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# Specifics of using image visualization within education of the upcoming chemistry teachers with augmented reality technology

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**Abstract.** It is beneficial to study chemical disciplines, applying the Augmented Reality for the upcoming chemistry teachers, as far as the visualisation of the demonstration material in the 3D helps students understand various processes and phenomena, the structure of chemical compounds and the mechanisms of their correlation in a better way. The object of the project is the development of program and printed tools, designed to visualize the education process within chemistry disciplines according to the augmented reality technology. The authors have developed applications, designed for visualisation of the study material with AR. When a mobile phone is pointed on a marker, the image “comes to life”, its three-dimensional model appears; it can be manipulated in some way (inversion, enlargement, viewing from different sides) to understand its structure, operating principle etc. better. Applying augmented reality objects gives the teacher an opportunity to explain big amount of theory quickly and effectively, and the students – to memorise it effectively, develops creativity and boosts motivation for study. Applying AR while training the upcoming chemistry teachers gives the ability to prepare them for applying this technology during the education process in the general secondary education establishments.

## 1. Introduction

At the present times, the educational process is being actively informatized. Nowadays, the development level of computer technologies demands utilization of new approaches to the educational process in higher educational establishments, new methods, forms of educational data management in order to activate the perceptual performance of students. Computerized systems are powerful information integrators within all the branches of knowledge, including the educational processes. Utilization of informational and communication technologies (ICT) within teaching chemistry gives an opportunity to intensify the education process, speed up the knowledge and experience transfer, as well as increase the quality of teaching and education [20], [23], [26].

It is common knowledge that chemistry is a science, requiring an illustration of the theory. A well-selected demonstration data can provide a better understanding of various processes and phenomena, the structure of chemicals and mechanisms of their interference. In this way, visualization of scientific material makes its perception and digestion easier [7]. Unfortunately, usual 2D images of the traditional handbooks, textbooks and monographs do not give the complete understanding of the mechanisms of chemical reaction paths, special structure of molecules, the nature of physical and chemical reactions etc. That is why, for an effective study of chemical disciplines and for training the



upcoming chemistry teachers, in the modern era the relevant aim is using numerous demonstrations in the teaching process, which are impossible without special chemistry programs, simulator apps and augmented reality apps [15], [24], [25], [27], [28], [29], [30], [37], [40], [45].

The object of the research is the development of program and printed tools, designed to visualize the education process within chemistry disciplines according to the augmented reality technology.

## 2. Discussion and results

Studying molecular structures of the chemical compounds is the crucial aim within teaching theory in chemistry, because the explanations of physical and chemical characteristics of the compounds, as well as methods of production are based on it. A 2D image of a molecule does not give the complete picture about its special configuration, the nature of connection between the atoms, interatomic distances and valence angles. For this reason, for a better imagination of the molecular structure, especially within the organic chemistry, 3D images are relevant to be used [15], [27], [28], [30], [37], [40], [45].

Using 3D-images of molecules while explaining theory boosts clearness, gives better understanding of chemical compound's structure, geometry of a molecule, as well as mechanisms of its interferences and prediction of chemical reaction products. Therefore, it expedites a better systemizing and digestion of chemistry knowledges.

Effective up-to-date technology of visualizing the education data is augmented reality (AR), which provides the maximal visualization of the object, in other words, converting a 2D image into 3D, as well as "make it live" [4], [18], [19]. The relevance of the introduction of AR technology and mobile learning in the educational process is highlighted in the works [2], [3], [9], [10], [11], [13], [16], [17], [21], [22], [31], [32], [34], [35], [36], [38], [39], [41], [42], [47], [48]. Utilization of such an ICT tool while studying new material brings an opportunity to increase the dimensional view of the students, "to see" and understand the heard material better, which contributes its better digestion and forms some practical skills [4], [20]. This method has advantages above using computer programs, because it provides the opportunity to visualize images in the educational textbooks with a mobile phone, wherever the student is located without a demand of being near a computer or laptop. This method became particularly effective during the distance education under the circumstances of the quarantine 2020, in the time of the world coronavirus COVID-19 pandemic, when the human endeavour and particularly the study process, were switched into the remote form in the most countries of the world [1], [5], [33], [43], [44], [46]. Visualisation of the study material with AR is effective when students' learning the disciplines "Organic chemistry", "Non-organic chemistry", "Radiation chemistry", "Crystal chemistry", etc.

The authors have developed applications, designed for visualisation of the study material with AR. Based on the Vuforia platform, augmented reality markers were created to use the AR technology [4]; 3D objects were modeled in 3DMax program, the augmented reality objects were realized in the Unity 3D, multi-platform tool for development of 2D and 3D mobile apps [6], [8], [12].

When a mobile phone is pointed on a marker, the image "comes to life", its 3D model appears; it can be manipulated in some way (inversion, enlargement, viewing from different sides) to understand its structure, operating principle etc. The explanation of study material, in this case, is being processed with mobile devices and image markers by the participants of study. The uploaded applications give the opportunity to visualize the study material and make it easier to memorize. As for the teacher, they have the ability to reduce the theory explanation timing and to benefit in discussing controversial questions, solving creative tasks etc.

In this way while being explained about structure of an atom in case of 3D visualization of atomic model, the student receives a picture, shown on figure 1, on his smartphone, which provides a better understanding of mechanisms of chemical bounds development and chemical reactions path.

Figure 2 show example of 3D images, generated from the specially developed 2D marker images for organic chemistry. The authors have developed a mobile application called LiCo.Organic which generates 3D images of organic compounds with AR [14]. This application is beneficial for upcoming

chemistry teachers, as far as it helps them learn theoretical basics of organic chemistry and prepares for the school work with kids during the chemistry lessons. LiCo.Organic has the following abilities, generating 3D-images of molecules, display homologous series of carbohydrates, investigation of the space structure of isomers.

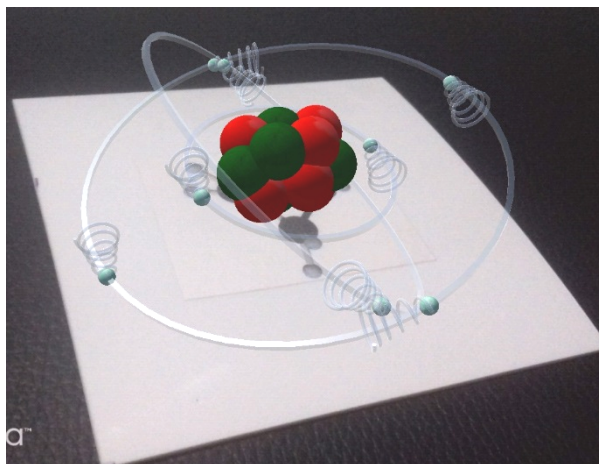


Figure 1. 3D-image of an atom model, generated with AR method [20].



Figure 2. 3D-image of ethyne, generated with the mobile app LiCo.Organic.

When a homologous series of a selected class of organic compounds is displayed, spatial molecules of the first 10 samples and the main quantitative characteristic can be seen: distances between the atoms and the valence angle (figure 3). The generated 3D image of the homologous species is animated, the structure of its samples (alkanes, alkenes, alkynes etc.) is displayed step-by-step, along with demonstration of the extension of the carbon chain. The presentation of the selected classes' of organic compounds isomers is also animated (figure 4).

Figure 5 is showing examples of 3D images, generated from 2D image markers, which are used for studying crystal chemistry.

Within the study of the “Radiochemistry and radioecology” by the upcoming chemistry teachers, students can explore the nuclear decay, nuclear fission, the chain reaction, structure of the nuclear weapon, operating principle of a nuclear powerplant and other subjects, when a crucial element of explaining the study material is not only a well-selected illustration of a concept, but also a

demonstration of the very process (nuclear fission, operation mechanism of a nuclear warhead, operation of a nuclear powerplant).

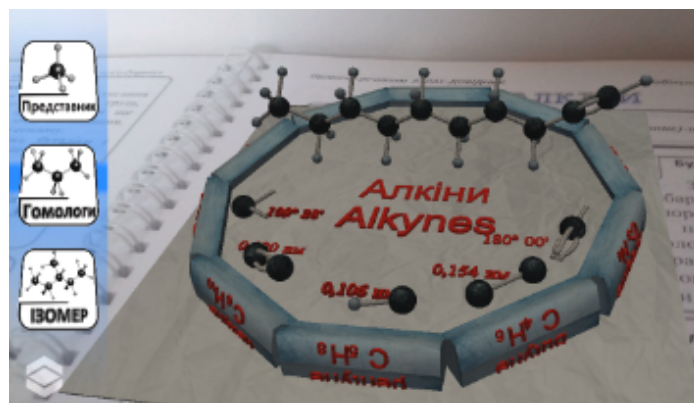


Figure 3. Homologous series of alkynes, generated with the mobile app.

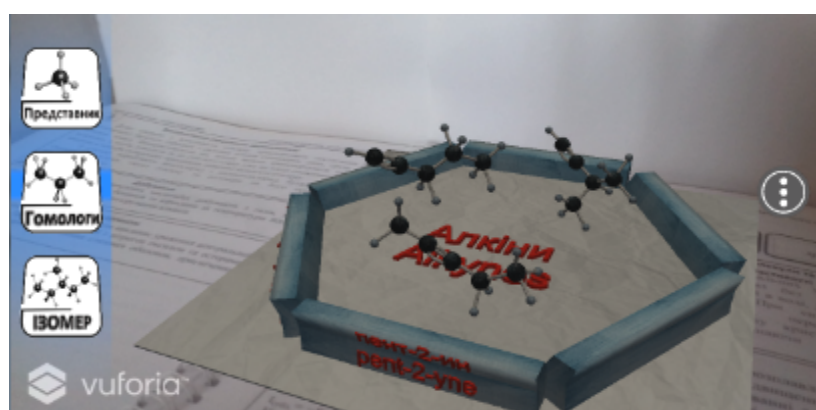
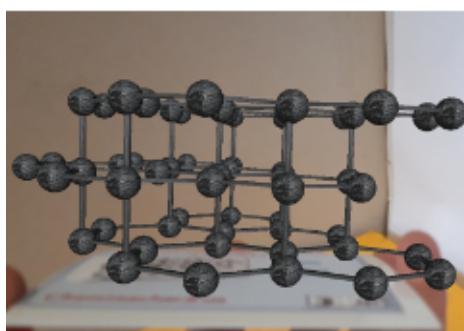
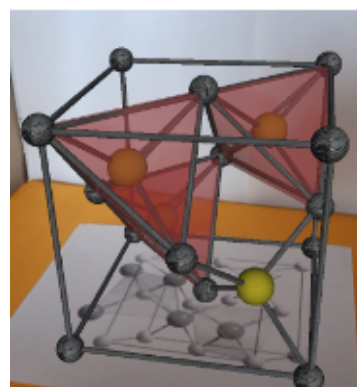


Figure 4. Isomers, generated with the mobile app.



a

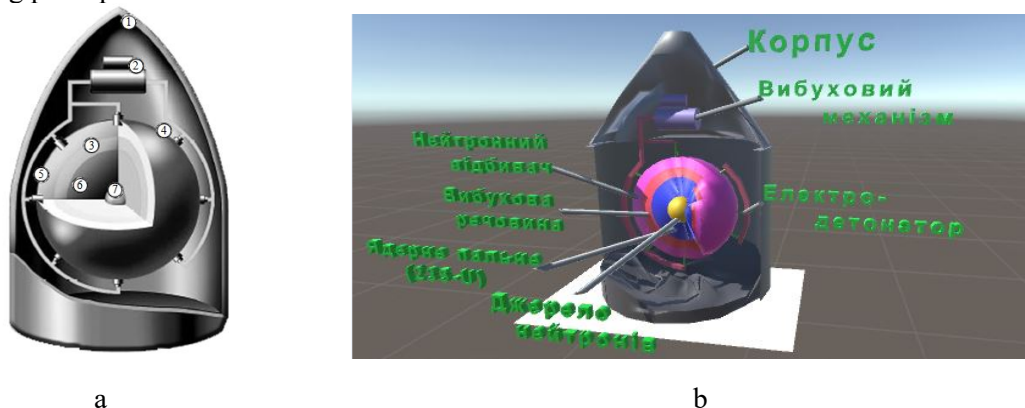


b

Figure. 5. 3D-images of the crystal grating of graphite (a) and ZnS (b).

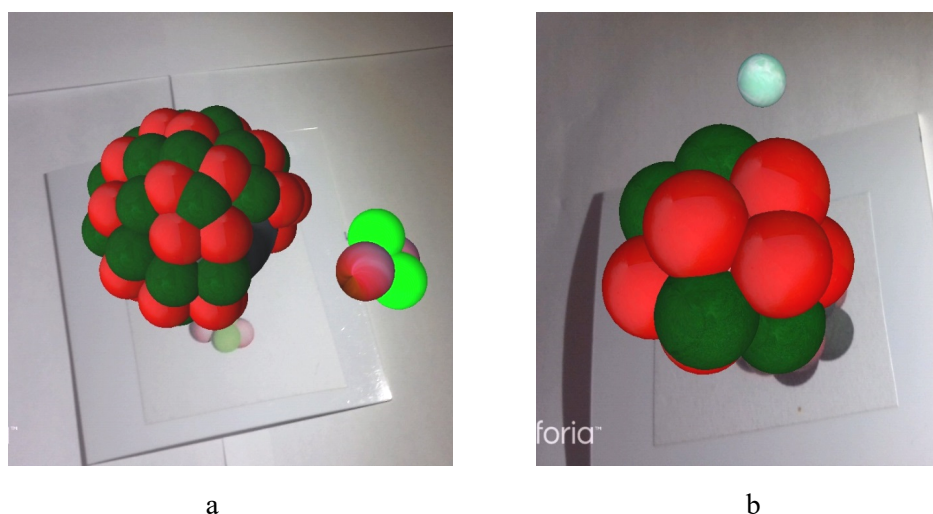
Applying AR technology, for example, the students can see a picture of nuclear weapon (figure 6) with caption of its parts, which “comes to life”, when pointing a cell-phone on it; a 3D model appears

on the screen and the model can be manipulated in some way for better understanding of its structure and operating principle.



**Figure 6.** 2D image of a nuclear warhead (a) and three-dimensional model of the nuclear weapon (b), generated with the mobile app (1 – body frame; 2 – detonating mechanism; 3 – detonating substance; 4 – electric detonator; 5 – neutron reflector; 6 – nuclear fuel ( $^{235}\text{U}$ ); 7 – neutron generator; 8 – compression of nuclear fuels by the explosion, aimed inside).

Analogically, with relevant markers  $\alpha$ - and  $\beta$ -fissions can easily be visualized not only with a static 3D-image, but also with animation effect (figure 7).



**Figure 7.** 3D-images of  $\alpha$ - fission scheme (a),  $\beta$ -fission scheme (b), generated with AR method.

### 3. Conclusions

The development of global mobility stimulates the research of new strategies for the study process in general education establishments, as well as creating theoretic materials in chemistry with Augmented Reality. These give the possibility to upgrade the clarity of theoretical data, to make it as close to reality, as possible, develop pupils' creative imagination and build particular skills and techniques, effective while performing a chemical experiment.

It is also reasonable for the upcoming chemical teachers to study chemical subjects with Augmented Reality, because memorizing a huge amount of chemical theory is significantly easier with its good-quality visualization. The 3D visualization of the illustrative data helps students, on one hand, understand various chemical phenomena and processes, as well as the structure of chemical

compounds and mechanisms of their correlation, and on the other hand, to master AR technology in order to use it in the future educational work. The upcoming teachers think that applying Augmented Reality objects gives the opportunity to diversify the education process, make it more interesting, and boost pupils' motivation for study. The main advantage of using the developed mobile applications is the access for study whenever you can, and wherever you are, which is vitally trending during remote education within the national quarantine.

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