

Ministry of Education and Science of the Republic of Kazakhstan  
Suleyman Demirel University



Salauat Arystanbekov

## **AR and VR technologies in Education**

THESIS

Presented in Partial Fulfillment for the  
Degree of Master of Science in Computing Systems and Software  
(degree code: 6M070400)

Department of Computer Sciences  
Faculty of Engineering and Natural Sciences

Supervisor: **PhD, Assist. Prof. Turan Cemil**

Kaskelen, 2019

# Abstract

This thesis work focuses on research on the impact of technologies, like virtual and augmented reality in the educational and professional training system. The major aims are to study and review of the quality of perception, understanding of educational information and define the role of technologies in the education process as well. We also consider the theoretical foundations of visual thinking, early researches, reaction, and problems. The history, current situation, prospects for the growth and development of virtual and augmented reality technologies in the nearest future are considered as well. For the practical part of the research were developed several mobile applications with educational materials from the general education school program and experiment was held. Experiment results were studied and examined to define if new technologies like Virtual and Augmented Reality effect on the quality of education.

## Аңдатпа

Бұл диссертация виртуалды және толықтырылған шындық сияқты технологиялардың білім беру жүйесіне және кәсіптік оқытуға қалай әсер ететінін зерттеуге бағытталған. Негізгі мақсаты - оқу материалдарын қабылдау мен түсіну сапасын зерттеу және талдау, сондай-ақ зерттелетін технологиялардың рөлі. Біз сондай-ақ визуалды ойлаудың теориялық негіздерін, ерте зерттеулерді, реакцияларды және проблемаларды қарастырамыз. Сондай-ақ виртуалды және толықтырылған шындық технологияларының тарихы, қазіргі жағдайы, жақын арадағы және келешектегі даму потенциалы талқыланады. Зерттеудің практикалық бөлігінде жалпы білім беретін оқу бағдарламаларының оқу материалдарымен бірнеше мобильдік қосымшалар әзірленді және тәжірибе жүргізілді. Тәжірибе нәтижелері виртуалды және кеңейтілген шындық сияқты жаңа технологиялардың білім сапасына әсерін анықтау үшін зерттеледі.

## Аннотация

Данная диссертационная работа посвящена исследованию влияния технологий, таких как виртуальная и дополненная реальность, на систему образования и профессиональной подготовки. Основными целями являются изучение и анализ качества восприятия и понимания образовательного материала, а также роли изучаемых технологий в них. Мы также рассмотрим теоретические основы визуального мышления, ранние исследования, реакции и проблемы. Также, будут изучены история, текущая ситуация, перспективы роста и развития технологий виртуальной и дополненной реальности в ближайшем будущем. Для практической части исследования было разработано несколько мобильных приложений с учебными материалами из общеобразовательной школьной программы и проведен эксперимент. Результаты эксперимента были изучены и исследованы, чтобы определить, влияют ли новые технологии, такие как виртуальная и дополненная реальность, на качество образования.

# Acknowledgements

I wish to thank my thesis supervisor PhD, Assist. Prof. Turan Cemil for his valuable and constructive suggestions during the planning and development of this thesis work. His willingness to give his time so generously has been very much appreciated. I would also like to thank PhD, Assist. Prof. Andrey Bogdanchikov for his constant support and direction. Also, I would like to extend my thanks to teachers and administration of Zerde school in Nur-Sultan for their help in organizing the practical part of this thesis work.

Finally, I wish to thank my family for their support and encouragement throughout my study.

# Contents

<b>1</b>	<b>Introduction</b>	<b>7</b>
1.1	Technology-enhanced learning . . . . .	7
1.2	Aims and Objectives . . . . .	8
1.3	What is Virtual Reality? . . . . .	10
1.4	What is Augmented Reality? . . . . .	11
<b>2</b>	<b>Research</b>	<b>14</b>
2.1	Related research works, articles and successful use-cases . . . . .	14
2.2	Methods and materials . . . . .	18
2.3	Experiment . . . . .	20
2.4	Data and results . . . . .	22
<b>3</b>	<b>Discussion</b>	<b>24</b>
<b>4</b>	<b>Conclusion</b>	<b>28</b>
<b>A</b>	<b>Appendix A</b>	<b>31</b>
<b>B</b>	<b>Appendix B</b>	<b>33</b>
	<b>References</b>	<b>34</b>

# Nomenclature

3D Three dimensional

AR Augmented Reality

CAGR Compound Annual Growth Rate

MR Mixed Reality

ROI Return on Investment

SDK Software Development Kit

SDU Suleyman Demirel University

SLAM Simultaneous localization and mapping

VR Virtual Reality

# 1. Introduction

## 1.1 Technology-enhanced learning

Nowadays technologies are always progressively non-stop developing and improving, which affects different aspects of a human being. Two decades ago people could not even think about what we will carry a portable computer in their pockets, now we call it a smartphone. Modern phones are several times more powerful and show incredible performance than personal computers of those times. Some of the people cannot even represent a single day without it. Along with the new technologies, different aspects of our lives started to closely interact and broadly use modern technologies, which are making lives simpler and more productive.

The teaching and learning process is not an exception, there have appeared terms like Technology-enhanced learning or Technology-enabled learning (TEL), which assumes tight integration with different technological solutions to the educational process. Education has always been the process of teaching and learning in the interests of the individual, society and the state, and will be important forever.

Now, starting from kindergarten children have been taught with the help of computers, projectors, multimedia boards, and the other peripherals to enhance the learning experience. There are some key points of the importance of TEL:

- More resources: there are no longer only books and textbooks, kids can watch videos, use interactive educational Software and learn in their own pace;
- Engagement: technologies bring a better learning experience and even boring topics could get interesting;

- Engagement: technologies bring a better learning experience and even boring topics could get interesting;
- Flexibility: can be accessed from anywhere and anytime.

TEL is applicable to all stages of education and is an integral part of modern education. Technologies such as Virtual Reality (VR) and Augmented Reality (AR), which seemed fantastic and futuristic several decades ago, are also approaches of TEL. And these technologies are already being used in everyday life and in various areas. According to Goldman Sachs Global Investment Research [1], market of VR and AR software will be divided into two major sectors in 2025:

- Enterprise and public sector (Healthcare, real estate, retail, education, military etc.) – 46%;
- Consumer (Entertainment, video games, live events etc.) – 54%;

Use share of VR and AR in education and professional training is about 15%. Proposed technologies mostly used in engineering and training employees. The biggest car manufacturers already use AR and VR for training stuff, modeling and process improvement.

But how this use share can be increased? How to measure efficiency of VR and AR in teaching and learning process? Actually, there are a lot questions to be studied and reported. This work is aimed to make attempt to answer the questions above.

## 1.2 Aims and Objectives

The aims of this research are to define the effect of virtual and augmented reality technologies on perception and understanding of educational materials and measure involvement and engagement at lessons, to get students and teachers reactions. VR and AR technologies in the educational process are examples of visual representation of information. Visualization has been one of the most effective methods of human thinking and learning for more than 300 years. Typical visualization (see Figure 1.1) [2] was considering static examples like pictures, graphs, diagrams and photos and dynamic examples like video and animation as

a main source of information for visual-spatial thinking and learning. But there is no interactivity as in proposed technologies. For example, VR and AR technologies can provide an educational experience that is impossible in the real world, like walking with dinosaurs or training surgery on the human heart many times, without harm to a real man.

As the main objectives of our research, we define followings:

1. Study the VR and AR technologies: History, big players, market, use-cases;
2. Study Immersive education, Technology-enhanced learning (TEL);
3. Examine related scientific researches and articles;
4. Define the method for an experiment;
5. Analyze the received data and make a conclusion;

Despite potential success in education we have to find out whether if these technologies are the most effective examples in visual-spatial thinking and learning? In addition, we need to observe the reaction of students and what problems could be faced during the educational process.

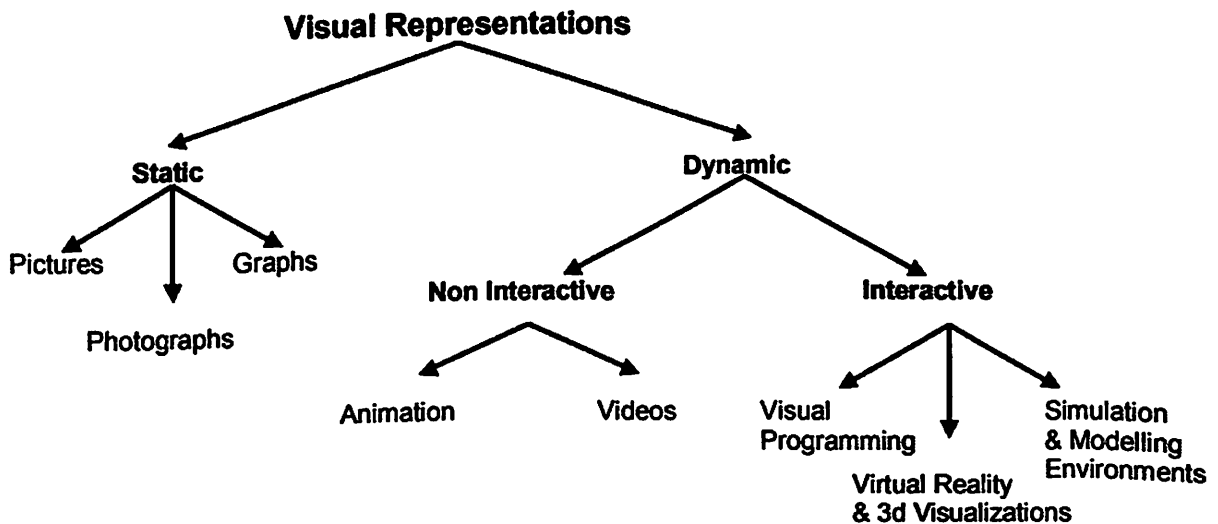


Figure 1.1: Types of Visual Representation

## 1.3 What is Virtual Reality?

Virtual Reality is a term used to describe three-dimensional computer-generated environment, which can be explored and interacted by a user. The basic principle of operating with VR technologies lies on specially-designed headset, which is also called goggles. Virtual reality has been studied and researched by scientists starting from beginning of previous century. In 1960s Ivan Sutherland [3] described VR concept as window through which a user perceives the virtual world as if looked, felt, sound real and in which the user could act realistically. But as the father of virtual reality is used to be considered Morton Heilig. He received this title for research and inventions made in the 1950s and 60s. On August 28, 1962, he patented the “Sensorama” simulator [4] (see Figure 1.2). Heilig himself also called it the immersion theater. After almost 30 years, Michael A. Gigante [5] described VR like “the illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on a 3D, stereoscopic head-tracker displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience” and it sounds more like modern definition of VR.

New era of VR development has started in 2012, when young computer engineer Palmer Luckey has started new project Oculus in Kickstarter. After successful start, Facebook bought Oculus for 2 billion USD and now, Oculus is the one of the major players in the market of VR, with 19% of all shipping. It sells several types of headsets and own application market. This deal shifted the entire IT industry and the big players like Google, Sony, Microsoft, HTC have successfully started their own development. According to IHS Markit research [6] (see Figure 1.3) in 2020 consumers will spend approximately 6.5 billion USD for AR based applications and 2.4 billion USD for VR content.

In 2021 market of content for AR will increase up to 23%, for VR up to 16%. IDC [7] (see Figure 1.4) researches forecast shipment of VR and AR devices 12.5 million and 2.5 million units respectively in 2020. Strong growth is expected to continue as global shipments climb to 68.6 million in 2023 with a compound annual growth rate (CAGR) of 66.7% over the 2019-2023 forecast period.

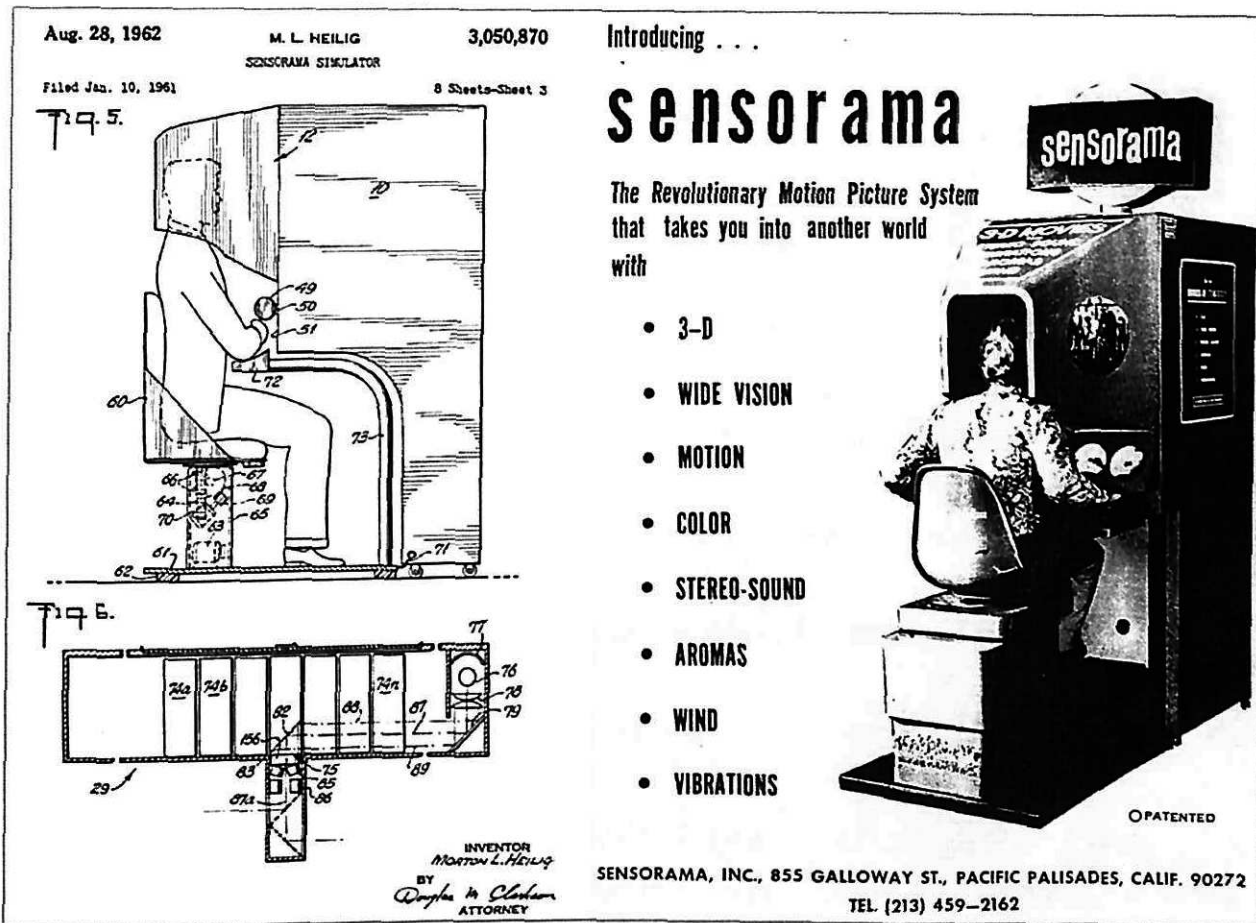


Figure 1.2: Sensorama simulator and patent scheme

## 1.4 What is Augmented Reality?

Augmented Reality is an improved form of reality where immediate or indirect perspectives of user's view are intercalated with computer-generated content, accordingly enhancing user's current perception of reality. In other words, augmented reality is the result of using technology to superimpose information — sounds, images and text — on the world we see. The primary value of augmented reality is the manner in which components of the digital world blend into a person's perception of the real world, not as a simple display of data, but through the integration of immersive sensations, which are perceived as natural parts of an environment. In comparison with VR the AR does not create a completely computer environment, but transfers digital elements to objects that surround you. Roughly speaking, new virtual information is superimposed on top of the physical elements. It works in real time, does not create for you any full-fledged simulations. Consequently, the main difference between AR and VR technologies

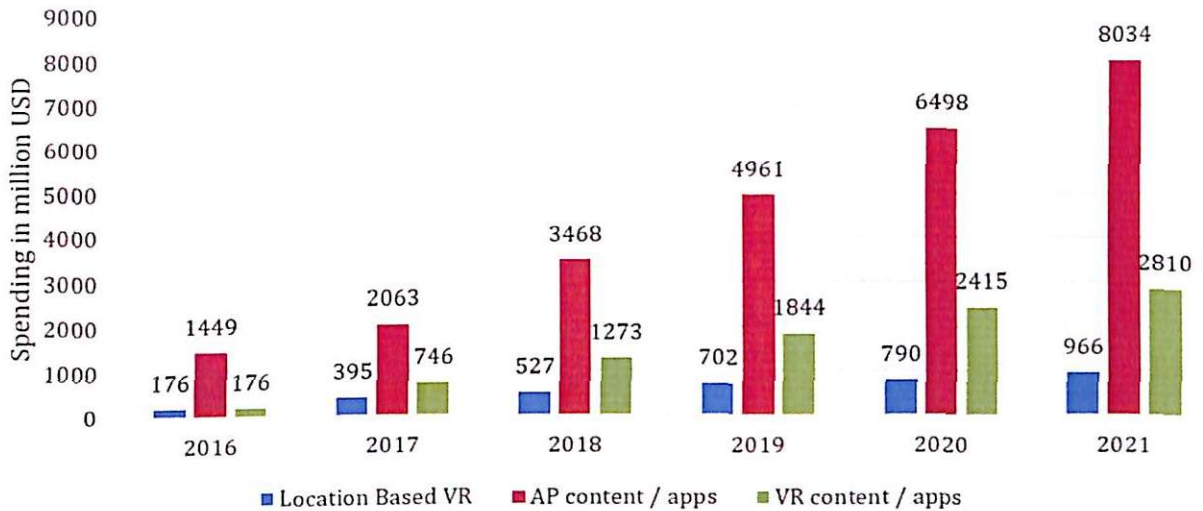


Figure 1.3: Consumer spending on AR/VR content and apps

is that VR uses human created virtual space as an environment, when AR uses real space with some virtual elements.

Like many other interesting studies, the history of manipulation of reality begins in literatures in genre of science fiction. The author of *The Wizard of Oz*, Lyman Frank Baum, in the novel *Master Key* [8], described a device that could mark people in real time with letters indicating their character and level of intelligence. The primitive tools of augmented reality were known long before: these were masks that Roman archers wore to aim better, and telescopes with distance markings, and so on. But the story of augmented reality, as we know it now, originates from developments concerning VR, especially “Sensorama” patent. The patent describes a virtual technology in which visual images are complemented by air movements and vibrations. The rationale for its existence was given this: “Today, the demand for methods of teaching and training people is constantly growing in such a way as to eliminate the risks and danger of real situations”. It was a device of an earlier version of virtual reality, and not augmented, but it gave impetus to the development of both AR and VR.

Modern AR is pattern recognition[9] and marker tracking technology. Markers are read with camera or other image input sensors to define coordinates and where virtual object should be placed. Tracking pattern and defining plane is quite difficult, due to huge amount objects should be processed with Artificial intelligence to define pattern and define plane. But there were found method SLAM (Simultaneous localization and mapping) [9] [10] in 1990s, which is still getting improved

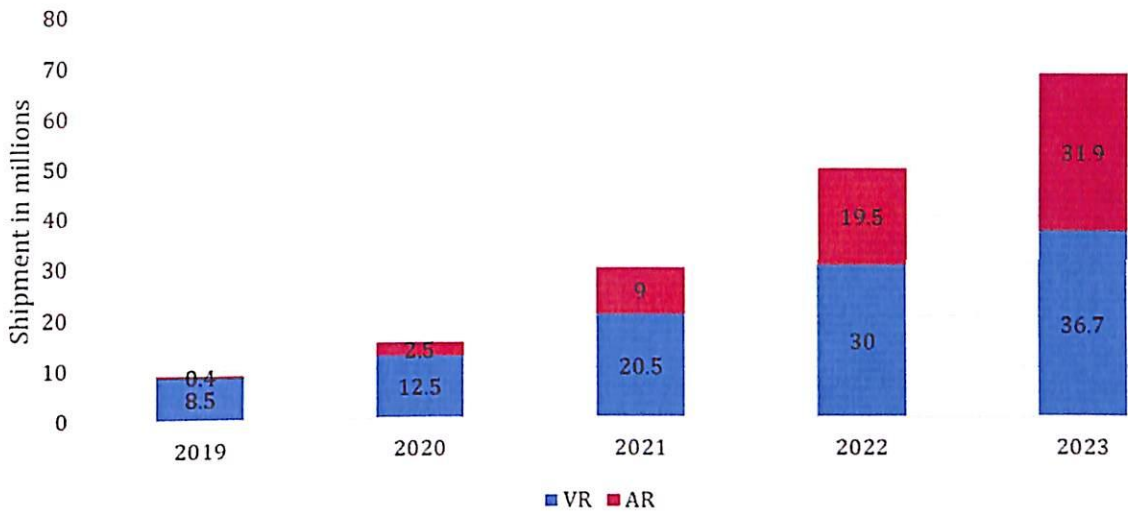


Figure 1.4: AR/VR Headset shipment forecast, 2018Q4

by researchers. Approach of SLAM is to build a map in an unknown space or to update the map in a previously known space while simultaneously monitoring your current location and distance traveled. The algorithm allows to memorize the position of points in space, returning to the same space from another you will see points in the same places where they were before.

Nowadays, due to the fact that the sphere of entertainment is one of the most profitable, augmented reality is the most often used in it. Many projects have been implemented, but mostly for the most affordable devices like a smartphone. But in 2016 Microsoft presented Hololens project - smartglasses with both AR and VR, also known as Mixed Reality (MR). However, Hololens project is still under development, but there are many enthusiastic reviews on the Internet, where people share their experiences of interacting with the virtual environment.

# 2. Research

## 2.1 Related research works, articles and successful use-cases

For society, education has always been a single process of physical and spiritual formation of personality, a process of socialization. In this understanding, education is an integral part of the life of all societies and all individuals without exception. The main institution of modern education is a school, then a college or university. Even working, people always learn, improving their skills.

According to review work [11] of Bacca, J., Baldiris, S., Fabregat, R., Graf, S., Kinshuk about application of AR in education, where they have reviewed 30 related research works, 40% of uses by “Field of Education” is Science, 21.9% is Humanities and Arts, 15.6% is Manufacturing, engineering, construction and rest is other categories (see Figure 2.1). Unfortunately, reviewed works didn’t contain information about use in fields like Education (teacher training in all levels of education) and Agriculture. The reason why the section “Engineering, manufacturing, and construction” is highly used, it is the fact that AR can be very financially and educationally effective in staff training, modeling, construction.

Researcher reviewed studies about use and application of AR in Education and found out that almost 35% of AR studies were carried out was Bachelor students of universities, and 49.5% was students of schools. As the main the top 5 advantages of AR in educational setting were:

- Learning gains – 43.75%
- Motivation – 31.25%
- Collaboration – 18.75%

- Facilitate Interaction – 12.5%
- Low cost – 12.5%

As well, they reported about limitations like:

- Designed only for a specific knowledge field – 3.13%;
- Educators cannot create new learning content – 3.13%;
- Difficulties maintaining superimposed information – 9.38%;
- Paying too much attention to virtual environment – 6.25%;
- Intrusive technology – 6.25%;

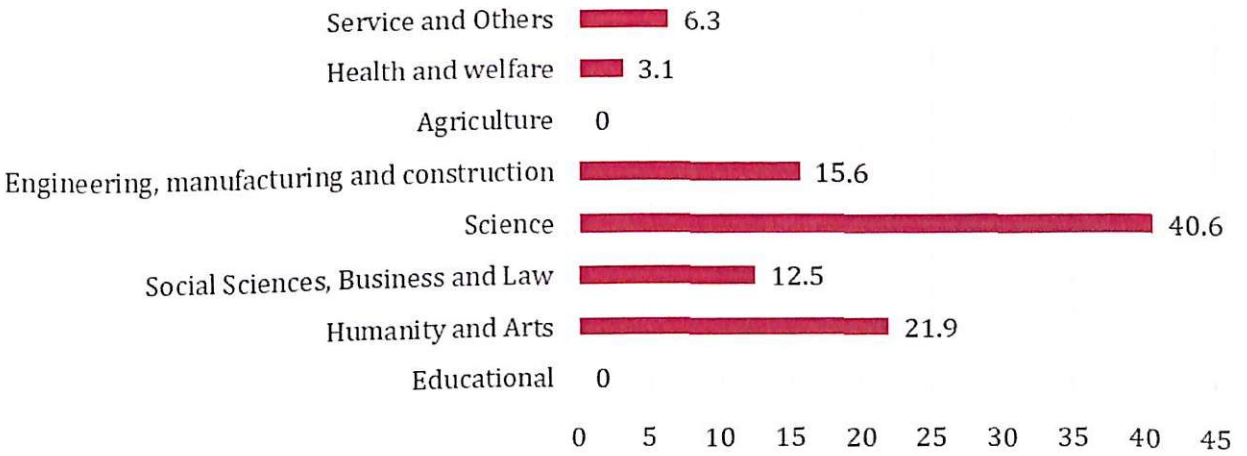


Figure 2.1: AR uses by "Field of education" in percents (%)

27 out of 30 studied works says that purpose of using AR in educational process is to explain the topic and augmenting learning materials with interactive virtual content. In section “Effectiveness of AR in Education” (see Table 2.1) was said, that most of the studies reported that AR application leads for “Better learning performance” (53.13%), which is actually good result. Also reported that it does not decrease the cost of education (0%).

The next prime example is, California based Scope AR [12] – a global leading company in AR solutions and applications development for industrial clients including sectors like manufacturing, training and field maintenance. The world’s industrial giants like Lockheed Martin, Toyota, Unilever, P&G, and Siemens are

Sub-category	Number of studies	Percentage (%)
Improved learning process	17	53.13
Increased motivation for learning	9	28.13
Better enjoyment of perceived information	4	12.50
Decrease the cost	0	0.00
Positive attitude	4	12.50
Engagement	5	16.63

Table 2.1: Effectiveness of AR in Education

already using Scope AR solutions in sectors mentioned above and have real-world results. Unilever uses AR application to solve technical problems in manufacturing, where tech-specialists can find and solve issues fast in field, using AR application as manual (guide) and instruction. They have reduced downtime to 50%, which saves 79 750 Euro per month. Return on Investment (ROI) is 1717%. If Unilever uses AR as technical guidance, Lockheed Martin uses AR solutions to train employees, who are working on construction of spacecraft. According to Shelley Peterson, Emerging Technologies Lead, they have reduced in time to information almost for 99%. And over-all time for training was reduced up to 85%. Majority of Scope AR clients left quite positive feedbacks.

German research agency Kantar EMNID and Samsung Electronics made a research [13] among 606 teachers throughout all schools in Germany about use of VR in classrooms. 92% of interviewed teachers support the use digital technologies in educational process. And 99% of educators under 30 fully supports use of technologies on lessons. At the time of survey, 67% of teachers said that they are already using digital equipment like computer, projector and multimedia walls in classrooms and they don't have any difficulties using it. Moreover, educators were very interested in use of VR on lessons:

- 18% have already used VR;
- 48% have willingness to try VR in classroom (or 58% teachers under 30);

Teachers have selected subjects like History (74%), Natural sciences (62%), Arts (44%), and Geography (80%) as the most suitable for VR. Despite the fact, that VR is a relatively new technology almost half (42%) of them believe that in near five-year VR will be used in classrooms. Educators (74%) says that if

VR devices will be available at schools, they would use it at least once in month. Provided survey reports that, 74% of teachers think, that VR will increase motivation, engagement of students and 62% have opinion that VR will improve their learning success of students. Whereas 58% of educators also feel that the use of the technology can help students better understand learning concepts. So, the survey shows that in the most cases more than 50% of educators supports usage of digital technologies in educational process and passing the time the numbers will definitely increase.

### **Improving Spatial Abilities by Geometry Education in Augmented Reality - Application and Evaluation Design Proceedings [14]**

This research work considers effectiveness of augmented reality as a space for geometry education to improve spatial abilities. In addition, researchers aimed to make it in collaborations, by developing special application which can show same content for several AR and VR devices. Developed Construct3D application has been tested during the 3 years, involving 250 high class students. According to survey, students think that Construct3D is easy to use. They've divided tested students into five groups: untrained, traditional school group (drawing with pencils), modern school group (CAD software), individual tutoring group, Construct3D. Six different spatial tests and three verbal ability tests were presented for participants. Test outcomes demonstrated that in female understudies, high spatial execution is identified with great thinking aptitudes and consistent deduction, while, for male understudies, speed and exactness of fundamental spatial procedures are the best indicators of spatial test execution.

### **Fourteen Propositions About Educational Uses of Virtual Reality [15]**

Despite this book was published almost 20 years ago, authors Winn W. and Jackson R. propose fourteen interesting ideas with observations for use of VR in education. Not only in schools, also in different industries. Some of them:

- VR is much more cheaper than physical simulators like simulator of airliner and safer than real-world training;
- VR allows quasi-natural interactions with objects;
- Mostly useful when VR embody concepts and principles that are impossible in real life;

- Presence is related to engagement and learning, and to reduction of malaise in virtual environment;
- Can situate learning experience in a meaningful context;
- Collaboration is possible and beneficial;

### **Augmented Reality Applications in Education [16]**

Authors of this article review augmented reality applications in education and its use in several learning theories. Defines some interesting uses in education:

- Use in traditional class;
- Use in special education - can provide a high quality educational experience to students with physical and thinking disabilities;
- Outside the classroom and combined learning;

In addition, authors pay attention to resources, technical problems, student reactions and educator's worries that AR will overtake their classes.

## **2.2 Methods and materials**

As the method of research, I have made an experiment at the local state school for obtaining qualitative results. Through this experiment I wanted to test the effectiveness of using AR and VR technologies in education process and to study its impact to student's perception of studying materials. From various options selected topic "Solar System" from state educational program, because it can be visualized in both VR and AR. According to new educational program in Kazakhstan this topic is learned at different grades, with different complexity levels and information volume. As the main participants of experiment were selected 8th grade students of State School "Zerde" in Nur-Sultan. They are already learned about Solar System and had a quiz about it exactly one year ago.

After learning materials from Physics book for 7th grade in Chapter 6, I found out that mostly Solar System topic is described very briefly. There are general information about planets, satellites and Renaissance era astronomer Nicolaus Copernicus. According to examined information I prepared a presentation about Solar System, where the main focus was about:

- Planets order;
- Physical parameters of planets: Size, distance to the Sun, period etc.;
- Satellites;
- Planet's structure;

AR and VR applications were developed for visualization of Solar System. According to presentation and materials from book, also been composed test about this topic for experiment participants to evaluate them. In addition, there has been composed survey for gathering information regarding knowledge about VR and AR technologies among students and their teachers. Questions were quite simple, mostly about planets ordering, physical structure and size of planets.

### **VR Application development for experiment**

The First mobile application was developed for Samsung Gear VR platform, VR headset developed by Samsung in collaboration with Oculus in 2015. Gear VR uses Samsung Galaxy series smartphones running Android OS to process and display virtual content. Oculus provides VR technology, application market and SDK. Oculus SDK is supported in both the most popular 3D engines, Unity and Unreal Engine 4. For this application was used Unity, which is free for non-commercial development and use. As the main advantages of Unity can be mentioned multi-platform feature and big community of developers, which definitely helpful in learning of this 3D engine.

Developed application (see Figure 2.2) demonstrates Solar System in different perspectives, with moving planets around the Sun and turning its own axis. User can close up to any planet. Also, all big satellites of Solar System planets are shown in application.

Due to fact, that I didn't have any experience in 3D modeling and programming on C#, it was quite hard to develop this VR application. Unfortunately, there were some problems with connection on Samsung Gear VR controller, so interactions are limited. Regardless, application runs very smooth and with quality 3D objects in it.

All materials and patterns can be found in Internet and there are a lot of tutorials for beginners. Even person with "beginner" level in programming can build simple virtual scenes. But there are limitations for mobile VR application,

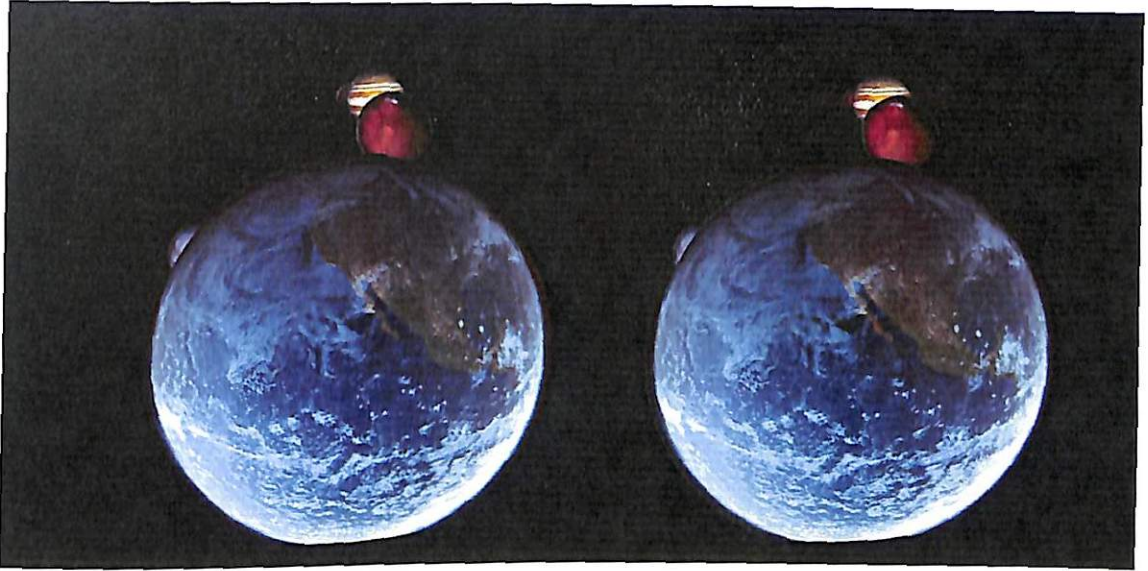


Figure 2.2: Screenshots of “Solar System” application for Samsung Galaxy VR: Close view of Earth model.

like relatively poor performance of smartphone hardware than regular PC. Which definitely affects the scale of the stage, visual effects, and the number of polygons of 3D models, which in turn affects the quality of virtual content.

### **AR Applications development for experiment**

In educational process AR can easily add interactivity for to any paper book, card or poster. For the visualization of Solar System was developed two application, first one (see Figure 2.3) shows animated Earth model and second one substitutes photo with video material. Both applications use Vuforia - the best-in-class computer vision technology for AR for detection and reading marker. As the 3D engine used Unity as well.

Proposed applications are very simple, there are no any interactive features as it could be. All applications run on Android OS, but Vuforia technology supports other platforms like iOS, Windows. Vuforia is free to use, but overlays watermark on the smartphone screen. Single application license costs about \$500 USD. All markers are stored in Cloud, and there is ability to add more markers and make dynamic content.

## **2.3 Experiment**

The experimental part of the research was aimed to get real and live data, and the source should be directly related to the educational and learning process. An

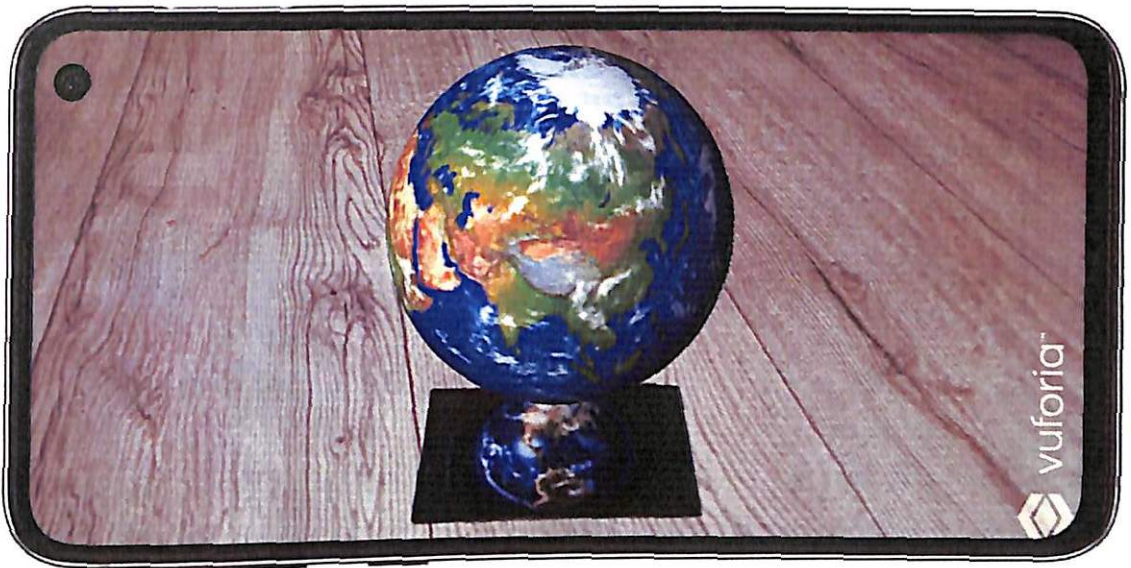


Figure 2.3: Screenshots of AR mobile application: Earth model appearance above the marker.

experiment had to be held in 5 steps (see Figure 2.4).



Figure 2.4: Steps of experiment

**Step 1** - As written above experimental part of research was held in state schools in Nur-Sultan. We had to select participants of experiment from same class, with characteristics like: same age, different genders, mixed general marks.

**Step 2** - We had a one hour lesson about Solar System according to the prepared presentation and discussed the selected topic with participants. Then started to show the visualized material in developed applications, thereby enhancing lesson with VR and AR.

**Step 3** - After the lesson and showcase of proposed technologies, participants had a test about the past topic Solar System.

**Step 4** - Survey was held to measure awareness and general knowledge about proposed technologies among regular mid-school students and teachers. There been composed survey, containing simple questions about VR and AR. Questions was aimed to find out: how technologies can improve educational materials, gath-

ering full feedback about purposed technologies, engagement and involvement to lesson and possibility of regular use.

**Step 5** - All results were processed and evaluated to give reasonable answers and to meet all objectives and aims of this research work.

See Appendix A.

## 2.4 Data and results

Total number of participants was 24 people, where 21 are students and 3 are teachers. Results of survey show us general view of use of VR and AR in educational process at mid and high schools. Proposed technologies are familiar to 85.2% of interviewed, where 38% know about both VR and AR, 42.5% know only about VR and 4.7% only about AR. Remaining 14.8% don't know about these technologies. Survey was conducted after demonstration of application, so 90.5% of interviewed found it interesting and engaging. Even if not all participants are interested, but all think that VR and AR can be implemented in educational process. Participant noticed some positive and negative features:

- Visualization helps to understand educational material - 47.6%
- Lesson becomes more interactive - 76.2%
- It improves educational process - 42.8%
- Increases interest and involvement in the lesson - 80.9%
- VR makes dizzy - 4.8%

Teachers and students was also asked about in which subjects they would like to see these technologies, and list was led by geography (85.71%), biology (80.95%) and physics (76.19%) respectively (see Figure 2.5). Participants had to choose several options.

And the last section of survey was about potential areas for VR and AR use beside the education. According to opinion of interviewed the most suitable are areas like science and entertainment. Also, in answers found options like military, industrial use, modeling. In general, we can conclude that survey results are quite similar to global researches.

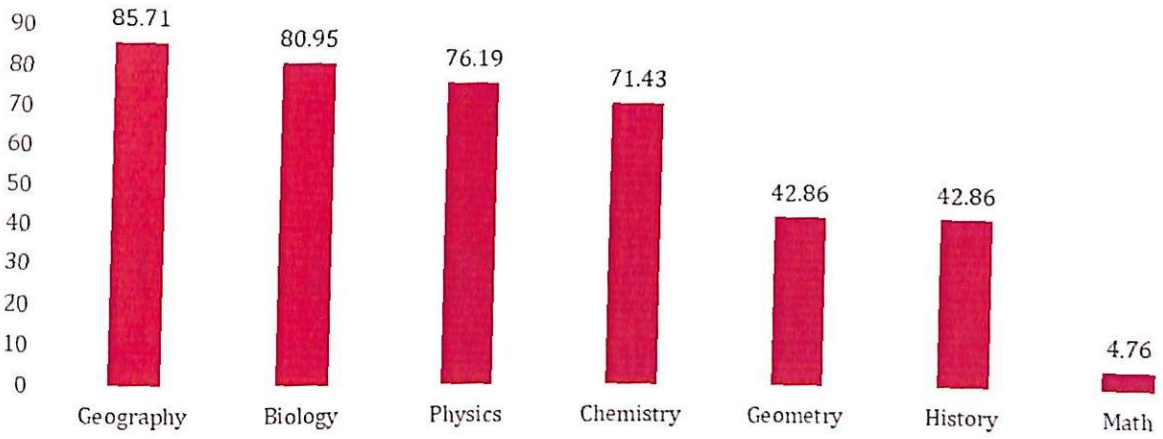


Figure 2.5: Results of survey, regarding for which subjects VR and AR suit more.

Students	Total	Ave. points in 2018	Ave. points in 2019 with AR/VR	Increase / De- crease
All	21	67.62	79.52	17.61%
Girls	7	85	74.29	-12.61%
Boys	14	58.93	82.14	39.4%

Table 2.2: Effectiveness of AR in Education

Test was prepared and passed only by students. Teacher of Physics provided last year results of quiz regarding Solar System for comparison. According to results (see Table 2.2) of testing, average result of participants has been increased. But same time average result of girls decreased to 10%. Boys have increased average almost to 40%.

Unfortunately, this experiment did not give us a complete answer to the questions asked about the effectiveness of these technologies in the educational process. But here we need to understand what we mean by the word "efficiency". If we consider from the side the influence on students' marks, then a long-term experiment should be carried out. Students should be selected and divided into two focus groups, conduct AB testing, in which one group studies according to an established educational program, the other using additional materials like AR and VR content. In this case, it is more likely that there will be a difference in the final estimates. However, if we consider the efficiency on the part of understanding and perception, I think we were able to answer the question. By learning subjects in a more effective perception and understanding, the student definitely may show better results.

### 3. Discussion

Considering the fact that VR and AR technologies and devices are becoming reachable and cheaper, they are able to bring more tangible approach to learning. There are many free and open-source tools for building applications of any complexity. AR and VR technologies have potential to improve and modify the process of gaining knowledge, to make it more effectively perceptive by students. The best minds can share their knowledge with students from all around the world in a virtual classroom in interactive mode. According to survey [17], almost 69% of parents think consider the fact that AR technologies are able to improve education systems. In the nearest future AR and VR technologies will become usual for people like a smartphone or internet.

Like other technologies, virtual and augmented reality technologies have pros and cons. The main problem of implementing AR and VR technologies into educational process is less amount of resources like 3D models and complexity of building that models, scenes, environments and the cost of proper devices. The second one is isolation: learning based on virtual reality and environment can distance understudies and diminish relational correspondence in class. AR technologies might cause problem with student control, they simply can play on smartphones during the lesson, if smartphones will be used as device for AR. But there are some mechanisms which are able to smooth the edges. For example: school AR app in student's smartphone could block all function except AR app and emergency calls during the lesson. Smartphone will receive time table of student and turn on described above feature.

One of the most obvious benefits of VR and AR is transforming lesson or lectures into immersive learning experiences, enabling teachers to truly bring their subject to life. Engineering or architecture students could use VR to design and build digital structures; history students could explore ancient ruins; marine

biology students could study deep oceans. You get the idea – the possibilities for immersive education are near endless.

The financial side of introducing advanced and high-tech tools into education is another important aspect. If the technology of augmented reality requires expenses mainly for the creation of 3D content, and for viewing it can use the student's or his parent's smartphone. That virtual reality requires much more, except for the content it is necessary to equip the class with VR helmets, a platform for managing all BPs for the teacher. When learning to learn and ready-to-use solutions, I can distinguish 2 optimal options: Google Cardboard as an affordable solution and ClassVR all-in-one solution.

Google Cardboard (see Figure 3.1) is the cheapest and available VR headset that I could find. It can be purchased for \$10 USD with shipment to Kazakhstan. The name Cardboard itself speaks of itself, it is made of cardboard and with built in two lenses. To get started user has to put into his/her smartphone and run one VR applications. There are many free to use and paid application already hosted in Play Market. The main disadvantage is the absence of its own display and processing unit, and it is only VR. Let's consider the most optimistic use case in a state school. For example, we have a class with 25 students, where all of them have own smartphones. And the teacher has already found the most suitable free application from the application market according to her educational plan. The class successfully uses VR in lessons by getting additional information about the topic. Total spending for one class is about \$250 USD.

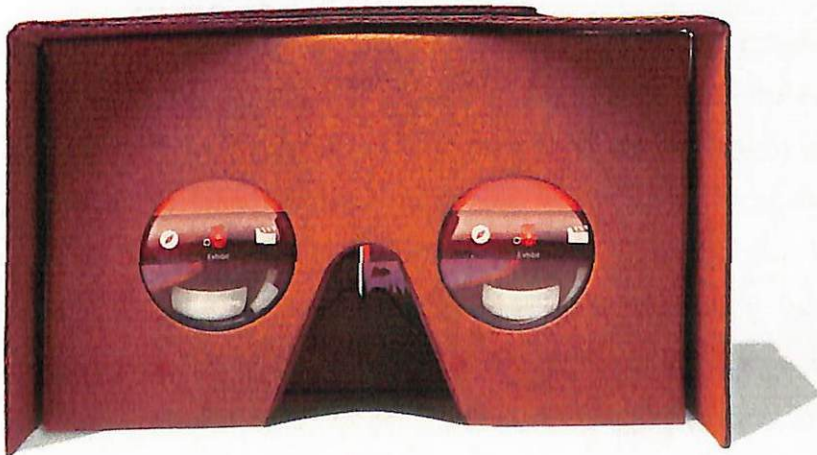


Figure 3.1: Google Cardboard, source: <https://store.google.com>

If we consider the real situation in Kazakhstan state schools, it is strongly pro-

hibited to use phones during the lessons, and most of the students don't have own phones. However, there is a solution, Cardboard can be bought by parents and only for individual use of student at home, which seems to avoid the collaborative learning approach. In this case, the school doesn't have spending on equipment, but there is a risk of a wave of disturbances from the parents of students regarding additional spendings. Definitely, Google Cardboard can be considered as the option, but only for VR experience. It will bring bright emotions and good experience to students.

ClassVR (see Figure 3.2) is not an only VR headset, it is a young company which proposes specially designed Mixed Reality Headset. ClassVR headset is a stand-alone device for use in the classroom and ensures full immersion in VR/AR under the guidance of a teacher. For the operation of the headset does not require additional devices. All necessary electronics are built directly into the ClassVR enclosure, reliable, intuitive and easy to use. At the heart of the solution is ClassVR - a portal for the teacher with all the necessary tools and content. With one mouse click, the teacher can start browsing content on all headsets, guide students through the immersive experience, and track the progress of each student. Teaching content and ready-made lesson plans help stimulate students' imagination and curiosity, enrich their experience with bright impressions and memories and visualize complex concepts and processes. In the library of educational materials, more than 900 tasks are available on various topics, including images with an overview of 360 and 3D models. The big range of topics and subjects. As well, there is the ability to upload own files and use them in the lesson.

ClassVR headsets are sold in boxes by 4 or 8 devices in it. Also, they provide special training for teachers and students to start the process of education. And the price for a box with 8 devices is \$3340 USD without shipment to Kazakhstan, and approximately \$3800 USD with the shipment. The box is used as a charging station and storage for headsets. To equip the class with 25 students school need to spend \$11 875 USD. And it is only cost for hardware, software and not localized materials. If state schools can still afford to equip at least 1 class annually, then they will not be able to afford material adaptation and creation. For the implementation of an already adapted and localized system, state schools need the full assistance and funding of the Ministry of Education.

There a lot of use-case studies are published on the official website of ClassVR,



Figure 3.2: ClassVR products, source: <http://www.classvr.com>

where teacher all over the world giving positive feedbacks. But there are no yet researches on long-term benefits of ClassVR, due to the youngness of the project.

## 4. Conclusion

Studying the results of the practical part of our research, we can say that, overall VR and AR technologies affect information perception. Students have improved average results almost 18%, or from 68 to 80 points. It is a rough evaluation of the quality of gained knowledge, due to less amount of VR and AR -enhanced lessons. If such lessons were conducted throughout the year, even on only one subject like Geography, then this year's results could be compared with previous years. Which would bring a more accurate assessment of the use of these technologies in the educational process. In this case, we meet another problem with a lack of virtual content developed in accordance with educational materials approved by the Ministry of Education of the Republic of Kazakhstan. But we can consider already has been created and used tools and materials, due to common with the subject where no need for translation and localization. Only high quality and correct visualization.

We were more pleased with the second part of the practical work, a survey that was held to measure awareness and general knowledge about VR and AR. Survey results are very close to global researches regarding the use of these technologies in education and training systems. As key features, we can highlight "interactivity on the lesson" and "high involvement to the lesson", which definitely improve the learning process.

After an experiment at school teachers and administration were very interested in proposed technologies. They say that the school administration can buy VR headsets, but the problem is content. There are no available software or applications in the Kazakh language at all, only a few in Russian. Before implementing VR or AR technologies in the educational process, the size of the VR/AR applications market should increase. Only in that way big players in the Digital Development area will pay more attention to school education and learning en-

hancement. Overall, teachers and director of state schools left positive feedback on this experiment (See Appendix B). Where they noticed some main points: the students were very interested, can give good results in individual study, a deductive approach on the learning and new of effective information perception. They recommend using studied technologies and tools in the practical part of the subject.

Taking to the notice aforesaid we can formulate the following general provisions on the specificity of AR and VR technologies as a method and means of learning:

1. Using AR and VR applications have a high potential for stimulating influence on the procedural and operational characteristics of the student's thinking, creativity, on the formation of specifically cognitive motivation, interest in learning and the creation of positive, harmonious mental states.

2. AR and VR are used in education, act as a method, tool and technology of education. This is determined by the fact that teaching through AR and VR applications introduce significant specificity to the activity of a teacher, a student, to the transformation of educational content, ensure the formation of a new, informational way of presenting and learning material.

3. The use of AR and VR in learning process, obviously, has negative aspects. For example, the "super-shaped" visual presentation of the education content with the wrong construction can cause misperception of the reality. VR headsets can cause dizziness, claustrophobia. So, developers recommend to use VR headsets not more than 15-20 minutes per one use.

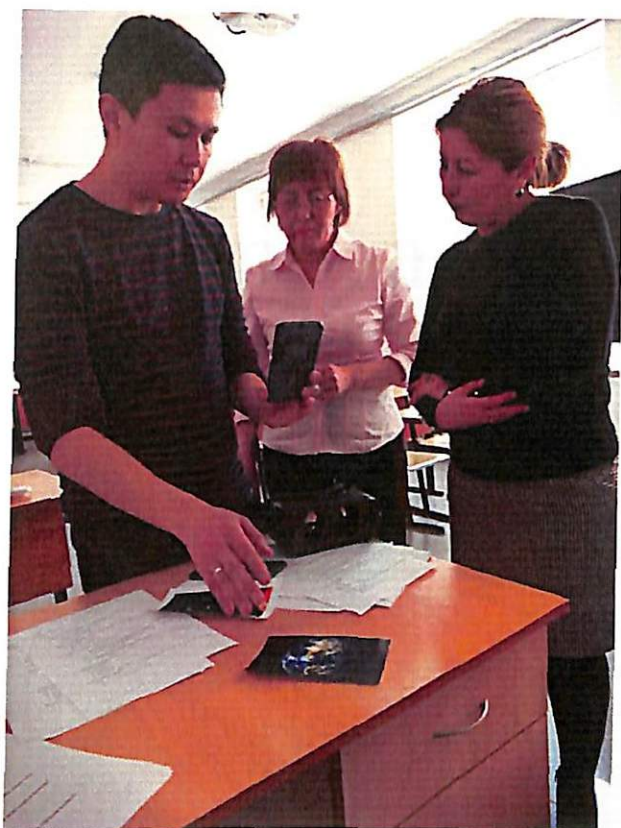
Most of Education systems traditionally refuse to accept changes. Notwithstanding it we have to be in the groove and use all new teaching models especially AR and VR which takes an important role and gives a really nice opportunity to test different devices, make some experiments, virtual trips into the history and get not only knowledge but also to get it through experience and visualization. Thanks to such interesting and attractive methods the teaching becomes more accessible. After some time, popular VR and AR devices will become cheaper and makes it much more popular among the people. But at the same time, it can have negative sides like social isolation. Also, it's very vital that all devices and gadgets for AR and VR technologies shall be properly tested, controlled and pass through the accreditation of authorized authorities. This is one of the key factors to use AR and VR technologies and implement them in the educational process

successfully.

Nevertheless, we cannot deny refusing that AR and VR will take enormous place in teaching and learning in the future and give the opportunity to make very appreciably step in the education process.

# A. Appendix A





# B. Appendix B

Нұр-Сұлтан қаласы «№9 «Зерде» мамандандырылған мектебінде»  
«Толықтырылған және виртуальды шындықты оқу үрдісінде  
пайдалану» тақырыбы бойынша өткізілген эксперименттік жұмысқа

## ПІКІР

Аталған тақырыптағы эксперименттік жұмыс физика пәнін оқитын 7-сынып оқушылары арасында өткізілді. Магистрант ұсынған құрал мен оған жасалған бағдарламаның пәнді оқытудың тәжірибелік бөлігінде қолдануға тиімді екені байқалды. Күн жүйесіндегі планеталар туралы түсінік берілген кезде, виртуальды түрде планеталарды елестету оқушыларды қызықтыра білді. Оқыту үрдісінде кез-келген тақырыпты түсіндіру барысында көрнекі құрал ретінде пайдалануға болады. Оқушылардың заманауи құралдарға қызығушылығы жоғары екенін ескеретін болсақ, бұл құралмен жаңа білімді игеру немесе өз бетінше жұмыс жасауға баулу кезінде пайдалану өз нәтижесін береді деп ойлаймын.

Виртуальды шындық (Virtual Reality, VR) — техникалық құрылғылардың көмегімен жасалған жасанды әлем пәнді оқытудың дидактикалық бөлімін қанағаттандырады. Сонымен қатар виртуальды шындық арқылы берілген білім оқушының сезіміне әсер етіп, берілген теориялық мәліметті жақсы қабылдауына көмегі зор.

Физика пәні бойынша қолданылған VR құрылғысы айқын көріністерді шынайы түрде қабылдауға әсерін тигізді. Осылайша пайдаланушыға виртуальды нысандармен немесе нысандарды пайдаланушымен әрекеттесуге мүмкіндік берді. Оқушылардың қызығушылықтары жоғары болғандықтан мұғалім сабақта пайдалану тиімді.

Мектеп бағдарламасындағы кез-келген пәннің практикалық бөлігінде қолдануға ұсынуға болады.

Пән мұғалімі  Д.Ертісхан  
Мектеп директоры  В.Жәнібекова



# References

- [1] Goldman Sachs Global Investment Research. *Profiles in Innovation: Virtual & Augmented Reality*. URL: <https://www.goldmansachs.com/insights/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf>. (published: 13.01.2016).
- [2] Prof. Dr. Wolfgang Schnotz, Dr. Shaaron Ainsworth. *Visual Thinking and Learning: ViTaL*. URL: [https://moodle.fct.unl.pt/pluginfile.php/20502/mod\\_resource/content/0/diversos/ESFViTaL.pdf](https://moodle.fct.unl.pt/pluginfile.php/20502/mod_resource/content/0/diversos/ESFViTaL.pdf).
- [3] Ivan Edward Sutherland. *From Wagner to Virtual Reality*. The Ultimate Display. Multimedia. New York, NY: Norton, 1965, pp. 506–508.
- [4] Morton L Heilig. “Sensorama Simulator. 8 Sheets-Sheet 1 Filed Jan. 10, 1961 ATTORNEY Aug. 28, 1962 M. L. HEILIG 3,050,870”. In: *Google Patents Database* (1961), pp. 891–921. DOI: <https://patents.google.com/patent/US3050870>.
- [5] Maddalena Gigante. “Virtual reality: definitions, history and applications.” In: *Virtual Real. Syst.* 3–14. 10.1016/B978-0-12-227748-1.50009-3 (1993), pp. 3–14.
- [6] IHS Markit. *Augmented and Virtual Reality Consumer Content and Apps Market Hits \$3.2 Billion in 2017*. URL: <https://technology.ihs.com/601858/augmented-and-virtual-reality-consumer-content-and-apps-market-hits-32-billion-in-2017-ihs-markit-says>. (published: April, 2018).
- [7] IDC. *Augmented Reality and Virtual Reality Headsets Poised for Significant Growth, According to IDC*. URL: <https://www.idc.com/getdoc.jsp?containerId=prUS44966319>. (published: March, 2019).
- [8] L. Frank Baum. *The Master Key*. Bobbs-Merrill Company, 1901, p. 94.

- [9] Randall C. Smith, Randall C. Smith. "On the Representation and Estimation of Spatial Uncertainty". In: *The International Journal of Robotics Research*. 5 (4) (1986), pp. 56–68.
- [10] John Leonard, Hugh F. Durrant-Whyte. "Simultaneous map building and localization for an autonomous mobile robot." In: *Intelligent Robots and Systems' 91. Intelligence for Mechanical Systems, Proceedings IROS'91. IEEE/RSJ International Workshop* (1991), pp. 1442–1447.
- [11] Jorge Bacca, Sabine Graf, Silvia Baldiris Ramon Fabregat. "Augmented Reality Trends in Education". In: *A Systematic Review of Research and Applications. Educational Technology and Society*, 17(4) (2014), pp. 133–149.
- [12] ScopeAR. *Augmented reality delivers real-world results*. URL: <https://www.scopear.com/>.
- [13] Samsung Newsroom Global. *VR in the Classroom. What teachers think about?* URL: <https://news.samsung.com/global/survey-shows-that-teachers-see-potential-for-virtual-reality-in-education>. (published: February, 2017).
- [14] Andreas Duenser et al. "Virtual and Augmented Reality as Spatial Ability Training Tools". In: *ACM International Conference Proceeding Series* 158 (Jan. 2006). DOI: 10.1145/1152760.1152776.
- [15] William Winn and Randy Jackson. "Fourteen Propositions About Educational Uses of Virtual Reality". In: *Educational Technology* 39.4 (1999), pp. 5–14. ISSN: 00131962. URL: <http://www.jstor.org/stable/44428537>.
- [16] Misty Antonioli, Corinne Blake, and Kelly Sparks. "Augmented Reality Applications in Education". In: *The Journal of Technology Studies* 40.1/2 (2014), pp. 96–107. ISSN: 10716084, 15419258. URL: <http://www.jstor.org/stable/43604312>.
- [17] Kristen Kessinger. *2016 ISACA IT Risk/Reward Barometer*. URL: <http://www.isaca.org/About-ISACA/Documents/rrb/2016-IT-RRB-US-Consumer-Results.pdf>. (published: October, 2016).