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Visualizing the school organic chemistry course with augmented reality

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Visualizing the school organic chemistry course with augmented reality

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Abstract. Nowadays, studying natural sciences, as well as chemistry, is impossible without good-quality visualization of the theoretic data. Supplying mobile apps with augmented reality give the opportunity to visualize the study information for the students and make its perception and learning easier. The paper is dedicated to developing a lap book and mobile app LiCo.STEAM Sugar with augmented reality and studying the "Carbohydrates" topic according to the 10^{th} grade chemistry program, and also to investigate it's efficiency within the chemistry lessons. The developed lap book includes the theories with carbohydrate molecules' images, an experimental part designed for performing chemical experiments and studying properties of organic compounds, and also tasks of different levels. Molecules of carbohydrates, their structure can be visualized with AR, and also video-experiments on this subjets can be played. Using the lap book "Carbohydrates" with augmented reality together with LiCo.STEAM Sugar mobile app allows to upgrade the content and the volumes of the theories, apply modern ICT within the study in order to build students' skills of a new level. Applying educational data with augmented reality give students the ability to memorize the theories in a better way, which is shown with the increased results of educational achievements of students in chemistry.

1. Introduction

1.1. The problem definition

Creative, analytical, innovation thinking, the team project work abilities, information literacy and effective information and communication technology (ICT) skills – this is not the full list of responsibilities of a successful modern person [1, 2]. The nowadays students need the comprehensive training in various different natural disciplines, engineering and technology. That is why STEM-education has become so vitally important. The main advantage of STEM-education is the complex integration of inter-discipline approach units with the project study that combines natural sciences with technology and engineering. Practically, all the gained knowledge and skills are interdependent and integrated into one single unit [1, 2]

One of the key factors of the nowadays education is building the child's "individual study" skills. The new-era child needs not so much knowledge, but what they do need is to think consequently and critically, they need the intellectual activity [3, 4]. The content and methods of education in school are designed to develop education, memory, creative thinking, to build the comparing skills, to define specific characteristics of subjects, classify them according to specific features, and get delighted in finding a solution. When the children themselves co-operate with the objects studied, they investigate the environment in a better way. That is why, while working with children, practical methods should be prioritized [3, 4]. For this reason, the tutors face a challenge of searching new unorthodox forms of cooperation with their students. Traditional study is changed with the productive one, which is designed to develop creative skills, to provide the curiosity for creative activities. One of the perspective approaches, which expedite solving this problem, is lap booking [3, 4].

We should keep it in mind, that natural sciences are mostly experimental. Memorizing natural science knowledge effectively, and after that memorizing physics, chemistry, geography and astronomy depends not only from the theory supply form, but also from realizing the experimental part (practical activities and laboratory experiments), which require proper theoretic training both for the teacher and for the students.

The up-to-date school chemistry course is integrated, which is evidenced with the list of main responsibilities. The present information and communication awareness leaves no doubt that good quality chemistry learning is supplied only with modern information technologies. There are a lot of professional chemistry software packets (chemical reaction simulators, virtual chemistry laboratories etc.) on the new-era IT market [5, 6]. The contemporary ICT trends are virtual reality (VR) and augmented reality (AR), integrated with mobile education.

In the digital era, especially nowadays, under the national pandemic circumstances, the whole study is fully or partially remote. In this case, information and communication technologies are critical, considering the fact that the main study tool for a present-day student is not a personal computer or a laptop, but a cellphone (Android or IOS). This is connected with the availability of cellphones, their convenience, and the huge amount of existing mobile application, which are not only easier to use, comparing to the computer programs, but also more powerful for their purposes.

The school chemistry course provides visualization of molecules in 3D, meaning AR technology is highly recommended. As far as the AR technology is multi-functional: it plays video-files, audio-files, images, 3D models, its appliance within the school chemistry course is pretty wide.

1.2. Research objective
The objective of the research is developing a lap book designed for studying "Carbohydrates" according to the 10^{th} grade chemistry program with augmented reality and investigating it's efficiency while studying organic chemistry.

2. Literature review
Developing a lap book is the new-era method of organizing the education activity. It develops creativity, perception and investigation of the new info, provides repetition and memorizing of the info, studied before, summarizing the knowledge and it is just an interesting type of corporate activity of the teacher and the students. It also includes a mind-game. With this being said, lap book is the final stage of the individual investigation work, which the student is doing when studying a specific subject. In order to fill out a lap book, the student needs to solve some tasks, make investigations, study the supplied material [7]. Creating a lap book helps capture and classify the learned material, and over-viewing it allows to refresh the completed subjects pretty quick. It allows both the student and the teacher to classify the subject theories and to understand and memorize the material in a better way. This is also a good way of replaying the learned info [3, 4]. In the cooperation with AR, lap book is an interesting interactive tool of study, which makes the teachers' work easier, visualizes the theories in good quality and boosts the students' perception level.

Augmented reality (AR) gives the opportunity to visualize any object to the max point (atoms and molecules, their correlations, equipment setups, technology processes etc.), meaning to convert 2D images into 3D and "make it alive" [8, 9]. Educational AR technologies boost the visual and contextual study, upgrading the study content to the point, when 80% of it is being memorized, comparing with the 25% received either by ear (classical lectures) or while reading [10]. Visualizing the study info makes it perception and memorizing easier. Descent demonstration data help better understand various processes and phenomena, structures of chemical compounds and mechanisms of their correlations when studying the basic chemical concepts. Usual 2D images of the traditional handbooks and schoolbooks do not give the full image of the key concepts of natural sciences: the spacial structure of molecules, physical processes, chemical reaction paths etc. The specifics of applying the AR into the chemistry educating process is defined in the following publications [11–13]. Particularly, the authors have claimed about these advantages of supplying this kind of technology:

- It is effective when studying imperceptible concepts (atom, molecule, chemical bonds etc.) [11];
- It has a positive impact on the students' curiosity and on the memorizing process [12,14,15];
- Accelerates the development of students' spacial intelligence, their ability to imagine and manipulate three-dimensional structures (molecules, crystal structures) [16, 17];
- Boosts motivation for studying chemistry [13, 17, 18].

Providing 3D models of molecules plays a significant role when it goes about the efficiency of studying organic chemistry [12, 19]. The authors [20, 21] emphasize on the efficiency of augmented reality for modeling chemical reactions, and, as a result, increasing curiosity for studying chemistry.

Furthermore, Su Cai and co-authors [16] claimed AR visualizing to have a positive impact on the students' understanding of the information, given in text form. This gives the idea that AR technology must be combined with the study content, which will include the text data as well, in the perceptible for the modern-age students grade.

3. Methods

A lap book, including the theories, tasks and image-markers for the mobile app with augmented reality was developed to study the "Carbohydrates" topic.

A free mobile application LiCo.STEAM.Sugar (powered by Android) was developed in order to visualize the chemical structure of carbohydrates and reproduce the laboratory experiment videos, which can be used both by the teacher and by the students to study the "Carbohydrates" topic. Augmented reality markers, designed for the AR technology, were developed [22] on the Vuforia platform; 3D objects (molecules of glucose, fructose, sucrose, starch and cellulose) were modeled [22] with the 3ds Max app, augmented reality objects were realized with the multi-platform tool, designed for developing two- and three-dimensional mobile applications Unity 3D.

4. Results and discussion

Using the lap book with augmented reality elements in a combination with the mobile application LiCo.STEAM.Sugar allows to perform renovation of the content and volume of the study data; apply new technologies while studying in order to develop high-level skills. The developed lap book provides the information according to the school chemistry program (10^{th} grade), about the below:

- Formula and molecular structures of glucose, fructose, sucrose, starch, and cellulose;
- Nutrition value of carbohydrates, the definition of fast and slow carbohydrates;

- Carbohydrates in food products,
- Their impact on the human body, consumption dose and consequences of overdosing;
- Methods of production and refining of sucrose from different stock material;
- Nutrition products, containing sugar;
- Interesting facts about carbohydrates.

For the purpose of building practical skills while studying this topic, they can perform the following experiments: analyzing the starch concentration of nutritive products, investigating starch concentration in cereal crops, identifying carbohydrates.

The 3D pictures of molecules of carbohydrates, learning which is required by the study program, give the opportunity to visualize the molecules of glucose, fructose, sucrose to the max point, “make them alive”, develop and boost the students’ spatial intelligence, and to give a deeper understanding of the study data, received by ear, which will boost its memorizing and building specific practical skills [19]. This method has much more advantages comparing to computer programs, as far as it gives the opportunity to visualize the lap book images no matter where the student is located (in class, during the city sightseeing, at home etc.) on the cellphone, and it does not require a computer or a laptop.

When a cellphone or a tablet with the uploaded app is pointed at a marker (see figure 1, 2, 3, 4, 5), the picture “becomes alive”, the screen shows its three-dimensional model, which can be manipulated in different ways (inversion, zoom-in, view from different angles), for better understanding its structure, operation concept etc.

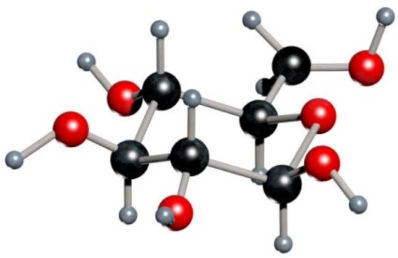

Figure 1. 2D image of glucose, located in the lap book, visualized with AR technology in the mobile app LiCo.STEAM.Sugar.

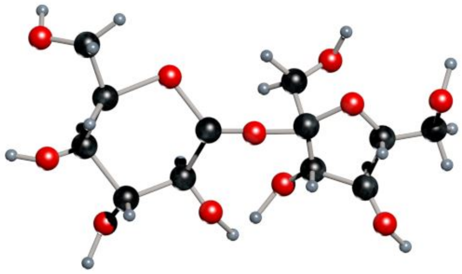

Figure 2. 2D image of sucrose, located in the lap book, visualized with AR technology in the mobile app LiCo.STEAM.Sugar.

Video-data of laboratory experiments investigating the concentration of starch in nutrition products, investigating starch in cereal crops, identifying carbohydrates were created for the

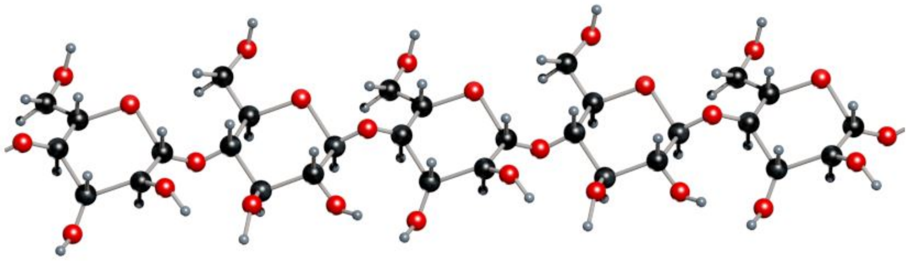

Figure 3. 2D image of cellulose, located in the lap book, visualized with AR technology in the mobile app LiCo.STEAM.Sugar.

purpose of supplying the experimental part. The developed videos are displayed on smartphones after "connecting" them with individual marker-images in the lap book.

The developed video-materials demonstrate laboratory experiments, performed by an experienced laboratory engineer, following all the safety regulations. The experimental performance is subtitled with text explanations. Using the developed video data give the student an opportunity (under the supervision of the teacher or parents) to repeat the same experiments in class or at home, makes the perception of this material much easier and the experimental part, too much complicated sometimes, is demonstrated understandably.

The figure 4 gives an example of one of the developed markers for the recommended laboratory experiments on the "Carbohydrates" topic, located in the lap book, designed for both teachers and students.

Vector images were selected as markers, they convey the context of the experiment, they are realized through a multi-platform tool, designed for developing two- and three-dimensional applications Unity 3D.

Also, the lap book "Carbohydrates" provides the setup of industrial production of sugar from sugar-beet, which every student can overview in AR. When the cellphone or tablet is pointed on the particular marker (see figure 5), an animation video is displayed on the screen (see figure 6).

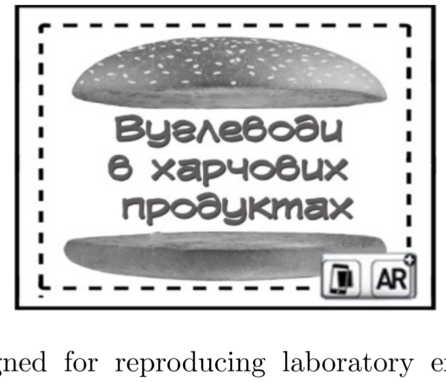

Figure 4. "Marker", designed for reproducing laboratory experiments (investigating the concentration of starch in nutritive products), located in the lap book (visualized with AR technology in the mobile app LiCo.STEAM.Sugar).

In order to identify the curiosity of 10^{th} grade students in using the augmented reality and its efficiency during the chemistry lesson, students of vocational school N24 in Ivano-Frankivsk city took a survey. The survey was taken by 60 people.

The survey results show that each student has a personal mobile device that can be used for study. All the students have used mobile apps with AR within the study process, and 100% of

Figure 5. Marker, developed to display an animation video "Production of sugar from sugar-beet" (visualized with AR in the mobile app LiCo.STEAM.Sugar).

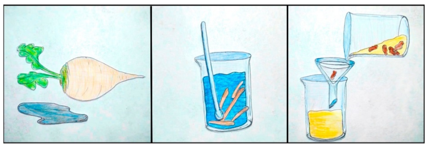

Figure 6. Animation video parts of "Production of sugar from sugar-beet" (visualized with AR in the mobile app LiCo.STEAM.Sugar).

the surveyed have confirmed the advantages, the technologies benefit in during the chemistry lessons. Furthermore, 83.87% of the surveyed think, these technologies would be efficient during other lessons. The survey results picture is shown on figure 7.

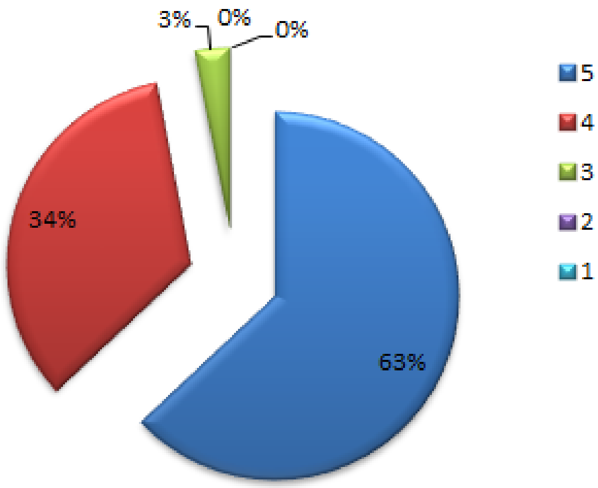

Figure 7. Efficiency rating of memorizing the study info, having used the "Carbohydrates" lap book and the mobile application LiCo.STEAM.Sugar during the chemistry lesson; marks from 5 to 1 (5 – it boosts the memorizing a lot, 1 – it is useless).

For the purpose of investigating the efficiency of using the developed mobile application and lap book during the chemistry lessons, a comparative analysis was made on the subject of students' educational achievements (two quiz-tests). They compared the achievements with the lap book and without it. The quiz was answered by 10^{th} grade students of high school N24 in Ivano-Frankivsk city. In order to realize the experiment, the students were divided into two model groups:

I. Group (30 students, with 11 high-level students, 12 – medium-level, 6 – sufficient, 1 – low):
   A) While studying the theory and preparing to the quiz N1 they were using the "Carbohydrates" lap book combined with the mobile application LiCo.STEAM.Sugar

The quiz was performed by the students on separate sheets of paper after short guide speech of the teacher.

B) While preparing to the quiz N2 and studying the theory, the lap book was not used. The group performed the quiz on separate sheets of paper after short guide speech of the teacher.

II. Group (30 students, with 10 high-level students, 12 – medium-level, 6 – sufficient, 2 – low):

A) While studying the theory and preparing to the quiz N1 the lap book was not used. The group performed the quiz, like group I, on separate sheets of paper after short guide speech of the teacher.

B) While studying the theory and preparing to the quiz N2 they were using the “Carbohydrates” lap book combined with the mobile application LiCo.STEAM.Sugar The quiz was performed by the students on separate sheets of paper after short guide speech of the teacher.

The calculation results are given in the table 1.

Table 1. The investigation results on efficiency of the developed mobile device and lap book during chemistry lessons.

Criterion	Group I		Group II	
	A (Lap book with AR)	B	A	B (Lap book with AR)
Average mark	8.21	7.00	7.15	8.07
Education achievement rate	84.61%	61.54%	50.1%	78.57%

Investigating the subjection of the experiment results to the normal division law showed [23], that the normal division law of students marks does not contradict with the results, received after the individual quiz.

In order to investigate the hypothesis about equality of common marks H_0: m_1=m_2 the t-criterion was being calculated, according to which a conclusion was made about statistic inequality of common marks among the students of groups I and II with the significance value α=0,05:

$t_{cI} = 2.00; t_T = 1.68; t_{cI} > t_T;$

$t_{cII} = 1.78; t_T = 1.68; t_{cII} > t_T.$

The results of this experiment in table 1 conclude that the lap book with the mobile app LiCo.STEAM.Sugar benefits in better perception and reproduction of the students’ knowledge and achievements. The students, using the lap book “Carbohydrates” integrated with the mobile app LiCo.STEAM.Sugar while studying the theory, had higher results, which is confirmed with the increase of education achievement rates.

As a conclusion, the students using the lap book with augmented reality elements in a combination with the mobile application LiCo.STEAM.Sugar for study achieved better results:

For group I: the quality has a 23.7% increase, the average mark is 1.21 higher (according to the absolute value).

For group II: the quality has a 22.47% increase, the average mark is 0.92 higher (according to the absolute value).

In fact, the students had to be very attentive while performing the practical works and laboratory experiments in chemistry, observing the real experiment. If a particular action of the teacher or the student, performing the work, was missed it would be re really hard to recover the sub-sequence of the whole reaction mechanism. The student does only see the final result, missing the intermediary steps, which are also important in order to do some calculations and build conclusions, which influences the perception quality. In order to address these issues of the studying process integrated with the chemical experiment, mobile apps with AR are the remedy, as far as they allow to repeat the missed theories, overview it again, expand separate stages of the process individually etc.

5. Conclusions

Providing mobile education technologies not only lift study to a new level, supplying the users access to knowledge 24 hours a day with no matter where they are, but also give wide opportunities for the students.

A lap book and a mobile app (on Android) was developed in order to visualize the chemical structure of carbohydrates and playing video-files of laboratory experiments and 3D models of molecules, which can be used both by the teacher and the students for an effective "Carbohydrates" drill in organic chemistry in the 10^{th} grade.

Reviewing the molecule images in 3D give the students an opportunity to understand the structure of organic compounds, predict their properties and realize mechanisms of their correlations. Video-experiments, reproduced with AR, help students prepare for performing a chemical experiment and perform it properly, according to all the health and safety regulations. This complex approach to studying the organic compounds' properties advantages in better memorizing the theoretic info, which is shown by increasing the perception quality value among the students and the common chemistry mark.

Combined with the augmented reality, the lap book gives the ability to improve understanding of the theory, expand and illustrate it, which boosts the perception and development of creative intelligence of the students, as well as increases the level of memorizing and reproduction of students' education achievements.

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