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Nataliia V. Soroko
PhD of Pedagogical Sciences, Head of the Department of Technologies of Open Learning Environment
Institute of Information Technologies and Learning Tools of NAES of Ukraine, Kyiv, Ukraine
ORCID ID 0000-0002-9189-6564
nvsoroko@gmail.com

Volodymyr M. Soroko
PhD of Technical Sciences, Associate Professor,
Scientific and Educational Institute of Public Administration and Civil Service, Department of Public Policy
Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
ORCID ID 0000-0002-7240-0818
vmsoroko@ukr.net

Manargul Mukasheva
PhD, Associate Professor
National Academy of Education named after I. Altynsarin, Nur-Sultan, Kazakhstan
ORCID ID 0000-0002-8611-8303
mg.mukasheva@gmail.com

Mª Matilde Ariza Montes
Physics and Chemistry teacher,
IES "Pedro Espinosa", Antequera (Málaga), Spain
ORCID ID 000-0002-6210-7167
matiariza@iespedroespinosa.es

Vitalii A. Tkachenko
Researcher of the Department of Network Technologies and Databases,
Institute of Information Technologies and Learning Tools of NAES of Ukraine, Kyiv, Ukraine
ORCID ID 0000-0003-4028-4522
tva@iitta.gov.ua

USING OF VIRTUAL REALITY TOOLS FOR THE DEVELOPMENT OF STEAM EDUCATION IN GENERAL SECONDARY EDUCATION

Abstract. The article researches the use of virtual reality to support STEAM education in general secondary school. To study the impact of STEAM education, the authors proposed a teaching project for the secondary school about convex mirrors and their importance for special visibility and human safety, where the interviewed teachers were able to learn about a real example of the implementation of STEAM education for teaching their disciplines. The purpose of the article is to analyze the meanings and approaches to the use of virtual reality by teachers for organizing the STEAM-oriented learning environment and to identify the basic requirements to VR for supporting the implementation and development of STEAM education. One of the main trends of education modernization is STEAM education, which involves the integration of the natural sciences, the technological sciences, engineering, mathematics and art in the learning process, in particular, at general secondary schools. In light of the findings, researchers indicate that electronic educational resources (including VR & AR) are not only teaching tools for teachers but also a source of inspiration for students, which motivates and stimulates creative thinking. This is an important point considering that creativity is increasingly an important life skill that can help young people cope with the difficulties and uncertainties in their future careers in the fields of STEAM. Prospects for further research are seen in the creation of a model for assessing student performance in STEAM projects. The authors are planning to take into account the differences and features of the use of virtual reality for learning STEAM in schools in different countries, including Ukraine, Spain and Kazakhstan, when creating a multilevel model of STEAM-oriented learning environment using virtual reality tools. The purpose of the model is to evaluate not only the results of tests taken by students after learning this material but also their personal contribution to the final project product, their leadership skills, creative ideas and suggestions, abilities and skills in using ICT and VR in project research. In our next publications, we will focus on several

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Spanish and Kazakhstani secondary schools to detect the possible differences found in the use of virtual reality to support STEAM education in Ukrainian schools.

Keywords: STEAM-oriented approach; STEAM education; STEAM-oriented educational environment; virtual reality.

1. INTRODUCTION

The problem statement. The international practice of labour market transformation testifies to the rapid introduction of virtual reality tools into traditional and new professions, which requires the formation of appropriate competencies in young people [22].

The main purpose of education is comprehensive development, upbringing, identification of talents, socialization of a person who is capable of living in society, has a desire for self-improvement and lifelong learning, is ready for conscious life choices and self-realization. Achievement of this goal is guaranteed by forming the key competencies necessary for every modern person to succeed in life and in particular competencies in the field of natural sciences, engineering and technology, innovation, including digital competence. One way to achieve this goal will be STEAM-education (education that encompasses science, technology, engineering, art and mathematics) – courses or learning programs that prepare students for further education after school or successful employment, require different and more technically complex skills, including the use of mathematical knowledge and scientific concepts [12]. The introduction of STEAM education promotes the development of abilities for research, analytical work, experimentation and critical thinking. It can also be a good idea for teachers of different subjects to devise specific STEAM projects, where students are required to use a range of different STEAM skills at once and ICT, particularly VR tools.

Information and communication technologies, in particular the virtual reality tools, can provide an approximation of reality for students to better understand subjects in the fields of STEAM [11]; [21]; [23].

Analysis of recent studies and publications. The digital era that began in the 20th century laid the foundations for an incipient change in our society, transforming it not only in terms of economic and professional aspects but also in the way of building knowledge and establishing social relationships. It is young people and, in particular, secondary education students who are at the forefront of its use, hence changes in pedagogy are taking place in a substantial, rapid and recognized way. Since the beginning of new technologies in the classroom and the increase in individual digital screens, teachers and students have assisted each other in the promotion of new digital strategies for teaching and learning. In this way, a new scenario was born based on digital pedagogy, in which computers in the classroom and different devices in homes have brought new challenges for teaching and learning with 21st century technologies. School 2.0 initiated, which launched digital classrooms. Education 3.0 followed with new ICT resources that promoted a new, more interactive, learning model and the use of social networks in the classroom. Currently, Education 4.0 is being introduced with great speed, promoting cooperative and competency learning, where the advancement of technologies such as virtual reality, among others, drives students' success in this technological and globally connected world.

The virtual reality (VR) as a learning tool has been researched by such scholars as P. Fuchs, G. Moreau and P. Guitton (2011), who studied virtual reality as an ambiguous concept, and the devices, motor interfaces for virtual reality that can be used in other sectors like metrology, robotics, etc. [14]. Williams Leslie Michelle (2013) described online learning environment using virtual reality tools in his dissertation "A Case Study of Virtual Physical

Education Teachers' Experiences in and Perspectives of Online Teaching" [23]. Martín-Gutiérrez et al. (2017) researched opportunities to teach in virtual environments that are impossible to visualize in physical classrooms, like accessing into virtual laboratories, visualizing machines, industrial plants, or even medical scenarios [8]. O. Pinchuk et al. (2020) offered a systemic structural model in the virtual reality that demonstrates psychophysiological regulation of the cognitive activity in VR [15]. S. Lytvynova et al. (2021) described the trends in the application of VR and AR (augmented reality) technologies for the popularization of science in education [7].

The VR as a tool for supporting the STEAM education has been researched by P. Truchly et al. (2018), who analyzed Virtual Reality Applications for STEM Education as "various VR-supported instructional design practices in K-12 (Primary and Secondary) and Higher Education in terms of participants' characteristics, methodological features, and pedagogical uses in alignment with applications, technological equipment, and instructional design strategies" [21]. R. Singh et al. (2020) described significant applications of virtual reality to STEM Education in COVID-19 pandemic [19].

Scholars note that VR is beneficial for remote sites and as a way to make STEAM learning more hands-on, exciting, and practical.

The research goal of the article is to analyze the meanings and approaches to the use of virtual reality by teachers for organizing the STEAM-oriented learning environment and to identify the basic requirements to VR for supporting the implementation and development of STEAM education.

It presumes to accomplish the following objectives:

- to stimulate teachers' and students' interest in STEAM careers;
- to introduce an example of a STEAM project for schools;
- to implement the STEAM project using virtual reality;
- to explore the extent of understanding of virtual reality used in STEAM education among teachers;
- to study the impact of virtual reality among teachers to support STEAM education in Secondary schools.

2. THE THEORETICAL BACKGROUND

Jaron Lanier et al. proposed the term "Virtual Reality (VR)" in the 1980s [14]. They described this term as the head-mounted displays that electricians used when assembling complicated wiring harnesses.

In 2014, Virtual Reality was encouraged by the arrival of helmets that are both more efficient and affordable. The Oculus Rift Headset was released to the market in 2013, and it was on the mainstream market in March 2016. Google was the first company to play the core role in the development of this technology proposing in 2014 a model of VR helmets in cardboard called Google Cardboard. Smartphones has been used as a display system since that time. Subsequently, other companies manufactured versions of the Cardboard, such as Samsung through its Gear VR (the mobile version of the Oculus Rift). Versions of VR headphones connected to a computer or game console have also been available on the public market since the year 2016.

Augmented Reality (AR) is a technology that allows virtual elements superimposed on our vision of reality. Thomas P. Caudell coined this term in 1992. AR is a system that has the following characteristics: it combines the real and the virtual, is interactive in real time, and registered in 3-D [16].

In 2020 the most popular applications of Virtual Reality were “Buzz Aldrin: Cycling Pathways to Mars”, followed by The Body VR, Universe Sandbox VR, 3D Organon Anatomy, Star Chart, Narupa XP, Solar AR, Earth AR, Aurasma / HPReveal, Cleanpolis VR, Acropolis interactive educational VR 3D, My Way VR, Boulevard, Titanic VR, Smart Education Labs, Unimersiv, Apollo 11 VR, The VR Museum of Fine Art, In Mind 2, Human Anatomy VR, among others.

Due to the big variety of applications related to virtual reality, they can be presented as the following core types:

1. VR according to the user's sense of reality (Fig. 1):

– VR with full immersion providing a realistic simulation of the virtual world with a high degree of detail (for example, Virtual Shooter gaming zone);
– VR with semi-immersion include the VR and real world attributes by embodying objects of computer graphic into the scene of the reality (for example, flight simulator) [2];
– VR without immersion refers to a virtual experience through a computer where we can control some characters or activities within the software, but the environment is not directly interacting with us (for example, World of WarCraft, ReHabgame);
– VR with collaborative infrastructure is a three-dimensional virtual world with elements of a social network (for example, Minecraft already has a virtual reality version that supports Oculus Rift and Gear VR helmets) [9];
– VR with AR, which does not fully immerse the user, but it differs in that it overlays virtual and real elements (for example, Pokemon Go) [9].

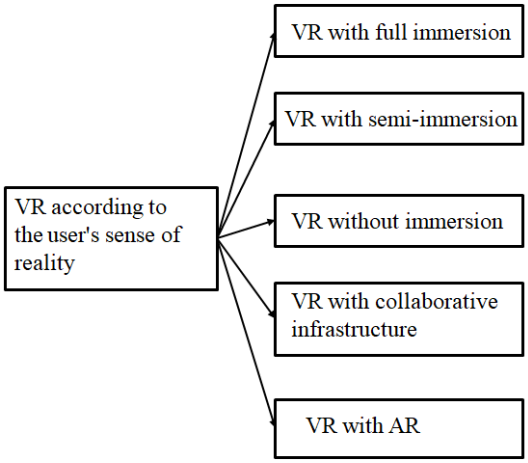

Figure 1. The classification of VR types according to the user's sense of reality

2. VR according to the type of VR applications:

– the simulation of real environments such as the interior of a building or a spaceship, often with the purpose of training or education (for example, Virtual pediatric simulation, Virtual Human Anatomy, VR Space Simulator et al.);
– the development of an imagined environment, typically for a game or educational adventure (for example, Virtual Reality on Steam (https://store.steampowered.com/vr/) et al.);
– CAVE Automatic Virtual Environment as a projection-based VR display that was first developed at the Electronic Visualization Laboratory [4] (for example, VisCube™ (http://www.visbox.com/products/cave/) et al.);

– apps for professionals who need to collaborate, meet, discuss, present, and make collective decisions (for example, Connec2, Immersed, MeetingRoom, vSpatial, Rumii, STAGE et al.).

3. VR according to the type of VR accessories (Fig. 2):

– types for VR with full immersion are such as VR chair (for example, https://www.rotovr.com/vrchair) or brain-controlled robotic exoskeleton and the VR helmets, gloves & body connectors with sense detectors, which can support the VR with full immersive technology [5], Room-based or CAVE-type systems [10];
– types for VR with semi-immersion are such as VR helmets with two controllers or VR glasses of different models;
– types for VR without immersion are a standard desktop computer, mouse and joystick or only smartphone [18];
– types for VR with collaborative infrastructure are, for example, Room-based or CAVE-type systems and VR helmets with two controllers [1];
– types for VR with AR are AR glasses, which superimpose synthetic information on a transparent glass and require an external pad – consisting of an Android device used to execute and to control its AR apps (for example, Epson Moverio) – and others such as do not need an external device (for example, Microsoft Hololens), or are more advanced and are equipped with sensors that permit users to interact with virtual objects naturally (for example, META) [8].

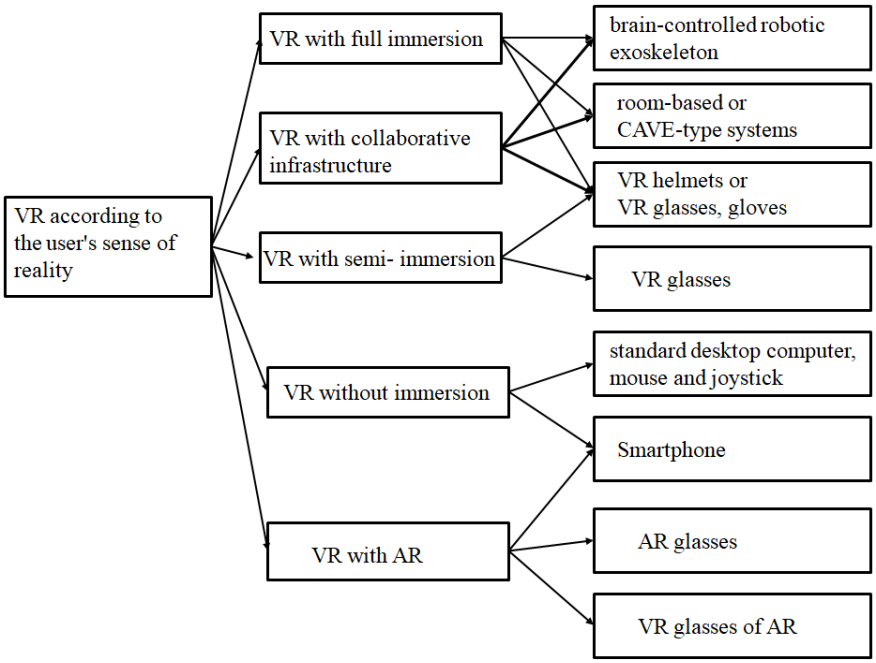

Figure 2. The classification of VR types according to the type of VR accessories

Someone owning a pair of VR glasses or a smartphone with a VR cardboard device can access education and training applications. In terms of learning, users are able to create special apps for VR which serve as a unique interactive platform. Schools have been experimenting with adding VR as a teaching tool and making VR lectures a part of the curricula.

We should pay attention to the fact that virtual reality tools are gaining significant relevance in STEAM Education.

A researcher can use search engine Open Access Theses and Dissertations (OATD), which is one of the largest archives of scientific research (there are about 2,800,000 dissertations and theses of graduates of more than 1,000 research institutes, universities and colleges), and find by keywords «Virtual Reality in STEAM Education» about 104,29270 documents for the period from 2017 to 2021 years. These documents include such research areas (https://oatd.org/oatd/search?q=Virtual+Reality+in+STEAM+Education&form=basic&pubdate.facet=2017): Psychology – 6136 documents, Mechanical Engineering – 5326 documents, Chemistry – 4297 documents, Computer Science – 4187 documents, Education – 4120 documents, Medicine, Nursing and Health Sciences – 4114 documents, Engineering – 3720 documents, Physics – 3103 documents, Electrical and Computer Engineering – 3082 documents, Civil Engineering – 2944 documents, Electrical Engineering – 2919 documents, Electrical Engineering and Computer Science (EECS) – 2707 documents, English language learning – 2554 documents, Economics – 2521 documents.

We looked at documents related to different levels of education (https://oatd.org/oatd/search?q=Virtual+Reality+in+STEAM+Education&form=basic&pubdate.facet=2017&discipline.facet=Education) and were able to determine that educators use VR for STEAM learning projects for such basic purposes: using VR museums, supporting teamwork and collaboration, using VR tools for study with specific purposes (research in mathematics, physics, chemistry, biology, medicine, business and scientific language, etc., which can be combined to solve a real problem of the study).

3. RESEARCH METHODS

To achieve the goal of the study, we used the method of systematic and comparative analysis of pedagogical, philosophical, sociological works, methodological and specialized literature to clarify the approaches to using VR tools in STEAM education; the method of analysis of experience of using STEAM-projects in schools; the method of synthesis and generalization of research literature to clarify the problem of using VR tools in STEAM education, to interpret research results within the topic of the article; the method of analysis of the results of teachers' survey on their attitudes and understanding the use of virtual reality in STEAM education.

The training project "Extra visibility and Security: The Convex Mirrors" on project implementation for a general education institution within VR and STEAM approach belongs to Soroko N., Mª Matilde Ariza Montes.

The advice on the methodology of using virtual reality and accessories for various purposes of using virtual reality in the classroom belongs to Soroko V. and Tkachenko V.

Consideration of national programs and ideas for the adaptation of the training project within VR and STEAM approach belongs to Manargul M.

4. THE RESULTS AND DISCUSSION

One of the tasks of our research was to study if teachers understand the use of virtual reality in STEAM education and aware the difficulties when implementing a STEAM project in the classroom, by using the computerized simulation of modern spaces, in particular virtual reality.

The suggested method included the introduction of a STEAM training project entitled "Extra visibility and Security: The Convex Mirrors", which short-term consequences provide the STEAM career in students. This STEAM project was conducted by Mª Matilde Ariza

Montes, from Instituto de Enseñanza Secundaria “Pedro Espinosa”, Antequera (Málaga, Spain), Nataliia V. Soroko, from Institute of Information Technologies and Learning Tools of NAES of Ukraine (Kyiv, Ukraine) and Kseniia Minakova, from National Technical University "Kharkiv Polytechnic Institute" (Kiev, Ukraine), in 2020 within the “Integrated STEM Teaching for Secondary Schools” MOOC by European Schoolnet Academy. We offer the plan and basic materials for the project in Table 1 The plan of the training Project “Extra visibility and Security: The Convex Mirrors”.

To obtain the objectives, our research is focused on teachers from Secondary schools (Levels I-III N1 in Brovary (Ukraine), Semipolkivskyi Secondary School of the 1st-3rd Grade (Ukraine), Specialized school №181 named after I. Kudri with in-depth study of foreign languages (Kyiv, Ukraine)) to determine their attitude to using virtual reality in STEAM education.

Table 1

The plan of the training Project “Extra visibility and Security: The Convex Mirrors”

The components of the project	The short description of components.
Title	“Extra visibility and Security: The Convex Mirrors”
Summary	The purpose of the STEAM learning about Convex Mirror is to introduce students to the principles of geometric optics and convex mirror technology. Students will use convex mirrors and rear mirrors, streets and buildings to explore the design and use of these technologies in real-live where they will be challenged to develop system solutions. Students will need to adhere to given specifications and constraints and come up with solutions in real-world situations. Students must understand and imagine the optical system of the human eye; properties of the eye as a natural optical device; understand and be able to apply the laws of light reflection in practice; to solve real problems connected with adjustment of spherical mirrors, control of a condition of the eyes.
Subjects and interdisciplinary connections for the STEAM learning	Physics: Laws of Geometric Optics of convex mirrors. Chemistry: Composition of convex mirrors. Technology: Discovery of manufacturing techniques for convex mirrors. Mathematics: Carrying out the calculations of the magnitudes involved in convex mirrors. IT: Consultation of web bibliography, intercommunication and presentation of the project, web blogs, web simulations. English Language: Use of this language for communication; professional slang. Literature: Umberto Eco “The Name of the Rose”; Lewis Carroll “Alice in Wonderful”. History: History of spherical mirrors in human civilization. Artistic Design: Design of new shapes for convex mirrors. Human Biology: 1. Human visual sensory system. Eye Anatomy. 2. Optical eye system. Accommodation. Refraction and its types. Visual impairment.
Real-life questions	How can we help people see around them? Is it possible to create an artificial eye that can work like a real one and see in the dark? Where is the necessary to use curved mirrors? Is it possible to make a spherical mirror yourself? Can we have total visibility in the bifurcations? Where do we use the convex and concave mirrors in our daily life? Where and when did humanity use mirrors in History? What type of mirror is used more in artwork?

Aims of the lessons in the project	Students are expected to demonstrate understanding how the selected subjects are used and linked between them. They need to understand why spherical mirrors are needed in real life; how these tools are related to human health. They must be creative and logical in creating the design of such a mirror, using knowledge of physics, geometry, biology, chemistry, etc. - Physics: Understanding the relationship between optics and convex mirrors. Explore the principles of convex mirrors and their technology. Design, build and demonstrate the importance of smart mirrors. Generate a map of places with poor visibility. Design innovative solutions to real-world problems, challenges and needs from citizens and drivers. - Mathematics: Study and become familiar with the geometric properties of the convex mirrors applied in Physics. - Chemistry: Chemical compounds of convex mirrors and some reactions take place thanks to environmental places too. - Biology: Students will study the parts of the eye and visual effects. - Art History: Identify the role of optics and, in particular, the convex mirrors as a fundamental way of studying using mirrors in history. - Literature: Strengthen the entrepreneurial spirit with attitudes of creativity, flexibility, initiative, teamwork, self-confidence and a critical sense. - Language: to develop students' abilities and skills to use scientific terms and concepts, to apply them in communication on the research topic.
Connection to STEAM careers	Physicist: Data analyst, design engineer, lab technician, physicist designer. Mathematician: Biostatistician, data scientist. Chemist: Analytical chemist, inorganic chemist, organic chemist, chemical engineer. Engineer: Coating technician, computer engineer, electronic engineer, laser engineer, optical engineer. Biologist: Biochemist, computational biologist, ophthalmologist. Artist/Historian: Architect, light designer, production designer, expert in museum installations.
Age of students	14-16 (Consolidation) 16-18 (Deepening)
Time	Preparation time: 50 min. Sharing ideas with colleagues to implement the activities in a significant way (60 min.). Teaching time: Subject 1 Physics: The CLIL approach was employed in order to introduce students to the topic of «The Convex Mirrors»: 60 min Subject 2 Mathematics: Students were introduced to the trigonometric relationships and the geometric properties of the sphere, the solid angle: 60 min. Subject 3 Chemistry: The lesson was dedicated to the study of chemical composition of convex mirrors, their chemical reactions and their kinetics: 60 min. Subject 4 Human biology: The lesson was dedicated to «Eye and sight, natural convex mirrors»: 60 min. Subject 5 Art History: Students were initiated to artworks with convex mirrors and their history: 60 min. Subject 6 Language: Students are initiated with new vocabulary and scientific expressions: 60 min. Subject 7 Literature: The lesson was dedicated to works of literature where authors write using convex mirrors.: 60 min.
Teaching resources (material & online tools)	Materials: Smartphone, PC, textbooks, resources provided by the teacher, Physics and Chemistry lab Tools that can be used as convex mirrors: covers from different objects, woks, ladles,

	eye model. A ruler for measuring the field of vision from convex mirrors in cars, streets and buildings. Online tools: For Physics lesson: https://www.insight-security.com/convex-mirrors#What%20is%20a%20convex%20mirror http://mirrortechnology.co.uk/ https://www.youtube.com/watch?v=jtTBOMVMSYM https://www.youtube.com/watch?v=tbcpAKRTYxE Games and simulation: https://www.physicsclassroom.com/Physics-Interactives/Reflection-and-Mirrors https://www.edumedia-sciences.com/en/media/275-plane-mirror https://www.edumedia-sciences.com/en/media/6-the-eye-inverted-image https://www.edumedia-sciences.com/en/media/727-nearsightedness Quiz: Lenses: https://www.edumedia-sciences.com/en/media/19-quiz-lenses Games and simulation: Optics of the Human Eye: https://ophysics.com/l16.html For Mathematics lesson: Online tools: GeoGebra Math Apps: https://www.geogebra.org For Biology lesson: Parts of the eye: https://www.aao.org/eye-health/anatomy/parts-of-eye Clastic anatomical model: http://museovirtualiespedroespinosa.blogspot.com/2015/11/ojo-a.html Quiz: accommodation of the eye: https://www.edumedia-sciences.com/en/media/489-quiz-accommodation-of-the-eye For History lesson: https://www.omelomirrors.com/blog/the-convex-mirror-in-renaissance-art/ https://www.furniturelibrary.com/mirror-glass-darkly/ For the Literature lesson: Book: Lewis Carroll “Alice in Wonderful” (12-16) https://www.adobe.com/be_en/active-use/pdf/Alice_in_Wonderland.pdf Book: Umberto Eco “The Name of the Rose” (16-18) http://www.goodwin.ee/ekafoto/tekstid/Eco%20Umberto%20-%20The%20Name%20Of%20The%20Rose.pdf
VR	For Physics and Mathematics lessons: the OptiLab; https://www.vrlabacademy.com/Product-Detail/416/Laser-Optics-Experiment.html; https://www.vrlabacademy.com/Product-Detail/388/Basic-Optics-Experiment.html. For Biology lesson: human anatomy atlas: https://www.visiblebody.com/anatomy-and-physiology-apps/human-anatomy-atlas. For Science and Art History lesson: the MUVIPA (Museo Virtual del Patrimonio del IES “Pedro Espinosa” / Virtual Museum of Heritage from IES “Pedro Espinosa”) in the link: http://museovirtualiespedroespinosa.blogspot.com/search?q=ESPEJO+CONVEXO+

In Table 2, we offer a schedule of project activities in accordance with the lessons in subjects in the STEAM fields, which displays and supports inquiry-based science education (IBSE) [6]; [17], project-based learning (PBL) [20], challenge-based learning (CBL) [6]. We have used the Museo Virtual del Patrimonio (Virtual Museum of Heritage) del IES “Pedro Espinosa” [3] in the STEAM project.

In this approach, a virtual prototype was implemented in VR with semi-immersion. The evaluation of VR approach is based on the students’ achievement of project goals. Teachers reported that the results of project implementation demonstrated a significant effectiveness of using VR in increasing the cumulative project grade and specifically the impact on the

implementation component of the project in addition to enhancing the engagement and motivation of the students and better course outcomes.

Table 2.

The schedule of project activities in accordance with the subjects in the STEAM fields

Name of activity	Procedure	Time
1st Lesson		
Brainstorming and discussion	What is a mirror? Why do you need a mirror? What is a spherical mirror? Where is a spherical mirror in the nature ? Combine students into groups for discussion (3 students in the group)	15 min (discussion); 20 min (students' presentations).
Discussion and preparation for the next lesson	Is it possible to create an artificial eye that can work like a real one and see in the dark? How can you design a smart eye, smart mirror? You can offer drawings of models with the help of programs, for example: GeoGebra Math Apps: https://www.geogebra.org; Optics of the Human Eye: https://ophysics.com/l16.html Group presentation Demonstration of the use of spherical mirrors, periscope model.	60 min (students work out of school).
2nd Lesson		
STEM Subject 1	Physics	
Understanding how to measure object and images with different convex mirrors	"Groups sharing understanding" activity: size difference between the object vs its image. Studying size difference between the object vs its image: to recall the concepts explained in Optics.	30 min.
Experiment A	Every student measures different object sizes with different convex mirrors to calculate image sizes	30 min.
Experiment B	All students in groups measure the visibility obtained in the convex mirrors in a car, a street and a building.	30 min (students work out of school).
Learning products	Outcomes of different researches from the groups. They must do a scientific poster that will be explained in class.	60 min (students work out of school).
3rd Lesson		
STEM Subject 2	Mathematics	
Entry test and flipped activity to deepen geometrical property of sphere	Entry test-trigonometry and geometry	30 min.
Convex mirrors Cost calculation	Students compare convex mirrors cost and calculate it for different places and buildings.	60 min.
Learning products	Outcomes of various activities using tables and graphs.	30 min.
4th Lesson		
STEM Subject 4	Chemistry	
Introduction to reactions and experiment	Chemistry lab experiment; Students are divided into five groups. Each group will have to develop an educational video to highlight the experimental method to make convex mirrors.	40 min.
Learning products	Presentation "Mirrors. How it's made" https://www.youtube.com/watch?v=u03S1Nmslw4	20 min.
5th Lesson		
STEM Subject 5	Human Biology	
Introduction to Anatomy	Students will learn about the parts of the eye.	30 min.

Introduction to reactions and experiment	The purpose is to deepen students' knowledge of the phenomenon of refraction; to acquaint students with the structure of the eye as an optical system; to form ideas about visual defects and methods of their correction; to explain the causes of visual impairment;to teach students to follow the rules of visual hygiene; to show the fundamental unity of the natural sciences	15 min.
Test about the parts of the eye	For example, "The Eye – Science Quiz": https://online.seterra.com/en-an/vgp/3802	15 min.
Learning products	Group presentation; Demonstration of the structure of the eye as an optical system by using PPT or Scratch	30 min.
6th Lesson		
Art Subject 1	Art History	
Introduction to Optics in History	Compare images of selected art masterpieces from the different periods. Reflect on how the light-work of art interaction has changed over time.	60 min.
Historical materials	Discover the MUVIPA (Museo Virtual del Patrimonio del IES "Pedro Espinosa" / Virtual Museum of Heritage from IES "Pedro Espinosa") in the link: http://museovirtualiespedroespinosa.blogspot.com/search?q=ESPEJO+CONVEXO+	30 min (students work out of school)
7th Lesson		
Art Subject 2	Language	
Introduction to new vocabulary in English	Topic: Professional language Learning a professional language is like being included into the profession through the shared use of metaphors and terminology. Knowledge of professional language is one of the steps to a successful future career.	45 min
Learning products	Make a blog with a glossary about some topics. Physics: Laws of Geometric Optics of convex mirrors. Human biology: 1. Human visual sensory system. Eye Anatomy. 2. Optic system for the eye. Accommodation. Refraction and its types. Visual impairment.	30 min (students work out of school)
8th Lesson		
Art Subject 3	Literature	
Discussion about mirrors in the literature	Students will discuss the creative abilities of authors of works of art when they use mirrors as an element of scientific knowledge transfer.	30 min.
Learning products	Each group will make a PowerPoint presentation in which they will use all the information learned during the lessons. Essays on the topic Extra Visibility and Security: The Convex Mirrors.	30 min (students work out of school)

This approach builds on the number of studies how VR can be used successfully within the Science, Technology, Engineering, Mathematics and Art (STEAM) curricula, and the recent availability of low cost and stand-alone VR headsets.

In addition, two surveys were designed where the pros and cons of this new methodology could be visualized, in such a way that each teacher reported a degree of their satisfaction, classified in five blocks from lowest to highest satisfaction:

- Strongly disagree (SD);
- Disagree (D);
- Neither agree nor disagree (NAND);
- Agree (A);
- Strongly agree (SA).

The first survey focused on their attitudes and understanding virtual reality in STEAM education The surveys were conducted online among 24 teachers from a Primary Education school and 70 teachers from Secondary General Education two schools (Levels I-III N1 in Brovary (Ukraine), Semipolkivskyi Secondary School of the 1st-3rd Grade (Ukraine), Specialized school №181 named after I. Kudri with in-depth study of foreign languages (Kyiv, Ukraine)). It consists of four statements:

- I have a clear understanding of what virtual reality is and how I can integrate it with STEAM education in my class;
- I have heard colleagues talking about virtual reality in STEAM education;
- I have talked with colleagues about virtual reality in STEAM education;
- I can use teaching approaches with virtual reality that foster integrated STEAM education.

The results of teachers' survey on their attitudes and understanding the use of virtual reality in STEAM education are demonstrated in Table 3 (Table 3, Figure 3).

Table 3.

The results of teachers' survey on their attitudes and understanding the use of virtual reality in STEAM education (Ukraine)

	Strongly disagree (%)	**Disagree (%)**	**Neither agree nor disagree (%)**	**Agree (%)**	**Strongly agree (%)**
I have a clear understanding of what virtual reality is and how I can integrate it with STEAM education in my class	18,0	37,0	12,0	29,0	4,2
I have heard colleagues talking about virtual reality in STEAM education	13,0	24,0	19,0	36,0	7,4
I have talked with colleagues about virtual reality in STEAM education	18,0	35,0	14,0	33,0	0,0
I can use teaching approaches with virtual reality that foster integrated STEAM education	18,0	43,6	25,5	12,7	0,0
Total (N= 94)					

According to the survey results on teachers' understanding VR to be provided for supporting the STEAM-oriented approach in the general school teaching process, the teachers are not highly interested in using VR in STEAM education.

At the same time, the results were found out to show certain teachers' interest in the use of VR in STEAM education.

Despite not very high percentage of positive responses, 68 teachers, who participated in the questionnaire, reported on their readiness to use VR technology in their lessons.

This data gave us the impetus to create, organize and conduct a training project using virtual reality.

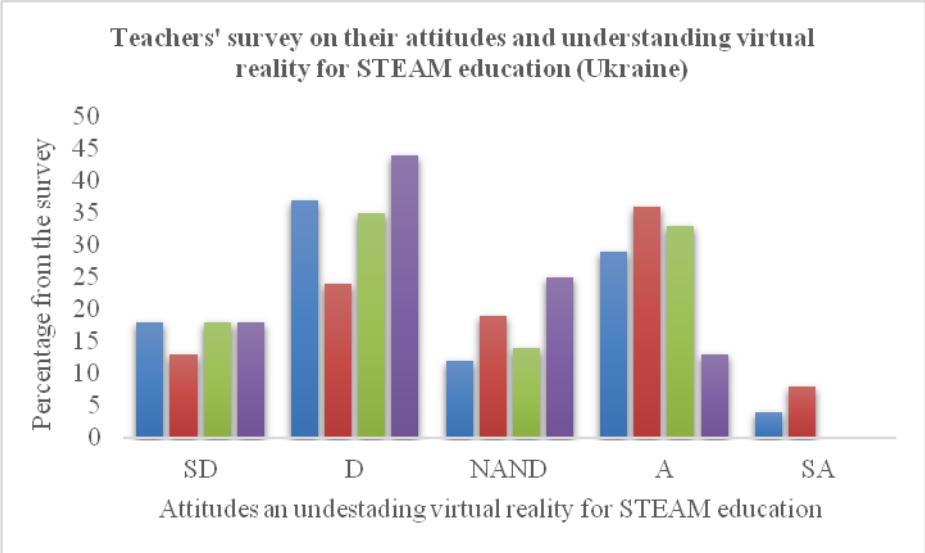

Figure 3. Teachers' survey on their attitudes and understanding the use of virtual reality in STEAM education (Ukraine)

It should be noted that it is important to find out all aspects of organizing the training project among the teachers who participated in it[11]. We had to plan the learning activity, to describe it and arrange the time for each lesson in STEAM project. For example, the team of teachers designed the following components of the project: activity, procedure and time for each component.

After conducting training project "Extra visibility and Security: The Convex Mirrors**"** in three schools (Ukraine, 2020), we asked the participants (68 secondary school teachers) to answer the questionnaire, which included the following questions related to their teaching experience (Table 4, Fig. 4):

- Impressions from the organization and realization of the event;
- Positive and negative experience of project implementation with using ICTs, in particular, VR;
- Problems that we met during the organization of the project at school;
- Problems that we had using VR in conducting research for students;
- Questions about the motivation of teachers to conduct training projects using VR;
- Questions about the motivation of students to participate in training projects using VR;
- Requirements for the teachers to use ICTs for the implementation of activities within STEAM projects; problems of carrying out the project remotely in the conditions of quarantine.

Thise survey focused on the impressions of the organization and realization of the event. It is made up of seven first-person statements:

- I enjoyed the project;
- I had many problems with the organization of project activities;
- I had some problems using tools for group work with teachers;
- I had some problems using tools for group work with students;
- I used all the ICTs and VR tools in the project plan;
- Students completed the tasks of all lessons;
- Students created the products that were offered in the project;

– I had no problems assessing students' performance.

Table 4.

The results of teachers' survey on impressions from the organization and realization of the event (Ukraine)

	Strongly disagree (%)	**Disagree (%)**	**Neither agree nor disagree (%)**	**Agree (%)**	**Strongly agree (%)**
I enjoyed the project	0	0	76,5	23,5	0
I had a lot of problems with the organization of project activities	76,5	23,5	0	0	0
I had problems using tools for group work with teachers	0	0	39,7	60,3	0
I had problems using tools for group work with students	22,1	63,5	14,7	0	0
I used all the ICTs and VR tools in the project plan	0	0	85,3	14,7	0
Students completed the tasks of all lessons	0	30,9	39,7	29,4	0
Students created the products that were offered in the project	0	0	22,1	77,9	0
I had no problems assessing students' performance	0	26,5	61,8	11,7	0
Total (N= 68)					

The results of the survey of teachers on their impressions from the organization and implementation of the training project "Extra visibility and Security: The Convex Mirrors" show that the indicative project plan, in particular the tools and activities, is useful for obtaining the final project product, and provides motivation for students and teachers to participate in the project. The teachers used almost all the proposed ICTs and VR tools, and considered them useful for the project.

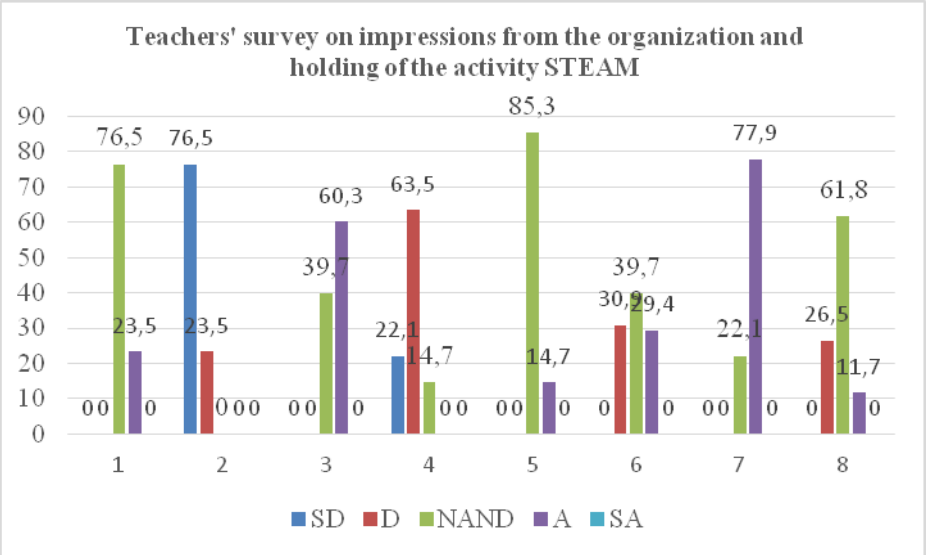

Figure 4. Teachers' survey on impressions from the organization and realization of the STEAM project

Our study showed that the main approaches to the use of virtual reality in STEAM education include as follows:

- using VR tools for collaboration with the team (discussion, conference, joint problem solving);
- using VR tools for specific purposes (the solving specific problems in mathematics, chemistry, biology, medicine, etc.);
- using VR museums to provide students all necessary research materials compatible with reality.

Teachers can combine these approaches according to the training project plan, and it should be noted, that teachers should use VR tools according to the topics of the lessons, the goals of the educational projects, the wishes of the students and other impact factors [13].

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Teachers are key players in the introduction of new methodologies for the students to be able to make a correct choice of sources related to learning by using new technologies.

Electronic educational resources, particularly virtual reality, are not only learning tools, but also a source of inspiration for individual production of students, which motivates and stimulates creative thinking. This is an important point considering that creativity is an increasingly important life skill which can help young people cope with the difficulties and uncertainties in their future careers in the STEAM fields. Project-based learning with VR tools is really an effective way to support STEAM education in general secondary school.

A STEAM project with VR tools is a teacher's detailed description of the course instruction or «learning trajectory» of using VR tools for a lesson, a guide and a document that will be continuously improved and updated. Designing a path based on methodologies such as solving life-real problems, studying projects, by using VR tools to allow us to incorporate design-based learning in the teaching activity taking care of real challenges in an authentic context all over world.

This approach builds on the number of studies how VR tools can be successfully used within the Science, Technology, Engineering, Mathematics and Art (STEAM) curricula, and the recent availability of low cost and stand-alone VR headsets. This concept highlights the

significance of the fact that engineers and other professionals are required to adapt constantly to the evolving realities of STEAM education as a developing ecosystem.

Research shows that the STEAM project with VR tools results in growing interest in Science, as well as students' motivation in STEM careers. Another important observation from the publication is that the benefits of the STEAM project with VR tools using are long-term and maintained, in contrast to the short-term acquisitions of traditional pedagogies that also come with less inclusion of both genders, and less interest in STEM.

According to the results of our project, teachers receive little support in implementing the STEAM project with VR tools in their classroom activity.

One way to achieve support for teachers in the development of STEAM education with VR tools will be the creation of a group of teachers in schools who will generate project ideas and organize them, and the cooperation of school management with institutes and specialists in the areas covered by the projects.

Prospects for further research are the creation of a model for assessing students' performance in STEAM projects.

The purpose of the model is to evaluate not only the results of tests taken by students after learning this material but also their personal contribution to the final project product, their leadership skills, creative ideas and suggestions, abilities and skills of using ICTs and VR tools in project research.

We plan to take into account the differences and features of the use of virtual reality for learning STEAM in schools in different countries, including Ukraine, Spain and Kazakhstan when creating a multilevel model of STEAM-oriented learning environment using virtual reality tools.

In the next research, we will focus on several Spanish and Kazakhstan secondary schools to determine the possible differences in the use of virtual reality to support STEAM education in Ukrainian schools.

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ВИКОРИСТАННЯ ЗАСОБІВ ВІРТУАЛЬНОЇ РЕАЛЬНОСТІ ДЛЯ РОЗВИТКУ STEAM ОСВІТИ У ЗАГАЛЬНООСВІТНІЙ ШКОЛІ

Сороко Наталія Володимирівна
кандидат педагогічних наук, завідувачка відділом технологій відкритого навчального середовища
Інститут інформаційних технологій та засобів навчання НАПН України, м. Київ, Україна
ORCID ID 0000-0002-9189-6564
nvsoroko@gmail.com

Сороко Володимир Миколайович
кандидат технічних наук, доцент,
Науково-освітній інститут державного управління та державної служби, кафедра державної політики
Київський національний університет імені Тараса Шевченка, м. Київ, Україна
ORCID ID 0000-0002-7240-0818
vmsoroko@ukr.net

Манаргуль Мукашева
кандидат педагогічних наук, доцент
Національна академія освіти ім. І. Алтинсарина, м. Нур-Султан, Казахстан
ORCID ID 0000-0002-8611-8303
mg.mukasheva@gmail.com

Матильда Аріза Монтес
вчитель фізики та хімії
ЗЗСО «Педро Еспіноса», м. Антекера (Малага), Іспанія
ORCID ID 000-0002-6210-7167
matiariza@iespedroespinosa.es

Ткаченко Віталій Анатолійович
науковий співробітник відділу мережних технологій та баз даних
Інститут інформаційних технологій та засобів навчання НАПН України, м. Київ, Україна
ORCID ID 0000-0003-4028-4522
tva@iitta.gov.ua

Анотація. Стаття присвячена дослідженню використання віртуальної реальності для підтримки STEAM-освіти в загальноосвітній школі. Щоб вивчити вплив STEAM-освіти, авторами був запропонований навчальний проєкт для середньої освітньої школи про опуклі дзеркала, їх важливість для особливої видимості і безпеки людини, під час впровадження якого вчителі змогли дізнатися про реальний приклад впровадження STEAM-освіти для викладання своїх дисциплін. Метою статті є проаналізувати значення та підходи до використання віртуальної реальності для організації STEAM-орієнтованого навчального середовища, та визначити основні вимоги до VR для підтримки впровадження та розвитку STEAM-освіти. Однією з основних тенденцій модернізації освіти є STEAM-освіта, яка передбачає інтеграцію природничих, технологічних наук, техніки, математики та мистецтва в навчальний процес закладів освіти, зокрема загальноосвітніх шкіл. У світлі отриманих результатів дослідники вказують, що електронні освітні ресурси (разом з VR та AR) є не лише засобами навчання, а й джерелом натхнення для індивідуального навчання учнів, що спонукають та стимулюють їхнє творче мислення. Це важливий момент, враховуючи, що творчість стає важливою життєвою навичкою, яка може допомогти молодим людям впоратися з труднощами та невизначеністю у своїй майбутній кар'єрі, зокрема у сфері STEAM. Перспективами подальших досліджень є створення моделі оцінки успішності студентів та учнів у проєктах STEAM за допомогою засобів віртуальної реальності. Автори планують враховувати відмінності та особливості використання віртуальної реальності для навчання STEAM у школах різних країн, зокрема в Україні, Іспанії та Казахстані, при створенні багаторівневої моделі середовища навчання, орієнтованого на STEAM, із застосуванням засобів віртуальної реальності. Метою моделі є оцінка не тільки результатів тестів, які учні пройшли після вивчення цього матеріалу, а й особистого внеску кожного здобувача освіти в кінцевий продукт проєкту, їхніх лідерських якостей, творчих ідей та пропозицій, умінь та навичок використання ІКТ та віртуальної реальності в дослідженнях у межах навчальних проєктів STEAM.

Ключові слова: STEAM-орієнтований підхід; STEAM-освіта; STEAM-орієнтоване освітнє середовище; віртуальна реальність.

ИСПОЛЬЗОВАНИЕ СРЕДСТВ ВИРТУАЛЬНОЙ РЕАЛЬНОСТИ ДЛЯ РАЗВИТИЯ STEAM ОБРАЗОВАНИЯ В ОБЩЕОБРАЗОВАТЕЛЬНОЙ ШКОЛЕ

Сороко Наталия Владимировна
кандидат педагогичных наук, заведующая отделом технологий открытой обучающей среды
Институт информационных технологий и средств обучения НАПН Украины, г. Киев, Украина
ORCID ID 0000-0002-9189-6564
nvsoroko@gmail.com

Сороко Владимир Николаевич
кандидат технических наук, доцент,
Научно-образовательный институт государственного управления и государственной службы, кафедра государственной политики
Киевский национальный университет имени Тараса Шевченко, г. Киев, Украина
ORCID ID 0000-0002-7240-0818
vmsoroko@ukr.net

Манаргуль Мукашева
кандидат педагогических наук, доцент
Национальная академия образования им. И. Алтынсарина, г. Нур-Султан, Казахстан
ORCID ID 0000-0002-8611-8303
mg.mukasheva@gmail.com

Матильда Аріза Монтес
учитель физики и химии
ЗОСО «Педро Еспиноса», г. Антекера (Малага), Испания
ORCID ID 0000-0002-6210-7167
matiariza@iespedroespinosa.es

Ткаченко Виталий Анатольевич
научный сотрудник отдела сетевых технологий и баз данных
Институт информационных технологий и средств обучения НАПН Украины, г. Киев, Украина
ORCID ID 0000-0003-4028-4522
tva@iitta.gov.ua

Аннотация. Статья посвящена исследованию использования виртуальной реальности для поддержки STEAM-образования в общеобразовательной школе. Чтобы изучить влияние STEAM-образования, авторами был предложен обучающий проект для средней образовательной школы о выпуклых зеркалах и их важности для особой видимости и безопасности человека, во время проведения которого учителя смогли узнать о реальном примере внедрения STEAM-образования для преподавания своих дисциплин. Статья написана с целью проанализировать значение и подходы к использованию виртуальной реальности для организации STEAM-ориентированной учебной среды и определить основные требования к VR для поддержки, внедрения и развития STEAM-образования. Одной из основных тенденций модернизации образования является STEAM-образование, которое предусматривает интеграцию естественных, технологических наук, техники, математики и искусства в учебный процесс учебных заведений, в частности общеобразовательных школ. В свете полученных результатов исследователи указывают, что электронные образовательные ресурсы (включая VR и AR) являются не только средствами обучения, но и источником вдохновения для индивидуального обучения учащихся, побуждают и стимулируют их творческое мышление. Это важный момент, учитывая, что творчество становится важным жизненным навыком, который может помочь молодым людям справиться с трудностями и неопределенностью в своей будущей карьере, особенно в области STEAM. Перспективами дальнейших исследований является создание модели оценки успеваемости студентов и учащихся в проектах STEAM с помощью средств виртуальной реальности. Авторы планируют учитывать различия и особенности использования виртуальной реальности для обучения STEAM в школах разных стран, включая Украину, Испанию и Казахстан, при создании многоуровневой модели среды обучения, ориентированного на STEAM, с применением средств виртуальной реальности. Целью модели является оценка не только результатов тестов, которые ученики прошли после изучения этого материала, но и личный вклад каждого ученика в конечный продукт проекта, их лидерских качеств, творческих идей и предложений, умений и навыков использования ИКТ и виртуальной реальности в исследованиях в рамках учебных проектов STEAM.

Ключевые слова: STEAM-ориентированный подход; STEAM образование; STEAM-ориентированная образовательная среда; виртуальная реальность.

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