The Effectiveness of Using Virtual and Augmented Reality Technologies for Teaching Computer Science in Schools

Nursaule Karelkhan and Nurgul Uderbayeva*

Computer Science Department, Faculty of Information Technology, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan
Email: karelkhan_n@enu.kz (N.K.); uderbaeva.n@kineu.kz (N.U.)
*Corresponding author

Manuscript received June 2, 2024; revised June 20, 2024; accepted August 13, 2024; published November 15, 2024

Abstract**—Currently, using new technologies in education provides great opportunities for schools. This research aims to determine the effectiveness of using Virtual reality and Augmented reality technologies for teaching Computer science in schools. Furthermore, using Virtual and Augmented Reality in teaching computer science has been proposed as a pedagogical approach. The article theoretically analyzes the use of virtual reality and augmented reality technologies, and determines the effectiveness of practical applications of Virtual reality created in the Unity environment, as well as Augmented reality created in the Vuforia environment for teaching Computer science at school with the non-parametric method of Pearson's chi-squared. Workbooks and digital educational materials for teaching computer science have been produced in the pedagogical model's methodological section. The participants of the research were students from schools in the Republic of Kazakhstan, whose total number was 151. They were divided into two groups: a control one and an experimental one. For teaching students in the control group, only traditional educational materials were used, while students in the experimental groups took part in the experiment involving the use of Virtual and Augmented reality applications. At the end of the research, both groups were assigned a test according to three motivational, content, and technical categories, which enabled them to compare the results. As a result, the effectiveness of using virtual reality and augmented reality to teach Computer Science to students at school was determined with the non-parametric method of Pearson's chi-squared. Compared to traditional teaching methods, research has demonstrated that virtual and augmented reality helps students learn computer skills better. This has led to improvements in motivation, content comprehension, and technical proficiency in computer science education in schools.**

Keywords**—augmented reality, school, teaching computer science, unity, virtual reality**

I. Introduction

The increasing significance of digitalization in various spheres of society, including education, is obvious. A great range of devices, comprising computers, televisions, and smartphones, enables individuals to access a considerable amount of information. However, the representatives of modern society are becoming less satisfied with the opportunities these pieces of technology can provide, which prompts them to search for new approaches to obtaining information. Such technological tools as Virtual Reality (VR) / Augmented Reality (AR) promote digital literacy, creative thinking, communication, collaboration, and problem-solving abilities. VR/AR improves traditional curricula to meet the diverse learning needs of students [1]. Augmented reality is an advanced and effective way for people to learn. The learning theory allows the users to attempt to explain human behavior by understanding cognition [2]. These days, Virtual reality and Augmented reality have begun to be applied to obtain information by encountering new sensory experiences.

Virtual Reality (VR) is becoming increasingly accessible and being utilized in various organizations to meet education and training needs [3]. Immersive Virtual Reality (IVR) applications that assist students in learning have become the subject of increasing interest. However, empirical studies exploring the educational potential of using IVR in primary school science classrooms are presented in the volume which does not completely cover the needs of modern schools [4]. Using AR applications, children interact with 3D models, through which they enhance their creativity and collaboration in teams [5]. Modern children quickly adapt to new information technologies in everyday life and show great interest. Therefore, Virtual reality and Augmented reality can be used as new teaching methods.

People's demands for education are growing as a result of the ongoing acceleration of information technologies, and instructors' teaching methods should be adjusted in response to students' various learning styles to adapt to the demands and changes of the times [6]. According to the concept of the development of preschool, secondary, technical, and vocational education in the Republic of Kazakhstan from 2023 to 2029, Modernization of digital infrastructure (updating the computer park, developing multimedia and interactive teaching tools, creating training management systems, carrying out international certification) and development of digital skills of personnel (certified training) measures will be worked out. The necessity for the introduction of innovative methods of teaching subjects and transferring educational materials to a digital format has been claimed.

International Computer and Information Literacy Study (ICILS, 2018) is a large-scale international assessment of computer and information literacy and computational thinking skills. According to the results of this ICILS-2018 study, the Republic of Kazakhstan demonstrates the lowest indicators, so improving the knowledge, skills, and abilities of computer and information literacy and computational thinking skills in the country beginning from schools appears to be significant [7]. The collection of research papers authored by such prominent researchers as Stavroulia & Lanitis provides a comprehensive overview of the growing importance of using Virtual Reality (VR) in education [8]. In the paper *Teaching Knowledge Sharing in Virtual Practice Teaching* the authors construct a knowledge-sharing model of virtual practice teaching based on the traditional evolutionary game and analyze the local stability of the

doi: 10.18178/ijiet.2024.14.11.2187

model based on the Jacobin Matrix. Experimental results verify the effectiveness of the model [9]. According to the authors of the paper *Virtual Classroom Usage and User Perception for English Learning as a Second Language at Universities in Lima*, virtual education provides a knowledge transfer opportunity for students using teaching-learning processes supported by various strategies that encourage studying so that students can learn or teach through this learning system [10]. The studies delve into various aspects of VR and AR integration in education, ranging from the development of knowledge-sharing models in virtual practice teaching to the exploration of virtual classroom usage for language learning. Martin & Meneses [11] highlight the motivational impact of technological tools on engineering students, while Eman *et al.* [12] discuss the potential of virtual education in developing countries. Additionally, Dirin *et al.* [13] present findings on the design of emotionally engaging collaborative learning experiences with VR.

The current thematic plan for the subject "Computer science" does not include topics that are relevant to the use of technology to encourage students' interest in learning it. Therefore, it promotes the necessity for applying modern technologies, which increases students' concern in above mentioned subject. According to the decree approved by the order of the Minister of Education of the Republic of Kazakhstan in 2022, "In the model curricula of general education subjects for general educational organizations, elective courses of, basic secondary and general secondary education levels" a "Museum Trip" (virtual or real) theme is included in the subject "Fine Art" for the 1st grade of the education level. Studying the English language in 10^{th}–11^{th} grades also includes topics related to virtual reality. In the computer science subject, the topic of familiarization with virtual and actual reality is considered in the topic of 3D modeling only in 11^{th} grade.

This research explains the significance of using VR and AR technologies across various disciplines and indicates the reasons why the fundamental ideas and techniques for applying Virtual reality and Augmented reality should be taught in Computer science classes at school. Despite numerous studies focusing on assessing the efficiency of using Virtual Reality (VR) and Augmented Reality (AR) applications in teaching some subjects, similar research within computer science in schools has not been conducted. Therefore, the effectiveness level of the implementation of these technologies has not yet been revealed.

This research aims to determine the effectiveness of using virtual reality and augmented reality technologies for teaching Computer science in schools.

To achieve the aim, the following objectives were set:

1) Determination of theoretical analysis of using Augmented and Virtual reality in teaching Computer science in education.
2) Determination of the effectiveness using the non-parametric method of Pearson's chi-squared of applying Virtual reality and Augmented reality for teaching Computer science at school.

The research method is quantitative, because hypotheses are tested with the use of the non-parametric method of Pearson's chi-squared test, and the interconnection between variables based on existing theories is explored.

II. Literature Review

The use of Augmented and Virtual reality at school is becoming more widespread all over the world. This is especially true for countries that have a developed technological infrastructure, for instance, the United States of America, the United Kingdom of Great Britain and Northern Ireland, China, Germany, Japan, South Korea, and France. In these countries, Augmented and Virtual realities are the tools that are often employed while teaching Physics, Chemistry, Biology, and History classes at the secondary and high school levels.

Currently, numerous research papers have proved the effectiveness of using VR and AR in various educational contexts, including Mathematics, Chemistry, Digital Graphic Design, and Language learning. The findings of the study titled *Effect of AR and Simulation on the Achievement of Mathematics and Visual Thinking Among Students* showed that students who used the augmented reality mode showed significantly better achievements and more highly developed visual thinking skills than those in the simulation mode [14]. The results demonstrated that virtual lab simulation in Chemistry contributed to a positive effect on learning achievements, self-efficacy, and learning experience. Students who attended a traditional lecture, followed by the virtual lab simulation, had significantly higher levels of knowledge and self-efficacy scores than those learning through only a traditional lecture [15]. The implementation of Virtual and Augmented reality technologies in education promotes interactivity and students' interest in learning Mathematics, contributing to more efficient understanding of mathematical concepts, when compared to traditional teaching methods [16]. The teacher-student relationship in the virtual Digital Graphic Design teaching environment can be illustrated by a directed, unweighted graph, where nodes represent the teacher and students, and edges teacher-student relationships in the virtual teaching environment [17]. Applying Virtual reality to the educational process is associated with the improvement in students' speaking skills; along with considering as an entertaining and exciting learning experience for both students and teachers [18]. The results indicate that Augmented reality-based writing exercises can enhance students' motivation for writing, which may result in improved performance [19]. Overall, this compilation of research underscores the transformative potential of VR and AR technologies in reshaping pedagogical practices and improving learning outcomes across diverse subjects and educational levels.

Today, only leading universities in Kazakhstan conduct their teaching with the use of Virtual reality and Augmented reality technologies. There are also scientists of the Republic of Kazakhstan who address the problem of implementation of Augmented reality (AR) and Virtual reality (VR) teaching, in particular, in the following works: "On the Issue of Compliance with Didactic Principles in Learning using Augmented Reality [20]", "Solving Tourism Management Challenges by Means of Mobile Augmented Reality Applications [21]" "The educational content and methods for big data courses including big data cluster analysis [22]", "The Role of Adaptive Personalized Technologies in the Learning Process: Stepik as a Tool for Teaching Mathematics [23]". Analysis of scientific literature and Internet resources shows that Virtual reality and Augmented reality courses are being implemented in the educational programs of the world's leading schools.

At present, in the Republic of Kazakhstan, Augmented Reality (AR) and Virtual Reality (VR) technologies are used at NUR Lab, which is equipped with Space technology, at Nazarbayev Intellectual School and School-Lyceum No. 73 in the city of Astana. These technologies are applied in Science, Math, and Anatomy classes in above mentioned schools. In addition, the "BIG DREAM LAB" company has opened virtual reality labs for Physics, Chemistry, and Biology classes in Astana schools, which are used in the education process. However, currently, there are no educational and methodological tools available to teach computer science in Kazakhstan using augmented and virtual reality.

Using augmented and virtual reality to teach computer science in schools is a promising approach. It leverages innovative methods to facilitate more effective learning in today's information-driven society. While not yet widely adopted, it holds the potential to generate interest among school-aged children. However, when using virtual reality glasses in the classroom, children should not use them excessively, the time limits should be determined according to the age of participants.

III. Materials and Methods

By the next objective of the study, the following work was carried out to create a methodology for using Virtual reality and Augmented reality in teaching Computer science and the practical basis for its implementation in the educational process in schools. In general, the work was performed according to the following pedagogical system Fig. 1:

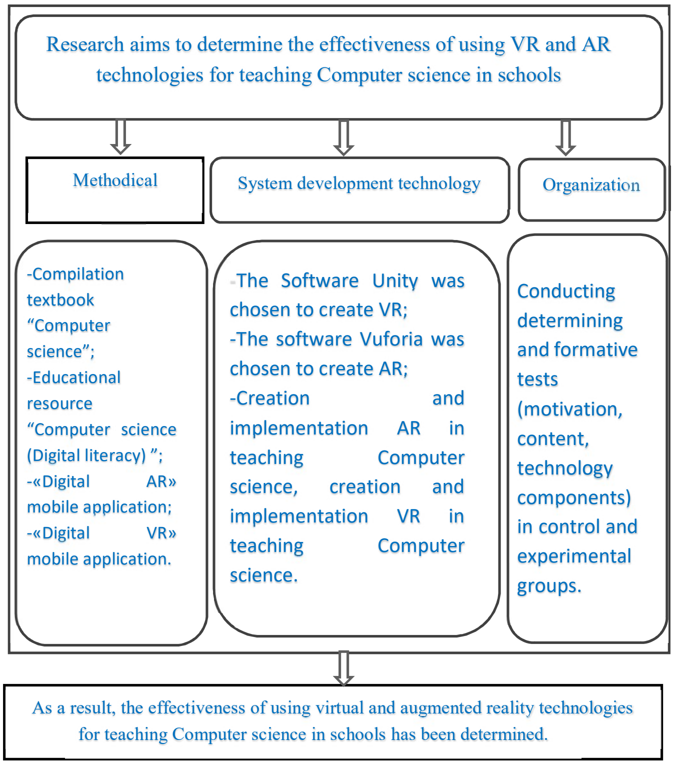

Fig. 1. The pedagogical model for using virtual reality and augmented reality for teaching computer science in schools.

In the research, a total number of 151 students from the schools of the Republic of Kazakhstan participated. They were divided into two groups: 72 school pupils from N. Naushabayev School-Gymnasium made up the control group, and 79 school pupils from the Zarechny school in Kostanay region (Kostanay oblast) were the members of the experimental group. Students in the control group used only traditional educational materials, while students in the experimental groups took part in the experiment by using the textbook "Computer Sciences" with Virtual Reality and Augmented Reality applications. At the final of the experiment, the results in both groups were compared with the assistance of the questionnaire. The questionnaire was used to evaluate the level of knowledge, and a Pearson criterion was used to measure effectiveness.

The textbook "Computer Science" and online instructional materials were created by the authors to teach Computer Science with VR and AR to pupils. Themes of lessons using VR technologies in the textbook "Computer Science" are the following:

1) Acquaintance with safety equipment
2) Robotics
3) Implementation of the algorithm

The instructions for using Virtual reality, uploaded on YouTube, can be received by scanning the QRcode (Fig. 2) on the smartphone, or by following the link: https://m.youtube.com/watch?v=X5_yDxRlTRE&feature=youtu.be. The lesson aims to cover the fundamentals of computer security and the historical evolution of robotics through the visualization of different robot generations.

Fig. 2. Virtual reality in teaching computer science.

The conduction of the experiment was essential to evaluate the efficacy of this educational method while instructing school pupils in the subject "Computer Science". Authors of the textbook and digital educational materials on Computer Science for schools have determined that such pieces of software as Blender, Unity, Unity3d, SketchUp, and Vuforia are now used to develop Virtual reality and Augmented reality technologies. We chose Unity for virtual reality production and Vuforia for augmented reality creation for practical use, considering the specific needs of computer science.

An example in the textbook supplemented by topics in the subject "Computer Science" and created using virtual reality technologies is taken into account to ascertain the practical features of the use of Virtual reality and Augmented reality technologies in teaching the subject “Computer Science” in schools. In the given example, the student wears Virtual reality glasses and familiarizes himself with the operating menu in a virtual room (scene). When turning the left hand, the student can see several topics (menu) and can change its language to Kazakh or Russian. Using Augmented and Virtual reality technologies he can learn about algorithms, security techniques, robots, the history of their development, and other options in the menu. Another beneficial alternative is the possibility for a student to approach robots and use teleportation to move. In this virtual environment, it is also possible for a student to manually pick up objects and place them elsewhere.

Themes of lessons using AR technologies in the textbook “Computer Science” are presented below:

1) Computer devices
2) Keyboard simulator
3) Sound recording and playback devices
4) Robotics: sensors

Scanning the QR presented in Fig. 3 with a smartphone camera allows viewing of augmented reality created by the authors. This can be done by downloading the App on Android OS and following the AR project created in Vuforia and Unity. Theme of lesson: Sound recording and playback devices. The lesson aims to introduce Audio Recording and Playback Devices.

Fig. 3. Augmented reality in teaching computer science.

These methods can be used to construct examples of employing Virtual reality and Augmented reality technologies created in the Unity software in Computer science teaching. Also, an example of how to construct AR using Vuforia has been demonstrated above.

IV. Result

To assess the efficacy of Augmented reality and Virtual reality in teaching computer science, a questionnaire was distributed to all 151 participants (Table 1) once the experiment was finished.

Table 1. Data from the participants of the experiment

School name	Experimental group	Control group	Number of participants
N. Naushabayev School-Gymnasium in Kostanay district of Kostanay region (Kostanay oblast)	38	34	72
Zarechny secondary school in Kostanay region (Kostanay oblast)	42	37	79
Total	80	71	151

Table 2. The questionnaire questions are divided into three categories to assess the student’s level

Motivation component	Content component	Technical component
Identification of increased interest among pupils through the use of augmented and virtual reality technology in the subject of “Computer Science”	To determine the level of understanding and mastery of content related to the subject “Computer Science”, using augmented and virtual reality technology.	Determining the qualification of using virtual reality (VR) glasses and software with augmented reality (AR) technology.
	Questionnaire questions	
1. Do you use your smartphone for learning purposes? 2. Have you heard about augmented reality (AR)? 3. Have you ever experienced virtual reality (VR)? 4. Is the topic of digital literacy of interest to you? 5. Would you like to use VR/AR technology for learning purposes?	1. What is an algorithm? 2. Name the types of algorithms based on the flowchart shown in augmented reality. 3. View the output devices of your computer through virtual reality and name each device. 4. Look at the input devices of your computer through augmented reality and name each one. 5. View the details of Mindstorms in augmented reality and name each component.	1. What technology is shown in this figure? 2. Can you see an object that is not near you through glasses? 3. What is the name of the technology that allows the user to see the device in the tutorial using a mobile phone? 4. Choose the correct definition of Augmented Reality (AR) technology. 5. Choose the correct definition for Virtual Reality (VR) technology.

The results of the survey were analyzed according to three main categories: motivational, content, and technical. To assess the effectiveness of this model, we analyzed the results of the study through the compilation of questionnaire questions based on three categories (Motivation component, Content component, and Technical component) presented in Table 2. Each component received a questionnaire containing 5 questions.

To measure motivation, we first conducted classes in an experimental group with VR and AR technologies implementation, and at the final stage of the lesson, the test to measure motivation was conducted. The frequency of low-level scores ranges from 0 to 49, medium scores from 50 to 84, and high scores from 85 to 100 (Table 3), theoretical frequency distribution table (Table 4), and summary table (Table 5).

Table 3. Motivation component. Empirical frequency table

Groups	Number of Participants	Low level	Average level	High level
Control group	79	45	23	11
Experimental group	72	18	37	17
Total	151	63	60	28

The second category is the Content component (Table 6–8). The frequency of low-level scores ranges from 0 to 49, medium scores from 50 to 84, and high scores from 85 to 100.

Table 4. Motivation component. Theoretical frequency distribution table

Groups	Low level	Average level	High level	Total
Control group	(63·79):151=33	(60·79):151 =31.4	(28·79):151 =14.6	79
Experimental group	(63·72):151=30	(60·72):151 =28.6	(28·72):151=13.4	72
Total	63	60	28	151

Table 5. Motivation component. Summary table

Groups	Levels	Empirical	Theory	$(E\text{-}T_{cr})^2/T_{cr}$
Control group	Low level	45	33	4.36
	Average level	23	31.4	2.25
	High level	11	14.6	0.89
Experimental group	Low level	18	30	4.80
	Average level	37	28.6	2.47
	High level	17	13.4	0.97
Total (X^2 Motivation)				15.73

Table 6. Content component. Empirical frequency table

Groups	Number of Participants	Low level	Average level	High level
Control group	79	43	28	8
Experimental group	72	16	39	17
Total	151	59	67	25

Table 7. Content component. Theoretical frequency distribution table

Groups	Low level	Average level	High level	Total
Control group	(59·79):151=30,86	(67·79):151=35.05	(25·79):151=13,1	79
Experimental group	(59·72):151=28,14	(67·72):151=31.95	(25·72):151=11,9	72
Total	59	67	25	n=151

Table 8. Content component. Summary table

Groups	Levels	Empirical	Theory	$(E\text{-}T_{cr})^2/T_{cr}$
Control group	Low level	43	30.86	4.78
	Average level	28	35.05	1.42
	High level	8	13.1	1.99
Experimental group	Low level	16	28.14	5.24
	Average level	39	31.95	1.56
	High level	17	11.9	2.19
Total (X^2 Content)				17.19

The third category is the Technical component (Table 9–11). The frequency of low-level scores ranges from 0 to 49, medium scores from 50 to 84, and high scores from 85 to 100.

Table 9. Technical component Empirical frequency table

Groups	Number of Participants	Low level	Average level	High level
Control group	79	48	24	7
Experimental group	72	19	37	16
Total	151	67	61	23

Table 10. Technical component Theoretical frequency distribution table

Groups	Low level	Average level	High level	Total
Control group	(67·79):151 =35.1	(61·79):151 =31.9	(23·79): 151 =12	79
Experimental group	(67·72):151 =31.9	(61·72):151 =29.1	(23·72): 151=11	72
Total	67	61	23	151

Table 11. Technical component. Summary table

Groups	Levels	Empirical	Theory	$(E\text{-}T_{cr})^2/T_{cr}$
Control group	Low level	48	35.1	4.74
	Average level	24	31.9	1.96
	High level	7	12	2.08
Experimental group	Low level	19	31.9	5.22
	Average level	37	29.1	2.14
	High level	16	11	2.27
Total (X^2 Technical)				18.41

While comparing the research results of pedagogical studies, the non-parametric method Pearson's chi-squared [24] was used to determine the difference between control and experimental groups:

$$\chi 2 = \frac{\sum\left|(Fe-Fb)^2\right|}{Fb} \qquad (1)$$

where,

Fe is the relative frequency of the data interval of the Experimental group;

Fb is the relative frequency of the data interval of the Control group.

df = (*R*-1)×(*C*-1), where R is the number of rows in the table and *C* is the number of columns. In our case, we have a certain number of degrees of freedom (3-1)×(3-1)=4. The level of significance that we pursue to maintain is 0.05. Referring to the table for the value of the Pearson's chi-square test, χ^2_{kr}=9,49. In our case, the control values were calculated as follows.

$$\chi 2_{Motivation}=15.73>9.49$$
$$\chi 2_{Content}=17.19>9.49$$
$$\chi 2_{Technical}=18.41>9.49$$

When selecting the control and experimental groups, a *Quota sampling* method was used, as the authors had specifically selected schools of the Kostanay region which were remote from the district center. Conduction of the experiment with schoolchildren was permitted by the ethics committee (a copy of the document in English is attached). To *calculate* the sample size using the Pearson criterion, a minimum of 30 participants was required, and in this study, the number of participants was 151.

For *control of confounding variables* Hypothesis in Pearson's chi-squared, Fig. 4:

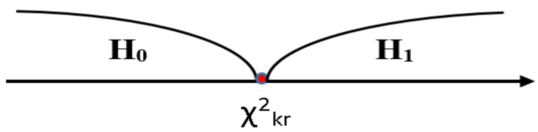

Fig. 4. Hypothesis in Pearson's chi-squared.

H_0: there is no correlation between the independent variable and the dependent variable.

H_1: there is a correlation between the independent and dependent variables.

Decision-making basis: If the value $\chi 2_{\text{Motivation}} > \chi^2_{kr}$, $\chi 2_{\text{Content}} > \chi^2_{kr}$, $\chi 2_{\text{Technical}} > \chi^2_{kr}$ H_0 rejected and H_1 accepted, else H_0 accepted and H_1 rejected. Therefore, we can conclude that the hypothesis proposed by Pearson's chi-squared test has been supported. In this experiment, a Google form was used to conduct the survey. The results of the study were analyzed based on the three categories: motivation, content, and technical readiness, presented in Table 12 and Fig. 5.

Table 12. Results of the experiment

Components and indicators of learners' desire to determine the effectiveness of VR and AR in teaching CS	Low level		Average level		High level	
	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group
	%	%	%	%	%	%
Motivation component	25	57	51.4	29.1	23.6	13.9
Content component	22.2	54.4	54.2	35.4	23.6	10.1
Technical component	26.4	60.8	51.4	30.4	22.2	8.9

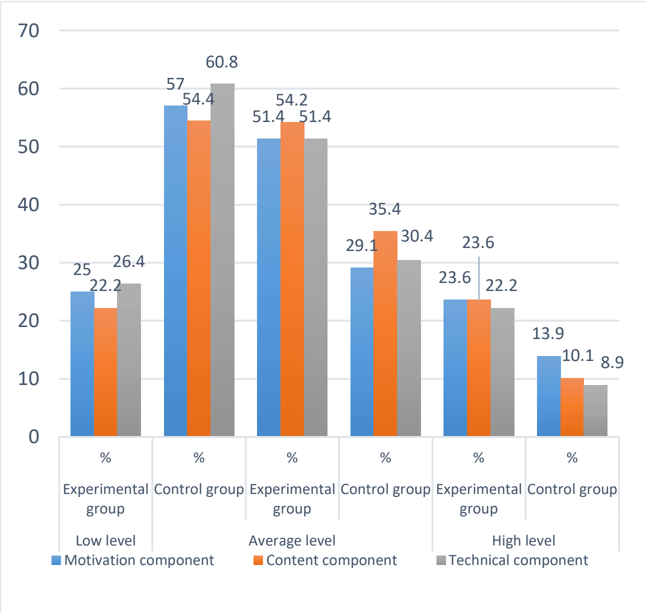

Fig. 5. Results of the experiment.

V. Discussion

Based on the survey findings, the experimental group of students agreed that the use of AR or VR applications in computer science lessons is highly engaging for them. Additionally, the students confirmed that VR/AR technology in computer science lessons promotes long-term retention of course content and technical dimensions. Students who used VR/AR technology in Computer Science class tended to achieve higher grades than students who did not use it. Although some students in the experimental group scored low, the number of low scores in the control group was significantly higher. Additionally, it should be noted that the average and high scores in the experimental group are significantly higher than those in the control group. Participants showed increased engagement and comprehension across motivational, content, and technical dimensions when engaged in AR and VR experiences, as compared to traditional learning methods.

The χ^2 value (15.73, 17.19, 18.41) for the motivational, content, and technological components exceeds the χ^2 value found at 9.49. Based on the study findings and compared research results of pedagogical studies Pearson's chi-squared, the efficiency of employing the pedagogical method for teaching computer science in schools and the accuracy of the scientific premise of our research effort were determined. The data collected revealed a significant potential for using virtual and augmented reality in teaching computer science at schools. This supports previous research findings on the impact of these technologies on student learning.

Similar studies have demonstrated the effectiveness of AR and VR in teaching subjects such as mathematics, chemistry, and physics at school. For instance, in physics teaching, mobile augmented reality technology makes the learning environment more interesting by visualizing abstract concepts in 3D simulations [25]. Additionally, AR has been recommended for use in the school mathematics curriculum to improve students' mathematical literacy [26]. Training courses can provide both teachers and pupils with the skills and knowledge needed to incorporate augmented reality in the learning environment [27]. VR and AR can bridge the gap between theoretical knowledge and real-world application, enhancing conceptual understanding, presenting information in 3D and 4D interactive experiences, and facilitating practical learning [28]. These technologies enable practical learning and make complex subjects, such as chemistry, more tangible and engaging for students, thereby improving their overall learning experience [29]. AR was found to promote kinesthetic (tactile) learning, enhance interactivity, facilitate students' engagement and participation, improve satisfaction with learning and outcomes, and encourage collaborative learning, among other benefits [30]. The study results are in line with previous research [25–30] emphasizing the positive impact of VR/AR technology on the academic performance of students. The findings of this study highlight the significant benefits of using augmented and virtual reality in education, particularly in the field of computer science. Empirical evidence supports the use of AR and VR technologies to enhance outcomes, suggesting that school children gain a deeper understanding of computer science principles and develop their technical skills through hands-on, practical learning approaches.

Additionally, users should be familiarized with some recommendations and important limitations when using virtual and augmented reality apps with children: Augmented reality applications should be applied in a supervised and controlled manner when used with children [31]. The Virtual Reality Health & Safety Usage Guide recommends that Class VR be used for no more than 15 minutes in any lesson. In this experiment, students were allowed to use virtual reality glasses for no more than 10–15 minutes. Therefore, virtual reality is often used in education as a tool to study realistic observations under controlled conditions, focusing on short-term effects lasting up to 15 minutes. These data emphasize how important it is for teachers to inform students about comments and suggestions regarding the use of these technologies.

Based on the findings of these studies, it can be concluded that, like in other fields, the use of augmented reality VR/AR technology in computer science teaching will be both interesting and effective in practice. As students' knowledge levels increased, their academic performance improved, leading to an overall increase in achievement and success. Additionally, the study found that the use of virtual and augmented reality in computer science classes can positively affect students' academic achievements, indicating the students' willingness to engage with these technologies through their active participation in classroom activities. Therefore, educators need to incorporate these tools into their teaching methods and encourage students to use them. The future of VR/AR technology in education appears promising, with emerging trends indicating a significant shift in the approach to learning and teaching.

VI. Conclusion

To accomplish the aim of identifying the effectiveness of using Virtual reality and Augmented reality technologies for teaching Computer science at schools, the following objectives were completed:

1) Theoretical analysis of literature on the implementation of Augmented and Virtual reality in Computer science teaching in schools was conducted. As a result, a pedagogical model based on an analysis of the features and experiences of using these technologies in the educational process in leading countries of the world was developed.
2) To determine the practical basis for using Augmented and Virtual reality in teaching computer science at school, we compiled the following materials: the textbook "Computer Science" [32], the educational resource "Digital Literacy", the mobile application "Digital AR" and the "Virtual Reality" application. Taking into account the specifics of the subject matter of Computer science and the creation of Augmented reality and Virtual reality technologies, we opted for the Unity and Vuforia programs for the development of virtual reality. The findings of the study were presented in tables and diagrams, and the conducted experiment was aimed at evaluating the effectiveness of the pedagogical approach with the use of Virtual and Augmented reality technologies for teaching Computer science in schools in the Republic of Kazakhstan. The effectiveness of using virtual and augmented reality technologies to teach computer science in schools using Pearson's chi-square criterion has been confirmed.

For the implementation of Virtual Reality (VR) in Computer Science (CS) workbooks VR glasses are required, along with smartphone devices which are necessary for using Augmented Reality (AR). In the future, the textbook "Computer Science", the Educational resource "Computer Science (digital literacy", the mobile application "Digital AR" and, "Digital VR" application and the online resources used in the project will be available in all schools in Kazakhstan.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Uderbayeva N. drafted the initial manuscript and conducted all the experiments. Karelkhan N. provided supervision of the research and provided insights into designing the experiment. All authors had approved the final version.

References

[1] G. Papanastasiou, A. Drigas, C. Skianis, M. Lytras, and E. Papanastasiou, "Virtual and augmented reality effects on K-12, higher, and tertiary education students' twenty-first-century skills," *Virtual Reality,* vol. 23, no. 4, pp. 425–436, 2019. doi:10.1007/s10055-018-0363-2

[2] B. Parhizkar, K. Oteng, O. Ndaba, A. H. Lashkari, and Z. M. Gebril, "Ubiquitous mobile real time visual translator using augmented reality for bahasa language," *International Journal of Information and Education Technology* vol. 3, no. 2, pp. 124–128, 2013.

[3] M. Yoon, K. Choi, S. Yoon, and I.-H. Jo, "Task type matters: The impact of virtual reality training on training performance," *Journal of Computer Assisted Learning,* vol. 40, no. 1, pp. 205–218, 2024. https://doi.org/10.1111/jcal.12874

[4] R. Liu, L. Wang, T. A. Koszalka, and K. Wan, "Effects of immersive virtual reality classrooms on students' academic achievement, motivation, and cognitive load in science lessons," *Journal of Computer Assisted Learning*, vol. 38(5, pp. 1422–1433, 2022. https://doi.org/10.1111/jcal.12688

[5] A. M. F. Yousef "Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school," *J Comput Assist Learn*. vol. 37, pp. 966–77. 2021. https://doi.org/10.1111/jcal.12536

[6] Y Jia and R. Qi, "Influence of an immersive virtual environment on learning effect and learning experience," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 18, no. 6, pp. 83–95, 2023. doi: 10.3991/ijet.v18i06.37815

[7] IEA. ICILS 2018 results. (2018). [Online]. Available: https://www.iea.nl/news-events/news/icils-2018-results

[8] K. E. Stavroulia and A. Lanitis, "Enhancing reflection and empathy skills via using a virtual reality-based learning framework," *International Journal of Emerging Technologies in Learning (iJET),* vol. 14, no. 7, pp. 18–36. 2019. doi: 10.3991/ijet.v14i07.9946

[9] L. Wang and F. Liu, "Teaching knowledge sharing in virtual practice teaching," *International Journal of Emerging Technologies in Learning (iJET),* vol. 18, no. 4, pp. 170–185. 2023. doi: 10.3991/ijet.v18i04.38239

[10] C. C. Castillo, "Virtual classroom usage and user perception for English learning as a second language at universities in Lima, Peru," *International Journal of Emerging Technologies in Learning (iJET),* vol. 16, no. 8, pp. 261–269. 2021. doi: 10.3991/ijet.v16i08.19221

[11] G. J. Martin and M. D. M. Fernandez. "Applying augmented reality in engineering education to improve academic performance & student motivation," *The International Journal of Engineering Education*, vol. 30, no. 3, 2014, pp. 625–635.

[12] A. E. Shudayfat, Y. Sharrab, M. Tarawneh, and F. Alzyoud, "Towards Virtual university based on virtual reality and terabits internet speed: A review paper," *International Journal of Emerging Technologies in Learning (iJET),* vol. 17, no. 24, pp. 57–68, 2022. doi: 10.3991/ijet.v17i24.36009

[13] A. Dirin, M. Nieminen, T. H. Laine *et al.*, "Correction to: Emotional contagion in collaborative virtual reality learning experiences: An eSports approach," *Education Information Technology*, 2023. doi: 10.1007/s10639-023-11945-9

[14] O. M Aldalalah, Z. Ababneh, A Bawaneh, and W. Alzubi, "Effect of augmented reality and simulation on the achievement of mathematics and visual thinking among students," *International Journal of Emerging Technologies in Learning (iJET),* vol. 14, no. 18, pp. 164–185, 2019. doi: 10.3991/ijet.v14i18.10748

[15] C. Peechapol, "Investigating the effect of virtual laboratory simulation in chemistry on learning achievement, self-efficacy, and learning experience," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 20, pp. 196–207, 2021. doi: 10.3991/ijet.v16i20.23561

[16] E. Demitriadou, K.-E. Stavroulia, and A. Lanitis "Comparative evaluation of virtual and augmented reality for teaching mathematics in education," *Education and Information Technologies,* vol. 25, issue 101, pp. 381–40, January 2020. doi: 10.1007/s10639-019-09973-5

[17] X. Li, A. Zhang, and Y. Shen, "Optimization of teachers' teaching behaviors in the virtual digital graphic design teaching environment,".

International Journal of Emerging Technologies in Learning, vol. 17, no. 18, pp. 146–160. 2022. doi: 10.3991/ijet.v17i18.34181

[18] C. S. Ironsi, "Investigating the use of virtual reality to improve speaking skills: Insights from students and teachers," *Smart Learn. Environ.*, vol. 10, no. 53, 2023. doi: 10.1186/s40561-023-00272-8

[19] F. L. Gaol and E. Prasolova-Førland, "Special section editorial: The frontiers of augmented and mixed reality in all levels of education," *Education and Information Technologies*, vol. 27, no. 1, pp. 611–623. 2022. doi: 10.1007/s10639-021-10746-2.

[20] Z. Nurbekova and B. Baigusheva, "On the issue of compliance with didactic principles in learning using ugmented reality," *International Journal of Emerging Technologies in Learning*, vol. 15, no. 15, pp. 121–132. 2020. doi: 10.3991/ijet.v15i15.14399

[21] A. Ghandour, A. Kintonova, N. Demidchik, and E. Sverdlikova, "Solving tourism management challenges by means of mobile augmented reality applications," *International Journal of Web-Based Learning and Teaching Technologies,* vol. 16, no. 6, 2021. doi:10.4018/IJWLTT.293280

[22] M. Serik, G. Nurbekova, M. Mukhambetova, and Z. Zulpykhar "The educational content and methods for big data courses including big data cluster analysis," *World Transactions on Engineering and Technology Education*, vol. 20, no. 3, pp. 203–208, 2023.

[23] R. Zhilmagambetova, Z. Kopeyev, A. Mubarakov, and A. Alimagambetova, "The role of adaptive personalized technologies in the learning process: Stepik as a tool for teaching mathematics," *International Journal of Virtual and Personal Learning Environments,* vol. 13, no. 1, 2023. DOI: 10.4018/IJVPLE.324079

[24] M. I. Grabar and K. A. Krasnianskaya, "Application of mathematical statistics in pedagogical research," *M.: Pedagogy*, p. 136, 1977.

[25] A. D. Rahmat, H. Kuswanto, I. Wilujeng, and R. Perdana, "Implementation of mobile augmented reality on physics learning in junior high school students," *Journal of Education and E-Learning Research,* vol. 10, no. 2, pp. 132–140, 2023. doi: 10.20448/jeelr.v10i2.4474

[26] H. Pujiastuti and R. Haryadi, "Enhancing mathematical literacy ability through guided inquiry learning with augmented reality," *Journal of Education and E-Learning Research*, vol. 10, no. 1, pp. 43–50, 2023. doi: 10.20448/jeelr.v10i1.4338

[27] B. Arymbekov, K. Turekhanova, and M. Turdalyuly, "The effect of Augmented Reality (AR) supported teaching activities on academic success and motivation to learn nuclear physics among high school pupils," *International Journal of Information and Education Technology* vol. 14, no. 5, pp. 743–760, 2024. doi: 10.18178/ijiet.2024.14.5.2099

[28] V. T. T. Hoai, P. N. Son *et al.*, "The current state of virtual reality and augmented reality adoption in Vietnamese education: A teacher's perspective on teaching natural sciences," *International Journal of Information and Education Technology*, vol. 14, no. 3, pp. 476-485, 2024. doi: 10.18178/ijiet.2024.14.3.2068

[29] W. Y. Yang and X. Wang, "Why do generative learning strategy improve memory in VR?—Based on ICALM," *International Journal of Information and Education Technology*, vol. 11, no. 12, pp. 646–650, 2021.

[30] A. Nouf, "Augmented reality: A systematic review of its benefits and challenges in e-learning contexts," *Applied Sciences,* vol. 10, pp. 56–60, 2020. doi. 10.3390/app10165660

[31] T. Cansu, "The impact of augmented reality technology on children's development: Scoping review," in *Proc. 7th International African Conference on Contemporary Scientific Research.*

[32] N. K. Uderbayeva, "For students of the 2nd grade of primary education," *Computer Science: Textbook*, Kostanai, p. 21, 2023.