (2018). "Virtual reality classroom applied to science education" in *In 2018 23rd international scientific-professional conference on information technology (IT)* (Zabljak, Montenegro: IEEE), 1–4.

Makransky, G., and Petersen, G. B. (2019). Investigating the process of learning with desktop virtual reality: a structural equation modeling approach. *Comput. Educ.* 134, 15–30. doi: 10.1016/j.compedu.2019.02.002

Morimoto, J., and Ponton, F. (2021). Virtual reality in biology: could we become virtual naturalists? *Evol. Educ. Outreach.* 14, 1–13. doi: 10.1186/s12052-021-00147

Moro, C., Štromberga, Z., Raikos, A., and Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anat. Sci. Educ.* 10, 549–559. doi: 10.1002/ase.1696

Mutlu-Bayraktar, D., Cosgun, V., and Altan, T. (2019). Cognitive load in multimedia learning environments: a systematic review. *Comput. Educ.* 141:103618. doi: 10.1016/j.compedu.2019.103618

Nussipova, G., Nordin, F., and Sörhammar, D. (2019). Value formation with immersive technologies: an activity perspective. *J. Bus. Ind. Mark.* 35, 483–494. doi: 10.1108/JBIM-12-2018-0407

Pandey, D., Ogunmola, G. A., Enbeyle, W., Abdullahi, M., Pandey, B. K., and Pramanik, S. (2022). COVID-19: a framework for effective delivering of online classes during lockdown. *Hum. Arenas* 5, 322–336. doi: 10.1007/s42087-020-00175-x

Parong, J., and Mayer, R. E. (2018). Learning science in immersive virtual reality. *J. Educ. Psychol.* 110, 785–797. doi: 10.1037/edu0000241

Pellas, N., Mystakidis, S., and Kazanidis, I. (2021). Immersive virtual reality in K-12 and higher education: a systematic review of the last decade scientific literature. *Virtual Real.* 25, 835–861. doi: 10.1007/s10055-020-00489-9

Proctor, R. W., and Van Zandt, T. (2018). *Human factors in simple and complex systems* CRC Press.

Qushem, U. B., Christopoulos, A., Oyelere, S. S., Ogata, H., and Laakso, M. J. (2021). Multimodal technologies in precision education: providing new opportunities or adding more challenges? *Educ. Sci.* 11:338. doi: 10.3390/educsci11070338

Reinke, N. B., Kynn, M., and Parkinson, A. L. (2021). Immersive 3D experience of osmosis improves learning outcomes of first-year cell biology students. CBE life. *Sci. Educ.* 20:ar1. doi: 10.1187/cbe.19-11-0254

Rutledge, C., Hawkins, E. J., Bordelon, M., and Gustin, T. S. (2020). Telehealth education: an interprofessional online immersion experience in response to COVID-19. *J. Nurs. Educ.* 59, 570–576. doi: 10.3928/01484834-20200921-06

Schaffernak, H., Moesl, B., Vorraber, W., and Koglbauer, I. V. (2020). Potential augmented reality application areas for pilot education: an exploratory study. *Educ. Sci.* 10:86. doi: 10.3390/educsci10040086

Sirakaya, M., and Alsancak Sirakaya, D. (2018). Trends in educational augmented reality studies: a systematic review. *Malays. Online J. Educ. Technol.* 6, 60–74. http://dx.doi.org/10.17220/mojet.2018.04.005

Slater, M., and Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Front. Robot. AI* 3:74. doi: 10.3389/frobt.2016.00074

Sopher, H., Fisher Gewirtzman, D., and Kalay, Y. E. (2019). Going immersive in a community of learners? Assessment of design processes in a multi-setting architecture studio. *Br. J. Educ. Technol.* 50, 2109–2128. doi: 10.1111/bjet.12857

Stanney, K., Lawson, B. D., Rokers, B., Dennison, M., Fidopiastis, C., Stoffregen, T., et al. (2020). Identifying causes of and solutions for cybersickness in immersive technology: reformulation of a research and development agenda. *Int. J. Hum. Comput. Interact.* 36, 1783–1803. doi: 10.1080/10447318.2020.1828535

Stepan, K., Zeiger, J., Hanchuk, S., Del Signore, A., Shrivastava, R., Govindaraj, S., et al. (2017). Immersive virtual reality as a teaching tool for neuroanatomy. *Int. Forum. Allergy Rhinol.* 7, 1006–1013. doi: 10.1002/alr.21986

Suleimenov, I. E., and Tasbulatova, Z. S. (2018). The principles of using artificial intelligence in Kazakhstan higher school. *Sci Tech Society "KAHAK"* 4, 55–62.

Tan, S., and Waugh, R. (2013). "Use of virtual-reality in teaching and learning molecular biology" in *3D immersive and interactive learning*. ed. Y. Cai (Singapore: Springer), 17–43. doi: 10.1007/978-981-4021- 90-6_2

Tchaikovsky, D. S., and Izotova, V. F. (2020). The impact of AR and VR technologies on the educational process. *Inf. Technol. Educ.* 3, 316–319.

Thompson, M. M., Wang, A., Uz Bilgin, C., Anteneh, M., Roy, D., Tan, P., et al. (2020). Influence of virtual reality on high school students' conceptions of cells. *J. Univers. Comput. Sci.* 26, 929–946. doi: 10.3897/jucs.2020.050

Zhao, H., Zhao, Q. H., and Ślusarczyk, B. (2019). Sustainability and digitalization of corporate management based on augmented/virtual reality tools usage: China and other world IT companies' experience. *Sustainability* 11:4717. doi: 10.3390/su11174717