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IRSTI 14.25.09 https://doi.org/10.51889/3005-6217.2024.79.1.011

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USING IT- IMPLEMENTS AS A MEANS OF PROVIDING NEW EDUCATIONAL OPPORTUNITIES IN THE PROCESS OF MASTERING ORGANIC CHEMISTRY

Abstract

The study results of immersive learning usage, which is supported by IT tools, including virtual reality (VR), augmented reality (AR), and QR code are presented in this article. The greater emphasis will be done on the use of VR/AR and QR code in the organic chemistry teaching process. The studied technologies are considered as an innovative learning environment for organic chemistry teaching. The problem relevance is due to the VR/AR technologies' rapid development and implementation in various social activity's areas, including in the organic chemistry's teaching process course of new generations students' objective reasons and subjective preferences. Theoretical assumptions are translated in these technologies' practical application field. Virtual reality-based training allows to convey knowledge in visual ways that are difficult or impossible to show in reality. We used several types of IT tools in our research: 360-degree video, platforms (Adobe InDesign), platforms and interactive programs (VR Chemistry lab and Mel Chemistry VR, "Chemical editor beta 1.0" on the website www. xumuk.ru., QR Code Generator (http:// qrcoder.ru/), special virtual reality glasses that convert 2D images and videos into 3D format. The platforms' application efficiency was investigated: http://molview.org/, PubChem, MolView. These platforms allow to build a 3D model of organic substances' molecules structure in the study of the organic substances' structure. The problems of introducing these technologies into the modern educational system remain relevant. It is important to mention that the IT tools usage determines key positions in the near future, and the prospects of immersive learning using allow us gain a new insight into the process of organic chemistry teaching at school and university.

Keywords: chemistry training, virtual reality VR, augmented reality AR, immersive learning, QR code, 3D format, Chemistry lab, MEL Chemistry VR.

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ОРГАНИКАЛЫҚ ХИМИЯНЫ ИГЕРУ ПРОЦЕСІНДЕ ЖАҢА БІЛІМ БЕРУ МҮМКІНДІКТЕРІН ҚАМТАМАСЫЗ ЕТУ РЕТІНДЕ IT - ҚҰРАЛДАРЫН ПАЙДАЛАНУ

Аңдатпа

Бұл мақалада виртуалды шындықты (VR), толықтырылған шындықты (AR) және QR кодын қоса алғанда, IT құралдары қолдайтын иммерсивті оқытуды қолдану бойынша зерттеу нәтижелері берілген. Бұл мақалада біз органикалық химияны оқыту процесінде VR/AR және QR кодын қолдануға көбірек көңіл бөлеміз. Органикалық химияны оқыту үшін зерттелетін технологиялар инновациялық оқыту ортасы ретінде қарастырылады. Проблематиканың өзектілігі VR/ AR технологияларының қоғамдық қызметтің әртүрлі салаларына, оның ішінде білім алушылардың жаңа буындарының объективті себептері мен субъективті қалауына байланысты органикалық химияны оқыту процесіне қарқынды дамуы мен енгізілуіне байланысты. Теориялық болжамдар осы технологияларды практикалық қолдану өрісінде таратылады. Виртуалды шындыққа негізделген оқыту білімді нақты көрсету қиын немесе мүмкін емес көрнекі тәсілдермен жеткізуге мүмкіндік береді. Біздің зерттеулерімізде IT құралдарының бірнеше түрі қолданылды: 360 градус бейне, платформалар (Adobe InDesign), платформалар және интерактивті бағдарламалар (VR Chemistry lab және Mel Chemistry VR, www сайтындағы "Beta 1.0 химиялық редакторы". xumuk. ru., QR Code Generator (http:// qrcoder.ru/)), 2D кескіндері мен бейнелерін 3D форматына аударатын арнайы виртуалды шындық көзілдірігі. Платформаның органикалық заттарының құрылымын зерттеуде қолданудың тиімділігі зерттелді: http://molview.org/, PubChem, MolView құруға мүмкіндік береді 3D моделі Органикалық заттардың молекуласының құрылымы. Осы технологияларды заманауи білім беру жүйесіне енгізу мәселелері өзекті болып қала береді. Сонымен, IT-құралдарды қолдану жақын болашақта негізгі ұстанымдарды анықтайды, ал иммерсивті оқытуды қолдану перспективалары мектеп пен университетте органикалық химияны оқыту процесіне жаңа көзқараспен қарауға мүмкіндік береді.

Түйін сөздер: химияны оқыту, виртуалды шындық, Ar кеңейтілген шындық, компьютерлік оқыту, QR коды, 3D форматы, химия зертханасы, Chemistry lab, MEL Chemistry VR.

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ИСПОЛЬЗОВАНИЕ IT-ИНСТРУМЕНТОВ КАК СРЕДСТВА ОБЕСПЕЧЕНИЯ НОВЫХ ОБРАЗОВАТЕЛЬНЫХ ВОЗМОЖНОСТЕЙ В ПРОЦЕССЕ УСВОЕНИЯ ОРГАНИЧЕСКОЙ ХИМИИ

Аннотация

В настоящей статье представлены результаты исследования применения иммерсивного обучения, которое поддерживается IT- инструментами, включая виртуальную реальность (VR), дополненную реальность (AR), а также QR-код. В данной статье мы делаем больший акцент на применении VR/AR и QR-кода в процессе обучения органической химии. Для преподавания органической химии изучаемые технологии рассматриваются в качестве инновационной среды обучения. Актуальность проблематики обусловлена стремительным развитием и внедрением VR/ AR технологий в разные области общественной деятельности, в том числе в процесс обучения органической химии в силу объективных причин и субъективных предпочтений новых поколений обучающихся. Теоретические предположения транслируются в поле практического применения данных технологий. Обучение на основе виртуальной реальности позволяет передать знания наглядными способами, которые в реальности сложно или невозможно показать. В наших исследованиях использовались несколько видов IT- инструментов: видео 360 градусов, платформы (Adobe InDesign), площадки и интерактивные программы (VR Chemistry lab и Mel Chemistry VR, «Химический редактор beta 1.0» на сайте www. xumuk. ru. QR Code Generator (http://qrcoder.ru/)), специальные очки виртуальной реальности, которые переводят 2D-изображения и видео в 3D-формат. Было исследована эффективность применения при изучении строении органических веществ платформы: http://molview.org/, PubChem, MolView которые позволяют построить 3D модель строение молекулы органических веществ. Проблемы внедрения данных технологий в современную образовательную систему остаются актуальными. Необходимо отметить, что применение IT-инструментов определяют ключевые позиции в ближайшем будущем, а перспективы использования иммерсивного обучения позволяет по-новому взглянуть на процесс преподавания органической химии в школе и вузе.

Ключевые слова: обучение химии, виртуальная реальность VR, дополненная реальность AR, иммерсивное обучение, QR-код, 3D-формат, Chemistry lab, MEL Chemistry VR.

Basic Provisions. The research problem is based on the immersive environment's usage that combines the real and virtual worlds using AR/VR technologies, creating an innovative educational environment. The analytical, experimental, psychodiagnostic, and statistical research methods are used in the study. 50 third-year undergraduate students studying organic chemistry at the Natural sciences faculty took part in this research.

Platforms and venues are virtual lectures or workshops that provide opportunities for teaching lessons. Interactive programs are a hybrid project of a traditional online course and practice in virtual reality. Within one platform and program, different types of content can be combined, which increases student engagement and makes available a wide arsenal of pedagogical methods and applications (VR Chemistry LAB is a virtual chemistry laboratory with a set of teaching materials and a function for tracking the actions of each user). Augmented reality (AR) is a technology that overlays digital information (sounds, videos and graphics) on real environment's top. The AR's rapid spread in education is not surprising, since mobile devices are available to everyone, and applications have become quite convenient for both teachers and students. When teaching organic chemistry, we suggest considering the following applications: VR Chemistry lab and Mel Chemistry VR in order to obtain visual illustrations of dangerous and complex chemical experiments, to reproduce the organic reactions' complex mechanisms when conducting a real experiment.

The relevance of this issue and its insufficient study associated with novelty determined the motivation for this study, the aim of which is to study the effectiveness of using virtual and augmented reality for visualization in organic chemistry teaching.

Introduction. The modern education system faces serious challenges, many of which are technological challenges. New group dynamics formats, access to a large amount of data and information - all this leads to the fact that teaching methods and tools are undergoing changes. Today we can say with confidence that IT tools are capable of revolutionizing education. The immersive learning is one of these methods [1].

Immersive learning uses an artificial or simulated environment through which students can become fully immersed in the learning process. This method allows to control the results by relating them to real experience, but in a safer environment. Nowadays, most immersive learning activities are supported by virtual tools, including virtual reality (VR), augmented reality (AR), and QR code [2]. In this article we will place greater emphasis on the VR/AR and QR code usage in the organic chemistry teaching process.

Analyzing virtual reality applications that can be used in organic chemistry teaching is the aim of this work.

By virtual reality (VR), we can understand the digital space. In this instance, virtual reality technologies encompass software and hardware systems enabling immersion into digital spaces. These technologies engage not only visual and auditory sensory channels, facilitated by devices for virtual reality, but also other sensory experiences like transmitting smells, feedback suits, and more. It's crucial to highlight the inclusion of educational content directly within these virtual reality experiences.

Educational VR content includes the following formats: 360-degree videos, platforms, sites and interactive programs. VR video is the simplest thing a teacher can use. Special virtual reality glasses convert 2D images and videos into 3D format, creating an enveloping image. For example, in a virtual laboratory you can carry out any chemical experiments that are impossible and even dangerous in a school classroom.

Literature Survey

AR and VR are often confused, but if virtual reality creates a completely artificial environment, then augmented reality changes the user's perception of the world around them. AR technologies enrich reality with digital data and multimedia through the smartphone, tablet, PC cameras or connected glasses, overlaying 3D models, videos and images in real time. The main aim of AR using is to assimilate and remember information, improve its perception, and stimulate cognitive development [3-4].

Today, Russian universities are already using three-dimensional models to test knowledge, and are also creating virtual assistants for teachers. If previously students and high school students put together presentations in PowerPoint, in the future they will be able to use augmented reality and create images that can be viewed from any angle.

The impact augmented reality has on student engagement and performance is unlikely to be matched by any other technology on the market (with the VR possible exception). Researches show that after students use mobile AR applications, their attention, confidence and satisfaction level increased by more than 30% [5].

Similar applications for studying organic chemistry (for example, courses on the molecules and crystals' symmetry, organic molecules' stereochemistry have been created) are developing now by Russian companies.

A QR code is an advanced level barcode that stores information: text, image, video, PDF, website link, etc.

The possibilities for using a QR code in organic chemistry teaching are very wide: from coding homework (which will allow to individualize the learning process and eliminate the cheating possibility) to creating QR quizzes.

QR code is one of the interesting IT training tools. The integration of QR codes can significantly support teachers and educators in both classroom and extracurricular activities. This technology holds several advantages for educational purposes, leveraging students' familiarity with daily use of phones and tablets during breaks, at home, or during leisure time [6].

Here are key opportunities for its application in the educational process:

Accessing Educational Resources: QR codes can link to various educational portals, multimedia sources, or resources that aid students in problem-solving.

Organizational Enhancements: Implement QR codes on posters, informational blocks, or comments during extracurricular events like quests or quizzes, streamlining access to additional information.

Enhancing Lesson Materials: Incorporate QR codes into handouts during lessons, providing access to comments, video links, 3D models, or other supplementary materials. They can also be included in testing materials.

Project-based Learning: Utilize QR codes to compile collections of links, information blocks, or other resources, offering diverse options for incorporating them into project activities. Below are some of them

1.QR Code Generator (http://qrcoder.ru/)

2.Kerem Erkan. QR Code and 2D code enerator.(https://keremerkan.net/qr-code-and-2d-code-generator/)

3.Tec-it. (https://qrcode.tec-it.com/ru)

4. Visualead (https://www.visualead.com/qr-code-generator)

5.Creambe (http://creambee.ru)

There are also many options, programs, applications for decoding (reading) QR codes:

1.Application for Android, IOS phones, QR code reader

2.Various online services, a program into which you can upload QR code image

By encoding a link to a chemical 3D model in QR code, we can make the material accessible; it also becomes possible to combine the combination of these technologies into a directory of additional material on chemistry that will help students learn school material on chemistry

The use of mobile devices in combination with 3D technologies in chemistry lessons can be a productive option for enhancing students' cognitive activity. Nowadays, mobile phones are a distraction for students in class due to misuse of the device. We suggest using mobile devices as an information conductor. The 3D technologies usage in teaching will make lessons interesting, educational, digital, and visually voluminous. 3D technology will allow to "immerse" the student in the studied lesson, making it possible to clearly explain to students the lesson's theme, for example, in chemistry lessons, this technology will allow you to study visually the molecules, crystal lattices structure, etc. [7].

There are various programs for creating 3D models: Chemcraft, reactor 2.1, 3D molecule editor, Xtaldraw, Avogadro, Molview. A platform for creating 3D models of molecules was considered, which would be productively used in chemistry lessons when the substances' structures studying: http://molview.org/ - this platform allows to build a 3D model of a molecule's structure easily, the student will need to know how these molecules are located in space and correctly put them on the platform [8].

Absolutely, a contemporary chemistry educator benefits greatly from proficiency in chemical graphic editors when preparing educational materials. These editors empower them to create chemical structural formulas, reaction diagrams, and replicate laboratory setups on digital screens. They can construct three-dimensional models of molecules and execute various manipulations, such as zooming, rotating, and repositioning these models.

These editors operate on a fundamental principle: assembling chemical formulas akin to constructing with a "building set," utilizing elements like benzene rings, chemical bonds, arrows, and more. The flexibility within these editors allows for easy adjustments to the entire formula or its individual components-inserting symbols, modifying size, or altering orientation on the plane, among other functionalities.

Moreover, these chemical editors typically offer extensive sets of complex formulas and pre-made drawings commonly employed in tasks. These resources encompass a wide range of components, including amino acids, peptides, carbohydrates, stereoisomers, nucleotides, laboratory equipment, and more, facilitating the creation of comprehensive educational materials [9].

Chemical editors can be categorized into two main types:

1) 2D editors that specifically generate flat images depicting chemical structures.

2) 3D editors designed to produce three-dimensional spatial representations, allowing for rotation and manipulation.

Among these, the widely acclaimed and versatile ChemOffice software package stands out. It comprises four specialized applications:

1) ChemDraw: A traditional tool used for editing chemical formulas.

2) Chem3D: Tailored for visualizing chemical compounds, conducting computer modeling, and executing calculations in a three-dimensional space.

3) ChemFinder: A specialized database editor that facilitates the creation, editing, and management of databases containing chemical compounds.

4) Table Editor: Specifically designed for visualizing and modifying tabular data used within the Chem3D package [10].

ChemDraw stands as a highly favored customized program for chemical graphics. Its main features encompass:

Multifunctional editing of two-dimensional molecular structures.

Seamless integration into MS Word using the clipboard.

Advanced graphical capabilities, notably the Chem3D module enabling high-quality volumetric structure visualization with an interface that produces top-notch images.

The Structure Perspective Tool, facilitating the adjustment of perspective parameters for displaying molecules within ChemDraw through straightforward mouse movements.

The incorporation of artificial intelligence elements that aid in verifying compound accuracy, issuing warnings and explanations during structure development, assessing valence degrees, and identifying potential errors in diagrams.

Chem3D, in contrast to 2D chemical editors, enables complete 3D modeling and visualization of chemical compounds. Its key features include:

Utilization of a two-dimensional model generated within simpler chemical editors.

Automated analysis of molecules' three-dimensional geometry, encompassing values like bond lengths and bond angles.;

– the ChemProp/Chem3D module allows to calculate physical properties such as boiling point, melting point, etc.

The MDL ISIS Draw program is a convenient graphic editor for chemical formulas. This particular program offers a localization feature, simplifying its usage. Its interface is intuitive and bears resemblance to ChemDraw in many aspects [11].

These chemical editors, including ACD/ChemSketch from ACD/Labs, Symyx Draw, among others, typically require installation on personal computers. However, the rise in mobile device usage and internet accessibility has highlighted the importance of cloud-based chemical editors. Unlike their installed counterparts, these cloud-based editors operate online without requiring installation.

Despite the widespread use of Android-based smartphones and tablets, there's a scarcity of Russian-language chemical applications developed for these platforms. An exception is the "Chemical Editor beta 1.0" available on www.xumuk.ru. While not a professional-grade editor, it enables quick input and copying of simple chemical formulas or equations, catering to basic needs in the field. It includes a set of pre-made cyclic compounds, bonds, chemical elements, and certain groups, catering to schoolchildren and students.

Moving to more complex English-language cloud-based options, the PubChem program stands out. Integrated into a well-known database of chemical compounds and mixtures, its interface is user-friendly and straightforward.

Another English-language cloud resource is the MolView editor, comprising two main sections: a structural formula editor and a 3D model viewer. The structural formula editor offers a standard set of tools. Upon creating a structural formula, there's an option to convert its 2D image into a 3D volumetric representation, instantly displayed for appropriate viewing in the respective window [10].

Problem Definition

The immersive environment is considered as a promising learning environment that is attractive to all participants in the educational process. The aim is to study the effectiveness of using virtual and augmented reality for visualization in organic chemistry teaching.

The future of education is associated today with the VR / AR technology's development, focused on artificial intelligence technologies, gaming technology, big data, the Internet of things, blockchain, the creation of a personal learning environment [11], an interconnected network of social immersive environments' creation, multisensory interaction of the real and virtual world, people and digital objects, VR and AR [12]. One of the aspects of VR / AR technologies usage for the development of practical skills and communicative competence is considered [13], which helps expand the capabilities and field of human activity, but at the same time creates a number of social problems and risks [14]. Ensuring coordinated interaction between the virtual and physical environment is a complex task [15], which necessitates clear criteria for its definition [16]. However, the combination of the real and virtual worlds is still at an early stage; it seems promising for users in many directions, among which one of the priorities is education [17]. The immersive environment of the educational process promotes students' maximum immersion in the educational environment, providing individual feedback, increasing students' motivation and interest in learning, developing their abilities and competencies of the 21st century [18].

Immersive VR technology promotes the knowledge accumulation, thereby providing an alternative learning process, which is of great importance for teaching organic chemistry as a discipline that requires a high level of visualization and physical interaction with virtual environments, which makes it relevant to study the possibilities of virtual (VR) and augmented (AR) reality for teaching organic chemistry in higher education institutions.

The theoretical substantiation possibilities and application promising areas' identification of AR/VR usage in the educational process of organic chemistry teaching is the scientific novelty of this research.

The research results' practical significance is the possibility of their use for improving the organic chemistry's teaching and learning in higher educational institutions through the transition to a new digitalization level, increasing the educational process' technologization based on the virtual and real educational space interaction.

Methodology & Implementation. An inductive-deductive method as well as situation analysis techniques are used to determine the prospects for the augmented and virtual reality technologies usage in the field of education. Statistical processing of the research results was carried out in Microsoft Excel, which was used to accumulate information, sort it and visualize the research results. Student's t-test was used to compare indicators, determine the statistical significance and reliability of the obtained results. The relationship degree's assessment between the methods scales was carried out by calculating the Pearson correlation coefficient rxy and its assessment in accordance with the Chaddock tables. Calculations were carried out using the Social Science Statistics online calculator.

The material for analysis is such applications as: VR Chemistry lab and Mel Chemistry VR. The Adobe InDesign platform was used to create a reference book of 3D molecules on chemistry. Creambe platform was used for directory layout. The MolView platform (http://molview.org/) was used to create a QR code (http://creambee.ru). The Paint Tool Sai platform was used to construct 3D molecules. Adobe photoshop was used to create the illustrations.

The main method in this work is descriptive. Virtual reality in teaching chemistry is mainly used when conducting chemical experiments. The chemical experiment takes a leading place in chemistry teaching, as it connects theory with practice. It contributes to the formation of students' cognitive interests, the ability to observe ongoing processes, analyze them, and then draw conclusions, develop attention and independent activity, etc. But performing a chemical experiment is not always safe and accessible. Therefore, the use of a chemical experiment in teaching is one of the most developed problems in the methodology of chemistry teaching.

Virtual laboratories allow to carry out a chemical experiment, which for some reason is impossible or undesirable to implement when chemistry teaching (danger, high cost of reagents, time constraints). An important advantage of a virtual experiment is that students can return to it repeatedly, which allows them to better understand the material. Currently, the use of virtual reality in organic chemistry teaching has become popular and accessible, since it only requires virtual reality glasses (for example, HTC Vive) and an installed application, of which there is a great abundance now.

We will consider the following applications in this article: VR Chemistry lab and Mel Chemistry VR.

1. VR Chemistry lab. A chemical laboratory in virtual reality, which makes it possible to safely experiment with reagents. In this virtual chemical laboratory, students can plan and conduct experiments, put forward hypotheses and test them in practice, make and correct mistakes. And in turn, this application is able to analyze the student’s actions and calculate the results of mixing certain reagents. It is not programmed in advance that substance A, when added to substance B, will give a crimson color, but take into account the concentration, proportions, substances amount, whether the interaction took place or everything burned out, or a precipitate formed, and so on. Currently there are many different labs available in the application on the following themes, such as amphotericity, oxide-water interactions, reducing properties of halides, metal oxides, anion determination, flame analysis, etc.

2. Mel Chemistry VR offers a comprehensive course of chemistry lessons in virtual reality, aligning with educational programs. This innovative approach utilizes virtual reality to transform the learning experience of chemistry basics into an engaging and immersive journey. By employing scientific games and the immersion method, it redefines the traditional approach to teaching chemistry, making it an exciting and interactive process for learners. Each lesson in this application lasts from three to seven minutes, that is, it is easily integrated into the framework of the lesson and helps to further visualize the topic being studied. The app currently contains 28 VR lessons and tests. For example, “Atomic structure”, “Atoms in solids and gases”, “Structure of atoms and molecules”, etc. Also, in Mel Chemistry VR there are lessons about isotopes, ions, electrons, interactive periodic table (chemical elements), molecular formulas and much more. Absolutely, the modernization of education involves a shift towards computerized learning, and the integration of virtual laboratories into chemistry education stands as an excellent method to captivate student interest. These virtual labs offer a compelling way to engage students in specific topics, actively involving them in the learning process. They provide students with the opportunity to conduct experiments independently within a controlled digital environment, granting them the freedom to make mistakes and learn from them. This approach encourages hands-on learning and empowers students to refine their understanding through practical exploration and correction of their own errors. And gives the teacher the opportunity to track actions student while working. The virtual laboratory [19] is safe, and all reagents and equipment are available in it, which not every student will have the opportunity to work with in reality.

Virtual reality technology, depending on the content, type and number of devices, can be integrated into the educational lesson system: - as educational material at the group work stage, together with other teaching methods; - as practice-oriented material at the stage group work and work in pairs for combining together with the problematic theoretical problems’ solution; - at the project creation stage if collaborative learning is used as an approach to solving problems with long deadlines; - at the introduction stage to provide context for the lesson or visualize the theoretical part.

It should be noted that the use of VR/AR technology in education is suitable for training in cooperation and problem learning; in addition, as a powerful tool for situational learning, enhancing the process of education by tailoring it to individual needs. Through its capabilities in material visualization, it enables students to grasp abstract concepts more effectively. Moreover, by simulating real-world situations, it encourages hands-on learning and offers a unique opportunity for personalized education.

The immersive nature of virtual labs captivates students' attention, ensuring 100 percent concentration by engaging them in interactive experiences. This heightened engagement ultimately boosts motivation, fostering a more enthusiastic and effective learning environment. A. I. Azevich [8] lists the advantages of virtual and augmented reality as: involvement in the learning environment; personal participation; a comprehensive solution to a learning task without being distracted by external factors. He considers the disadvantage of voluminous virtual content, the filling of which requires considerable financial investments.

Results & Discussions. During classes in organic chemistry, VR/AR applications were tested at the Pedagogical university. The testing involved 3rd year students of the Chemistry department, totaling 51 people - 25 students in the experimental group (EG) and 26 students in the control group (CG).

A survey was conducted among students regarding the use of VR/AR technology. 51 respondents participated in the survey. The survey results are shown in the diagram.

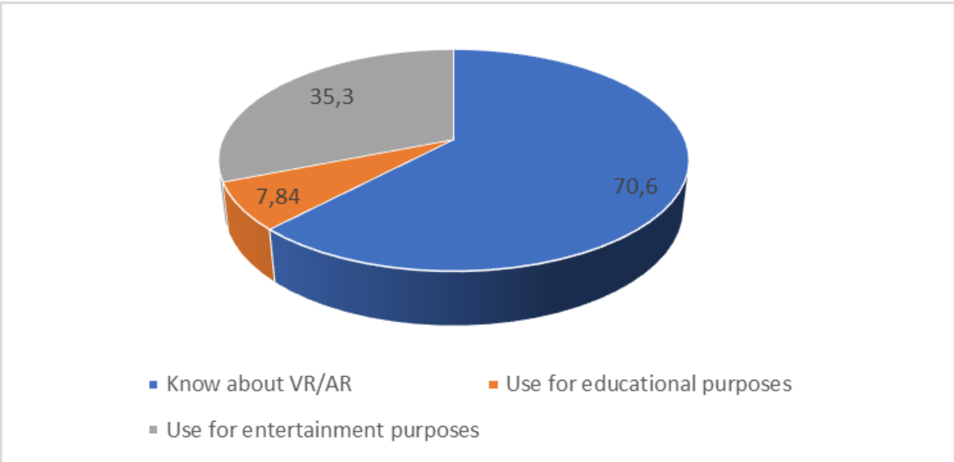

Figure -1. Survey results

A survey results showed that 70.6% of respondents know about the VR/AR technology, only 7.84% use VR/AR technology applications for educational purposes. The virtual and augmented reality applications used by respondents are an entertainment nature; 35.3% of respondents turn to VR/AR technology.

The immersion learning environments help improve students' performance according to scientific literature sources. A pilot study was carried out to test the truth of this statement in the study of organic chemistry.

The study results of the students' initial academic performance in the experimental and control groups are presented in Table 1.

Table 1 – Initial level of academic performance in the experimental (EG) and control (CG) groups

№	Levels	EG	CG
1	High	24,0	11,5
2	Medium	64,0	69,2
3	Low	16,0	19,3
4	Number of students	25	26

Based on the data in Table 1, it is clear that the students' academic performance levels result in the experimental and control groups at the study's initial stage, were comparable and were in the range of average values, except an academic performance's high level (24.0%; 11.5% in the EG, CG respectively).

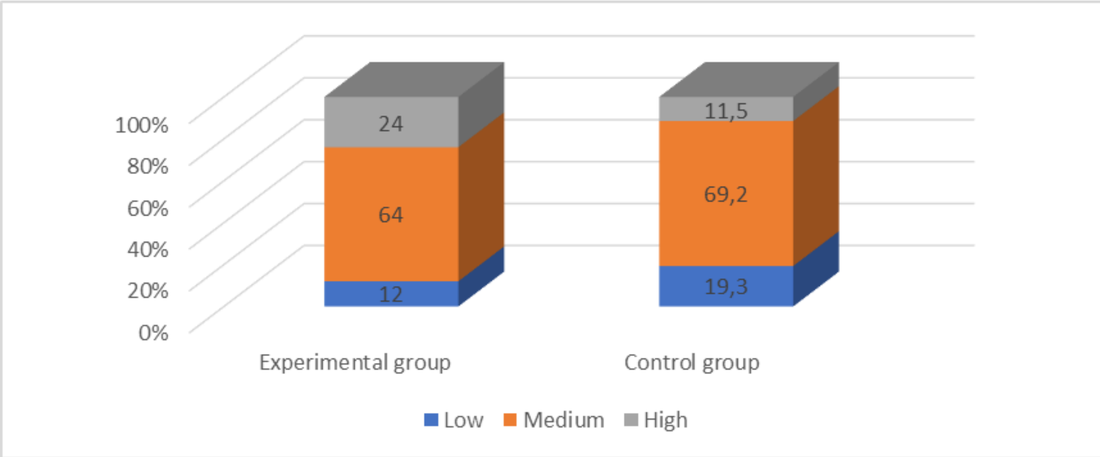

Figure - 2. Comparative data for initial performance levels

A study of students' educational activities was conducted in the experimental group (EG) using AR/VR and in the control group (CG) using traditional teaching methods. The re-test results are shown in Table 2.

Table 2 - Dynamics of students' educational activities in the experimental group (EG) and in the control group (CG) using AR/VR

№	Levels	EG	CG
1	High	52,0	23,0
2	Medium	44,0	61,5
3	Low	4,0	15,5
4	Number of students	25	26

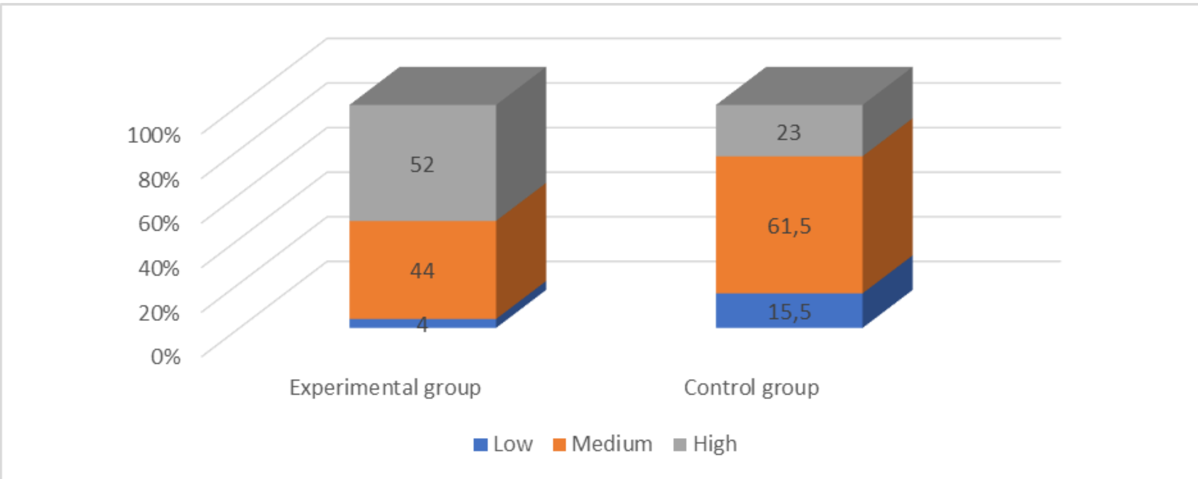

Figure - 3. Comparative data of the achievement's level after re-test

In a restudy, students in the experimental group who studied organic chemistry using immersive VR/AR technologies showed pronounced positive dynamics, while in the control group the changes were not statistically significant. A statistically significant increase in the high level of academic performance from 24% to 52% indicates an increase in the students' interest in the experimental group in the theoretical principles of organic chemistry, the chemical elements properties, and the desire to acquire new knowledge.

The students' orientation formation in the experimental group toward independent acquisition of knowledge is confirmed by a significant decrease in average and low levels of academic performance from 64% to 44% and 12% to 4%, respectively. There is a pronounced direct correlation between academic results (Pearson correlation coefficient rxy=0.7364 in the experimental group and rxy=0.6294 in the control group of respondents).

Thus, the study results indicate that immersive chemistry teaching using VR/AR technologies contributes to the growth of educational motivation, which has a positive impact on the acquisition of theoretical knowledge and the acquisition of practical skills, leading to a more pronounced improvement in the students' academic success compared to traditional training.

Conclusions. It is shown that the possibilities of VR/AR technology using in organic chemistry teaching are in significant interest to researchers, however, empirical studies in this area are not sufficiently represented in the scientific literature. At this stage, immersive VR/AR technologies are used to teach organic chemistry, which can be considered only as the initial stage of its formation, which does not detract from the importance of these technologies for improving teaching and learning.

Thus, it has been shown that organic chemistry teaching using VR/AR technologies has a positive impact on the acquisition of theoretical knowledge and the acquisition of practical skills, leading to a more pronounced improvement in the students' academic success compared to traditional training.

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