

Using Blippar to create augmented reality in chemistry education

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Abstract

This paper presents an analysis of the possibilities and advantages of augmented reality technologies and their implementation in training of future Chemistry and Biology teachers. The study revealed that the use of augmented reality technologies in education creates a number of advantages, such as: visualization of educational material; interesting and attractive learning process; increasing student motivation to study and others. Several augmented reality applications were analyzed. The Blippar app has been determined to have great benefits: it's free; the interface is simple and user-friendly; the possibility of using different file types; the possibility of combining a large amount of information and logically structuring it; loading different types of information: video, images, 3D models, links to sites, etc. Thus, convenient interactive projects were developed using the Blippar application, which were called study guide with AR elements, and implemented in teaching chemical disciplines such as Laboratory Chemical Practice and Organic Chemistry. Using such study guide with AR elements during classes in a real chemical laboratory is safe and does not require expensive glassware. The student interviews revealed that the use of the Blippar application facilitated new material understanding, saved time needed to learn material, and was an effective addition to real-life learning.

Keywords

augmented reality, augmented reality applications, chemistry education, Blippar, QR code

1. Introduction

Modern society is at a new stage in its development – in the era of informatization [1]. Students of higher education institutions are representatives of the modern generation, for whom it is quite natural to use their digital gadgets in all spheres of life – for entertainment and recreation, for ordering food and shopping, for travel. And, of course, in training.

For the modern generation of students, the educational process within augmented and virtual reality is natural and understandable.

Augmented reality (AR) technologies create unique opportunities in education [2]. By applying AR technologies to the educational environment, and by supplementing them with

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appropriate visual information, it is possible to create a visual model of educational material [3]. As a result, teaching and learning activities, independent research activities of students are intensified, especially in the context of distance learning; learning motivation and focus on both lessons and homework increases [4].

This was the reason for the introduction of AR technologies in the learning process and practical training of future Chemistry and Biology teachers and motivated us to create teaching materials with AR elements and to conduct classes using augmented reality applications to achieve educational goals.

2. Literature review

Over the last few years, a very large number of augmented reality applications have appeared at the disposal of educators. These applications differ in both purpose and complexity.

Yuen et al. [5] offer the following classification of AR learning applications:

- Discovery-Based Learning – applications that provide additional information about the object while considering it. Such AR applications are often used in museums, historical sites, sightseeing, astronomical education, etc.
- Object-Modeling – applications that use models that allow learners to visualize how an object would look from different viewpoints. Such applications are often used in the study of anatomy, architectural education.
- AR Books – learners use special devices such as special glasses. Such books contain 3D virtual presentations and interactive materials and assignments.
- Game-Based Learning – applications that allow to create and use AR games in learning. There are different ways to use AR in games. For example, marker technology is used in games where a flat board or map displays in a 3D shape and then can be viewed with a mobile device. These kinds of AR games can be used in the study of archeology, anthropology, history, geography. Other types of AR games offer interaction with AR objects. Such virtual objects are first created and then applied in specific locations in the real world.
- Skills Training – AR applications are used for training in specific areas, such as military or airplane maintenance.

According to the analysis of the literature data by Majeed and Ali [6], the use of AR applications in Discovery-Based Learning has the greatest number of positive effects in education. For example, such benefits as:

In recent years, more and more attention has been paid to the use of augmented reality technologies in teaching chemistry, starting from school [7]. Research shows that the AR tool is useful for improving student learning outcomes.

Belokhvostov and Arshanskiy [8] propose the following classification of augmented reality tools in chemistry teaching based on their content:

1. Ideal (augmented reality means textual, illustrative information (infographics, virtual demonstrations), as well as virtual chemical laboratories):

- a) cognitive-textual – means supplementing educational texts with small portions of cognitive material. Additional texts typically contain definitions of the concepts and terms that are used, the most important characteristics of the composition and structure of substances, information about the unique properties of substances and the chemical reactions, information from the history of chemistry, information about outstanding scientists-chemists, etc. As a means of augmented reality, cognitive texts may accompany textual or illustrative material on paper or electronic media. Using the possibilities of augmented reality when reading paper text significantly expands the didactic potential of the textbook and enhances its interactivity [9];
- b) virtual-illustrative – the human brain assimilates much better information presented in visual rather than textual forms. Therefore, in the methodology of teaching chemistry, various types of visualization (study notes, tables, frame models, etc.) have proven themselves well. An example of such an AR application is ISOMERS AR from Alchemie. This application allows user to build chains of different alkane isomers containing up to 10 carbon atoms. For each isomer its systematic name is displayed. So, the user can learn the concept of isomerism, the rules for the construction of alkanes and the rules for alkane nomenclature.
- c) virtual demonstration – special computer programs are used, which reproduce dynamic images on a computer. These images create visual effects that simulate signs and conditions of chemical processes. Such a program does not allow user interference in the algorithm that implements its work. The virtual demonstration is a type of virtual chemical experiment with great didactic capabilities:
 - reproducing the subtle details of experiment unnoticed while a real experiment;
 - providing visual, dynamic and memorable illustrations of complex or dangerous chemical experiments;
 - simulating experiments require expensive reagents, dangerous and time-consuming;
 - simulating situations not available in a real chemical experiment.

For example, Elements 4D is a great free Android and iOS tablet or smartphone app that allows user to visualize 36 elements of the periodic table and information about them.

Another BiochemAR application offers visualization of complex biomacromolecules such as peptides and proteins [10].

- d) virtual research – virtual chemical laboratories, like virtual demonstrations, are a type of virtual chemical experiment. An example of a virtual laboratory is the “Entertaining Chemistry AR” mobile application, which allows to conduct virtual chemical experiments without special equipment and reagents. The program was created using augmented reality technology and contains colorful instructions for conducting a virtual experiment [8].

There is also an ARChemEx application that allows simulating chemical reactions [11]. Or ARchemy, which allows you to simulate some transformations in organic chemistry [12].

2. Real (video experiments, photographs of real substances, instruments, laboratory installations are supplemented by virtual objects). This includes real experiments in which the computer records the data obtained and processes them using special programs.
 - a) text-clarifying – involves the use of photos and videos showing real devices and laboratory equipment, chemicals and chemical reactions, chemical manufacturing equipment, but using AR technologies, which allow them to be supplemented with clarifying texts, that greatly enhances their didactic capabilities;
 - b) real-illustrative – illustrative photos of explosives, poisonous and flammable substances, as well as inaccessible chemical reactions are incorporated into educational texts on paper and electronic media by means of augmented reality technology. Real images of substances and chemical processes help motivate the subject studying, make the process of learning chemistry interesting;
 - c) real demonstration – videos containing a real-life chemical experiment are used;
 - d) real research – experiments are used, accompanied by computer processing of the obtained experimental data.

Different applications can be used to create augmented reality objects and elements while teaching chemistry. They vary in complexity, accessibility and functionality. For example, ARToolKit, HP Reveal (Aurasma), Vuforia, Augment platforms [13, 14].

It should be noted that Vuforia, in our opinion, may seem difficult for a person who has not previously encountered the creation of augmented reality objects. It also requires the installation of another Unity program. The Augment platform offers the possibility of creating augmented reality objects and using ready-made models which can be downloaded. However, it can only be used for 30 days for free. For further use is assumed a user fee.

The authors [13, 15] used HP Reveal (Aurasma), which is free, more understandable and convenient. However, in 2020 the developer of HP Reveal application announced the closure of the project and the end of application support, as well as the removal of all accounts.

There is also a free Blippar application [16, 17] that can be used in creating augmented reality and in teaching.

Through literature data and research analysis, we believe that the use of augmented reality technologies in the educational process creates a number of advantages [12, 8, 7, 18, 19, 20, 21, 22, 13, 15, 23, 24, 25, 26, 27, 28], among them:

- visualization of educational material, the possibility of displaying either the objects of the micro-world, or objects not available in the educational institution;
- using of modern teaching methods familiar to the subjects of the educational process makes the learning process more attractive and interesting; against such a positive background, the quality of information perception and comprehension increases;
- increasing students' motivation for research work;
- familiarization with laboratory equipment before starting to work with them;
- increasing the efficiency of students' independent work;
- providing an opportunity for students with special educational needs to participate in a joint project, to perform a practical task.

The potential of augmented reality technologies in distance education should be emphasized in particular. Without the possibility of face-to-face communication with the subjects of the educational process, the teacher has not only to present new material in videotelephony software programs, to provide texts and videos for study, but also to make educational material as accessible and comprehensible as possible, as well as constantly stimulate the interest of students [29, 30].

In our view, the augmented reality technologies have all these features, if they are used properly in the educational process.

3. Research methodology

In the process of research, the following methods were used.

To clarify the state of the problem and the objectives of the study: study and generalization of pedagogical experience and scientific pedagogical literature about the usage AR technologies in the educational process; analysis of online resources, methodological literature on the generalization of augmented reality opportunities and benefits; analysis of the available AR applications that can be used in teaching chemistry, were used.

In the practical part of the research: interviewing students; observing students while using Blippar to study some chemical disciplines.

4. Results and discussion

At the Department of Chemistry and Methods of Teaching Chemistry at Sumy State Pedagogical University named after A.S. Makarenko, applications for creating augmented reality have not previously been used in the educational process. But as such applications are increasingly gaining acceptance from scholars and teachers, we also decided to introduce augmented reality technologies in the teaching of chemistry disciplines that are taught to our students.

4.1. Creating projects in Blippbuilder

We analyzed several augmented reality applications. And chose Blippar. It should be noted that this application has a paid version that can be used for commercial purposes. But there is also a free version that cannot be used for commercial purposes, and projects created with it can only be viewed using a test code and will be watermarked, but it includes access to all features within Blippbuilder. However, these disadvantages are not significant given the advantages of the application.

Teacher can create AR objects with Blippbuilder [16]. If he is working with this application for the first time, it is necessary to register on the site. As our experience with Blippar has shown, the registration process is quite simple and formal, but necessary to use the application.

The application allows users to create an augmented reality both for viewing in a mobile application and in a browser. The first option is more appropriate in the classroom.

To start creating a project – blipp (figure 1), teacher needs to select a marker. This marker can be an image or a word. Students use this particular image or text as a marker. The program

recognizes it and displays augmented reality objects.

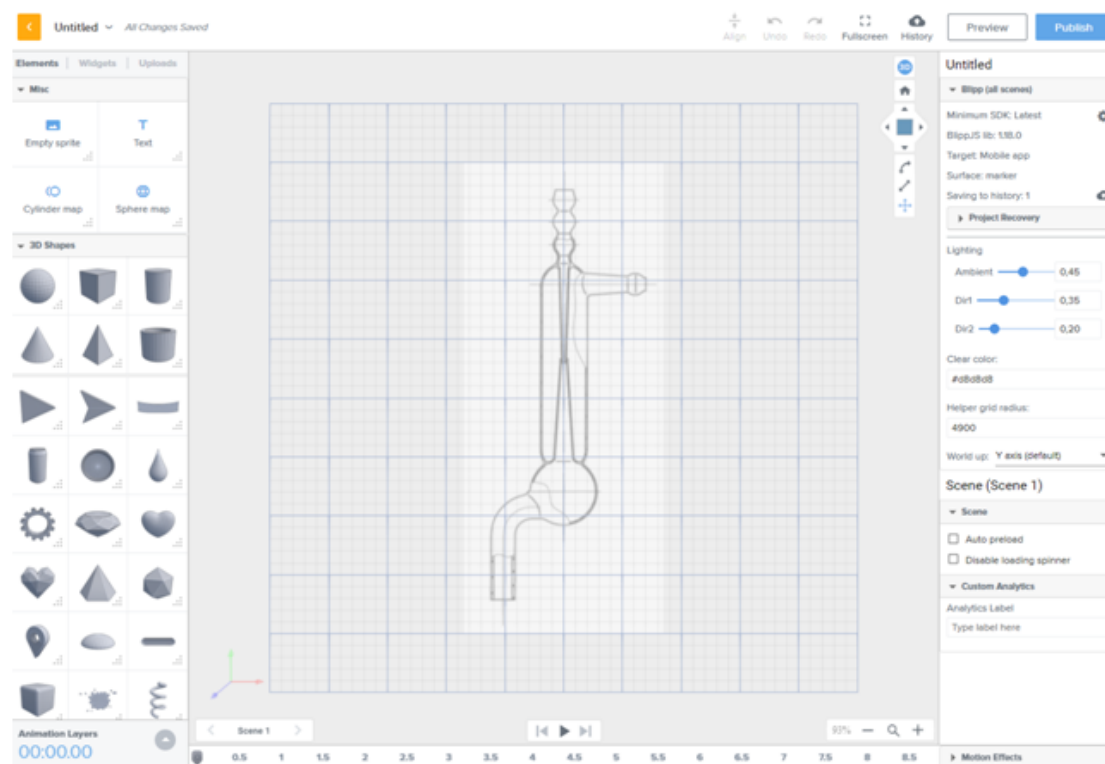


Figure 1: Getting started with a new project (blipp) in Blippbuilder.

The application offers ready-made models to use. And it is possible to upload your own models and other elements (images, documents of different formats, links to sites and social networks, audio and video files). Entering text in this application is not very convenient. By default, it is in one line. If the text is large, it is better to create it in a graphics editor and attach it as a picture.

It is convenient to create several scenes and place different elements on them. In this case, buttons for moving forward and backward are created on each scene (figure 2).

Once the blipp is finished, the application generates the code that is required for the subsequent use of the blipp.

4.2. The use of AR app in “Laboratory Chemical Practice”

This educational practice is intended for 1st year students majoring in 014 Secondary education (Chemistry).

Its goal is to acquire skills in working in a laboratory, mastering theoretical and practical knowledge and mastering methods for performing various types of work in a chemical laboratory. In practical classes, students need to familiarize themselves with the technique of carrying out

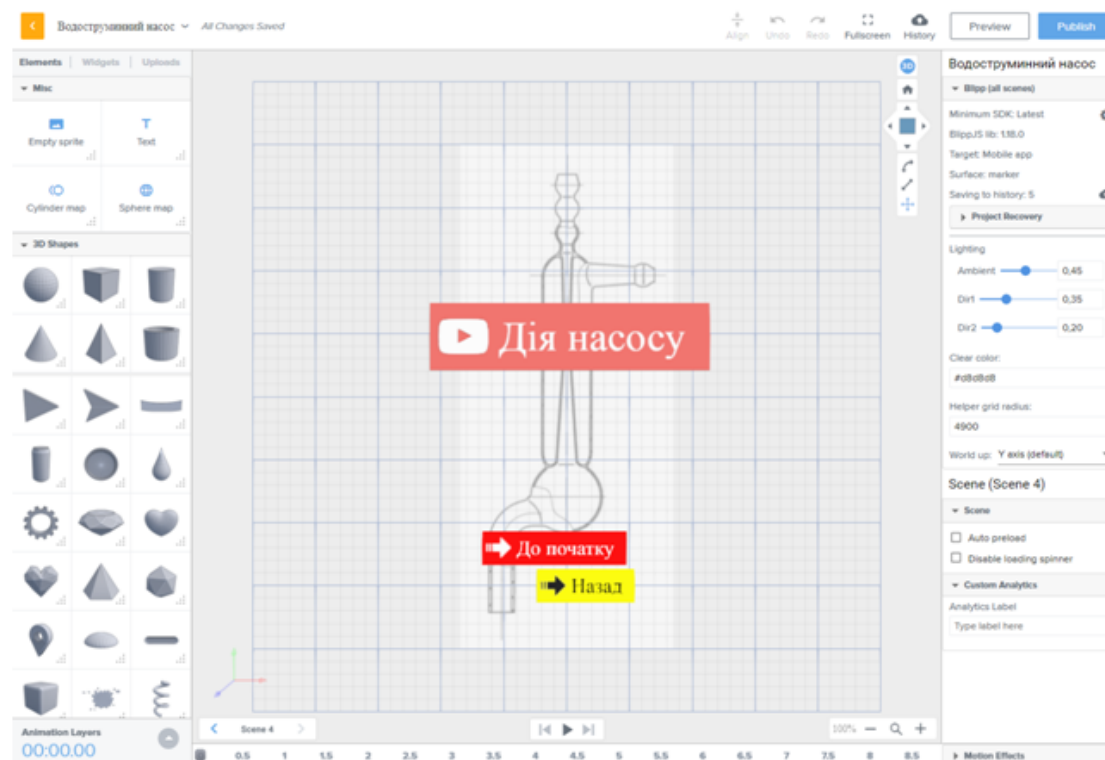


Figure 2: The project (blipp) contains 4 scenes and buttons for switching between them.

certain operations in chemistry, learn the basic techniques of working in a chemical laboratory and practice the skills of fulfilling life safety requirements. It is during this practice that students first become familiar with chemical glassware and equipment, their purpose and methods of handling them. Therefore, it is a very important component of the practical training of a chemist and future chemistry teacher. During distance learning, students do not have the opportunity to be in the laboratory and to work with laboratory glassware and equipment. The use of augmented reality makes it easy to solve this problem. In addition, da Silva et al. [19] shows the lab class in which the augmented reality application is used to study laboratory glassware is as effective as in a real laboratory. At the same time, using the application is safer and does not require expensive glassware.

According to student-centered learning students have the right for choosing methods and approaches to study new material in class. In practical classes we offer students a choice – how to study new material, what tools to use for this. One of these tools is the BlippAR augmented reality app, and the second is a printed training material containing text, explanatory pictures and supplemented with a QR code.

To get acquainted with a new type of equipment, the operation with chemical laboratory glassware, the method of work students do not yet know, they choose one of two cards. One of them has an image – marker and the corresponding code for use in BlippAR. The image needs to

be scanned using the Blippar app pre-installed on the mobile device.

When preparing for classes using AR application, we combined several different objects that related to one concept (phenomenon, process) in one project – blipp. Thus, we created an interactive study guide with AR elements, as we called it.

To work with such an interactive study guide with AR elements in class the teacher gives out a printed marker image – AR notecards, to the students and tells the code that matches it. To start working a Blippar application must be installed on students' mobile devices. The mobile version of Blippar requires at least 158 MB of gadget memory. Students enter the code, hover their smartphone camera over the marker and start working with augmented reality elements (figure 3).

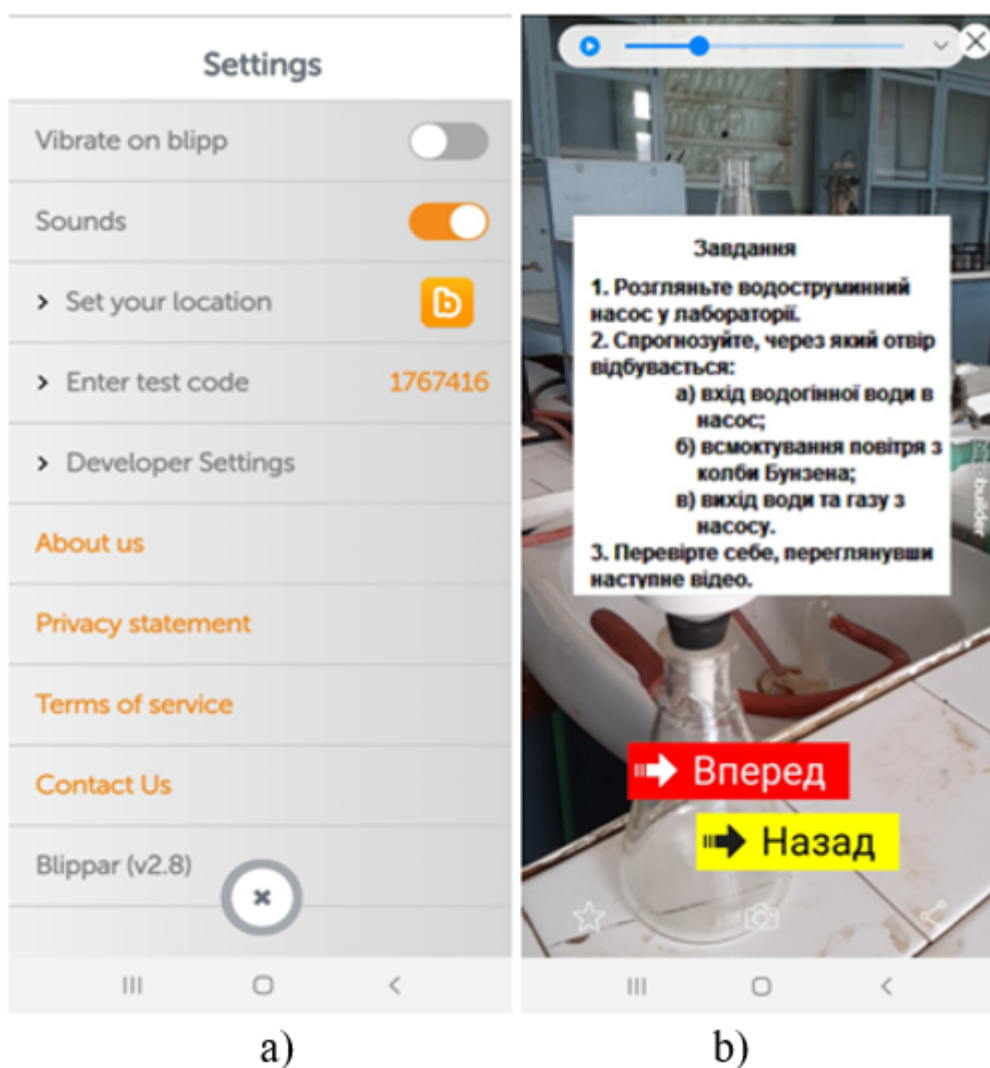
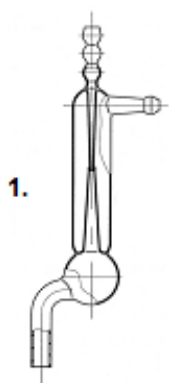


Figure 3: Working with Blippar: a) entering the code on a mobile device; b) completing assignments.

After the marker is recognized, all the material necessary for the lesson appears on the screen: a short text – a description of the chemical glassware, equipment or process that conforms to the pictures and signatures to them, video fragments, tests for self-control etc. This is what we call the study guide with AR elements. Navigation in it is quite convenient, there is always an opportunity to return to an obscure fragment and study it again carefully. After acquaintance with the description of the equipment and methods of working with it, the student can proceed directly to the implementation of the laboratory work.

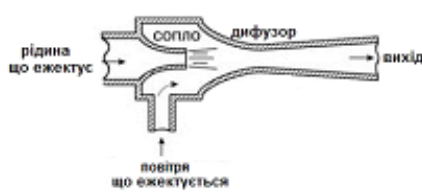
The second card, which the student can choose, contains almost identical material – short text, drawings and captions to them – but printed on one or more sheets of paper. This is an instructional card, which is complemented by QR codes so that students can scan the code using their mobile device. Such cards are intended for those who prefer to work with already known learning tools (figure 4).

Водоструминний насос



1.

2. ПРИНЦИП ДІЇ



За принципом дії належить до ежекційних насосів (ежекторів) - (фр. *éjecteur*, від *éjecter* - викидати). Ежектор, працюючи за законом Бернуллі, створює в звужуючому перетині знижений тиск одного середовища (рідини), що викликає підсмоктування в потік іншого середовища (повітря).

3. Завдання

1. Розгляньте водоструминний насос у лабораторії.
2. Спрогнозуйте, через який отвір відбувається:
 - а) вхід водогінної води в насос;
 - б) всмоктування повітря з колби Бунзена;
 - в) вихід води та газу з насосу.
3. Перевірте себе, переглянувши наступне відео.

4. Перегляньте відео за QR-кодом



Figure 4: Instructional card with QR code.

Every lesson, we offered first-year students a free choice – work with the Blippar augmented reality application or with an instructional card that contains a QR code. Students often chose the first option. Instructional cards were also popular. Often, students took both a marker image and an instruction card. They understood that their content was essentially identical. But they

took both and used at their own discretion.

4.3. The use of AR app in “Organic Chemistry”

According to the educational programs at our university second-year students of the specialties 014 Secondary education (Chemistry) and 014 Secondary education (Biology) start studying organic chemistry.

The teaching organic chemistry experience at our department shows that the study of organic chemistry causes difficulties for students, primarily due to the large number of organic compounds and the peculiarities of their spatial structure. The lack of a system of ideas about the chemical, electronic and spatial structure of organic molecules and its effect on the substance properties leads to unproductive mechanical memorization of a large amount of factual material. Often, to understand the course and mechanism of a reaction, you must first understand how a molecule is made, especially when it comes to substances such as carbohydrates. Using augmented reality helps to meet this challenge [13, 22].

It became clear from the conversation with the students, that it is difficult for them to imagine the spatial structure of the cyclic form of monosaccharides, the process of creating pyranoses or furanoses. The use of visualization elements such as diagrams, images, videos during the study of these substances certainly facilitates the comprehension. But when watching such a video or image, students fail to understand something, they are often embarrassed to say it and ask to repeat. And if for some reason the student is not present at the lecture, he or she should study the omitted topic himself, using a textbook or methodological recommendation. And most traditional textbooks use 2D images that do not give a complete picture of the three-dimensional organization of molecules, and this makes it difficult for students to understand the material.

The COVID-19 pandemic [31] has become another challenge in organizing the study of organic chemistry. And the teachers had to revise the traditional teaching methods and introduce new approaches and methods into the teaching process. And augmented reality technologies in this situation have become one of the powerful tools that allow to collect different information in one place, to visualize objects and processes, and to replace real processes and experiments with virtual ones. After all, chemistry is not only a set of theoretical data, it is also an equally important practical component. Chemistry contains information about the spatial structure, the physical properties of substances, their aggregate state, interaction with other substances, the effects accompanying these interactions. And visualizing these aspects – real or virtual – is very important for successful learning.

You can link augmented reality objects with 2D images that can be found in textbooks, methodological recommendations or instruction cards using QR codes. Free convenient QR code generators are available online. Thus, it is possible to link the generated graphic code to any image, video or website. To use this code, students only need a smartphone with a video camera that can scan the code and redirect to the appropriate link. In our opinion, this method has one drawback. Only one element can correspond to one code.

For example, when studying the topic “Monosaccharides” we consider the cyclic form formation of monosaccharides and the stability of different conformational forms. Information cards containing several QR codes (figure 5) have been developed to better understand the material. Students can scan these codes and familiarize themselves with the scheme for the cyclic forms.



Figure 5: Instructional card on the topic.

The same cards have been developed for other topics. For example, for “Polysaccharides” to visualize the structure of these macromolecules and their reactivity. And for the reaction of cellulose nitration, using the QR code, students can watch a video of the experiment. A mixture of concentrated nitric and sulphuric acids is used to obtain nitrocellulose and must be handled very carefully. Nitrocellulose itself is a flammable substance. Before conducting such experiments, it is very important to thoroughly prepare for them, study the technique of conducting the experiment, and simulate it by means of augmented reality.

It should be noted that when such cards were offered for use for the first time, one student could not use them, since her smartphone could not recognize QR codes and it was necessary to install a special application, after that problems no longer arose. The rest of the students had no problems using QR codes.

To create augmented reality objects, we decided to use the Blippar application too.

Creating instructional cards (AR notecards) with Blippar allows to collect different objects of augmented reality in one place, linking them to only one marker. Moreover, such a marker can be an image, or it can be a word, for example, the name of a substance. This means that the student does not have to have a marker in front of them all the time. If the marker is a word, the student can scan it with the phone camera, even in the text, and see the result. As it mentioned above, for each marker, its own code is created and before scanning the marker, the student has to enter the appropriate code in the Blippar browser application on the phone.

For example, for the already described material on the spatial structure and stability of conformations for glucose a marker “Glucose” was created and assigned the corresponding code in the Blippbuilder application (figure 6). During the lesson the students get this code and they also get cards – AR notecards, on which both the marker and the code are indicated.



Figure 6: Marker created in Blippbuilder.

The marker selected is very simple. Students can find the term glucose both in the lecture notes and in the description of laboratory work and can scan it with the telephones even when pointing the phone camera at the computer screen, as shown in the figure 7, (which is very convenient while distance learning) and easily use the Blippar browser application to view the information.

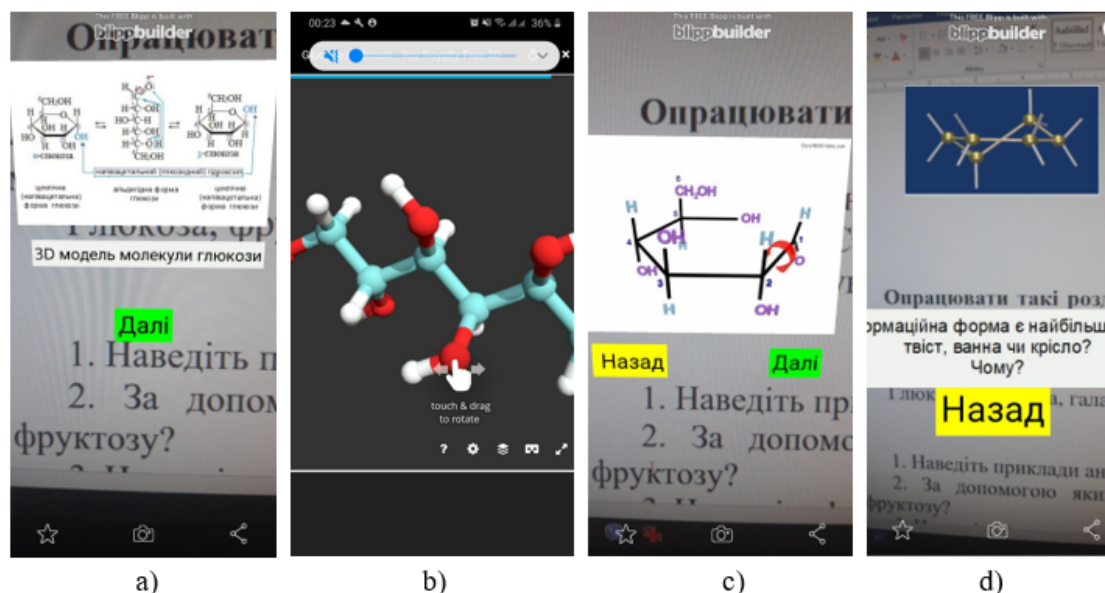


Figure 7: Displaying a blipp (study guide with AR elements) on the screen: a) scheme, b) 3D model of the molecule, c) video, d) task.

First, they see a schematic representation of the cyclic structure formation. They can also, by clicking on the corresponding image, go to the 3D model that allows the molecule to be viewed from different points. Then students can go to the animation that illustrates the cyclic structure formation. At this stage, if necessary, it is possible to return to the previous scene – the scheme and the three-dimensional model. Or they can go to the next one to see the transformation of one conformation into another. So, the application allows students to freely move from one scene to another, if they need to look through the information again. Or they can watch the video several times or stop it if they want to note something.

Thus, using just one word and a phone app, students can analyze the spatial structure of glucose. And they don't have to look for information from different sources and go to other sites to watch the video – all of this is in one study guide with AR elements.

The Blippar app allows users to upload videos. Therefore, the teacher can shoot the videos he wants and link them to the marker. Or he can use ready-made videos and link the site where they are to a marker.

Our experience of using Blippbuilder shows that it is better to create text fragments when creating blips not transparent, but on a colored background. This makes them more visible and user-friendly. And when scanning, it is better, but not necessary, that the marker is on a vertical

surface.

4.4. Student interview results

At the end of the classes that were held using AR study guides, we interviewed 25 students to find out what they thought about using augmented reality while studying organic chemistry and laboratory chemical practice. We have summarized all the responses received (figure 8).

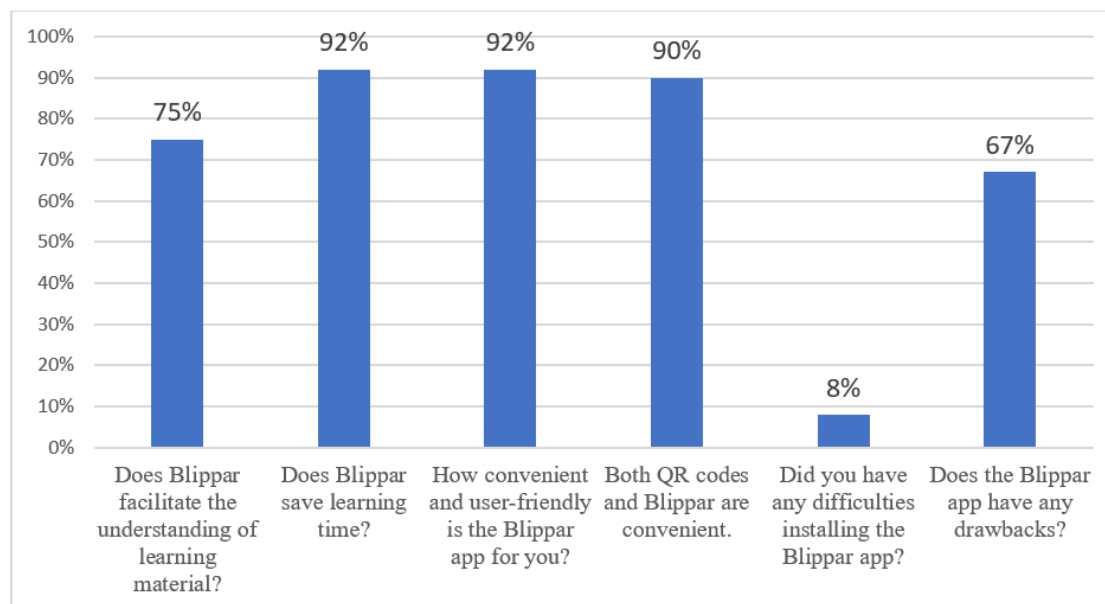


Figure 8: Student interview results (showing the percentage of those who answered positively).

To the question “Does Blippar facilitate the perception and understanding of learning material?” 75% of the respondents replied in the affirmative and added that AR technologies were an effective addition to real-life learning. Others noted that they did not see the benefits of using the Blippar application.

To the question “Does Blippar save time needed to learn material” 92% of the students answered affirmatively and argued that they did not need to search for information from different sources – everything that was necessary for the study was tied to one image-marker. 8% of students found it difficult to answer the question.

Answering the question “How convenient and user-friendly is the Blippar for you?” 92% of those surveyed said that the application was convenient and user-friendly. At the same time, when asked which option was more convenient for them: using QR codes or the Blippar browser, 90% students answered that both options were approximately equally convenient.

It should be noted that 8% of our students had technical problems installing and using the Blippar application or using QR codes.

When asked about the disadvantages of the Blippar application, 67% of students indicated the need to install the application on the gadget. Accordingly, 33% did not notice any.

Also, students expressed their wishes that we include markers and their corresponding codes in lecture notes, guidelines and recommendations for independent work,

5. Conclusions and directions of further research

Interviewing and observing students while using Blippar, as well as our work experience with this application, lead to the following conclusions.

The undoubted advantages of Blippar are:

- it is a free application if used for educational, not for commercial purposes;
- does not require much space to install;
- the interface is simple and user-friendly;
- any image or text can be used as a marker – Blippar allows to use a wide variety of file types;
- one marker – several elements of augmented reality – the teacher can combine a large amount of different information and logically present it;
- the application allows to upload different types of information – videos, images, 3D models, links to sites, etc., that is to create a study guide with AR elements;
- after scanning the marker, students should not hold the screen of their mobile device (smartphone, tablet) only in one position relative to the marker, they can take it aside – the augmented reality objects will not disappear;
- using the interactive study guide with AR elements, created in the Blippar for classes in a real-life chemical laboratory is safe and does not require expensive glassware.

With all the obvious advantages, working with Blippar has its drawbacks:

- to work with Blippar, students need to install it on their device;
- students need to enter a special code to work with the marker image, each marker has its own code;
- 3D models of chemical laboratory equipment and molecules of substances are very few, and they are not for free.

We believe that these disadvantages are insignificant compared to all the advantages of the Blippar application in creating augmented reality objects which it provides for education, including the study of chemistry.

Further studies are related to conduct of classes using the Blippar application for students of other courses and other specialties, checking their effectiveness; expanding the list of disciplines with using technology of augmented reality; to develop lecture notes, teaching aids for classes using AR technologies; and involving in future research students from schools and colleges those who are interested in studying chemistry in depth.

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