Augmented reality as a part of STEM lessons

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Abstract. Modern teachers and the managers of educational establishments have big challenge – to organize the lectures and the study process so that the students are provided with the necessary skills and to meet their educational needs, as well as their parents' expectations. An integrated lesson that is developed with a synthesis of information on different educational subjects stimulates the students' analytic thinking, which in exchange boosts the integral perception of the reality. That is why STEM lessons are becoming more and more popular among the educators, as far as the specifics of this approach can really solve a lot of tasks. Modern IT-developments are an appropriate T – component during STEM lessons and while developing STEM projects. One of these up-to-date trends is called Augmented Reality (AR), which allows visualizing the study material and improves its reception and memorizing. The purpose of the research is development of a mobile app (on Android) for STEM lessons, designed for visualization of the chemical structure of organic, biologically active substances, which can be used by the teacher and students in order to carry out integrated lessons of biochemical area; revealing key specifics of using STEM technologies while studying natural sciences.

1. Introduction

1.1. The problem statement

Nowadays, it is pretty obvious that if the problems are solved with ancient methods, a new level of education quality cannot be reached. New strategies, new up-to-date pedagogic technologies are a must-have [1–3].

An integrated lesson is one of the innovations of the modern methodology [4, 5]. This technology is becoming a part of school courses with ambitious confidence and connects subjects, incompatible at glimpse. The "Chemistry" subject is integrated by definition (a priori) [6]. It is overfilled with inter-subject connections and, along with other natural disciplines, offers the students wide knowledge in many fields of science, art, culture and the daily routine.

An integrated lesson that is developed with a synthesis of information on different educational subjects stimulates the students' analytic thinking, which in exchange boosts the integral perception of the reality [4, 5]. Integrated lessons can solve information, communication, educational and theoretic issues. Editions and choices on the structure of integrated lessons are widely different. Two or more subjects can be integrated. Information, communication, valuable and semantic competencies (responsibilities) are formed during these lessons [4, 5].

The nowadays pedagogic science claims that "in order to have the student receive the knowledge efficiently and to promote their intellectual development, it is vitally important to

set-up wide connections not only with different units of the study course, but also with numerous disciplines overall" (Inbound and internal subject integration) [1]. The experience shows that with the integrated education, which is updated and repeated by other fields of study, provides extremely better results in comparison with classic study of the disciplines [1, 4, 5, 7]. The integrated approach accelerates establishment of the knowledge system, develops the abilities to transfer these into different branches.

1.2. The purpose of the research

The purpose of the research is development of a mobile app (on Android) for STEM lessons, designed for visualization of the chemical structure of organic, biologically active substances, which can be used by the teacher and students in order to carry out integrated lessons of biochemical area; revealing key specifics of using STEM technologies while studying natural sciences.

2. Discussion and results

The result of the integrating natural and mathematical sciences with elements of technology and engineering is STEM education (STEM = Science + Technology + Engineering + Mathematics; STEAM = Science + Technology + Engineering + Arts + Mathematics; STREAM = Science + Technology + Reading+wRiting + Engineering + Arts + Mathematics) [8–12].

Nowadays, the teachers and the managers of educational establishments have big challenge – to organize the lectures and the study process so that the students are provided with the necessary skills and to meet their educational needs, as well as their parents' expectations [13].

That is why STEM lessons are becoming more and more popular among the educators, as far as the specifics of this approach can really solve a lot of tasks. Contemporary graduates – the upcoming disrupts and innovators need to receive the basic knowledge in natural and technical sciences, combined with 21st Century skills, like the communication ability, teamwork ability as well as the power to solve problems in the light of innovation opportunities and demands of the society [8, 13, 14].

During a STEM lesson every single activity is clear for the students, the lab equipment, robotics are directly involved into the structure of the lecture.

Modern IT-developments are an appropriate T – component during STEM lessons and while developing STEM projects. One of these up-to-date trends is called Augmented Reality (AR), which allows visualizing the study material and improves its reception and memorizing [15–18].

Establishing study system, involving AR technologies, can obviously make it easier for the students to understand the theory, as far as they have the capability to reinforce it in practice (to make virtual models in real time) [18–29]. Due to implementing innovations into the education system, especially virtual educational tools (3D modelling, augmented reality) the efficiency of study is improving overall.

The competitive approach requires a motivated selection of the integrated lessons, applying the results in daily routine. From this perspective, there are a couple of spicy biochemical subjects: Chemistry of Love, Chemistry of Happiness, Chemistry of Smell etc., which give the ability to understand the chemical processes, going on inside a human body. In the modern era, in most of the study plans of the course "General education (chemistry)", the discipline "Biochemistry" is one of the optional disciplines. Studying this subject will definitely help the upcoming chemistry teachers to explain biological processes of the human body, give examples during the chemistry lectures, perform integrated lessons and apply the knowledge, gained, in order to intensify the students' education curiosity.

A mobile application LiCo.School, capable of visualizing the study material was designed to image the molecules of bio-organic compounds. It can be downloaded with the QR-code

(figure 1). Formulae of organic compounds, provided in this paper, are markers for this mobile app.

Figure 1. QR-code to uploaded the LiCo.School mobile application.

At the first stage, 3D pictures of molecules were developed for this mobile app. For the purpose of applying AR, augmented reality markers were developed [30] on the Vuforia platform; 3D objects were modeled in 3ds Max, augmented reality objects were realized with the multi-platform tool for developing two- and three-dimensional mobile applications Unity 3D.

The natural science courses involve a lot of subjects, which are absolutely impossible without integration. For example, an integrated lesson can be performed in the 8^{th} grade in order to study the "Metabolism and energy transformation in the human body" topic. According to the study program, the student must operate with the definitions (metabolism, energetic needs, and vitamins), give examples of vitamins, describe the ingredients of nutrition products, food as a source of energy, the metabolism and energy transformation in the human body, nutritional and energetic needs of a human, explain the functional value of the proteins, fats, carbohydrates, vitamins, water and mineral substances for the human body. Supplying this knowledge is only possible with integration of physics, chemistry and biology. Also, this subject can be reviewed in the context of exotic fruits, which became popular in the shops, in order to make the lesson up-to-date.

For the majority of people, the most popular fruit is mango. Mango is occupied by vitamins, minerals and antioxidants, and furthermore, like all other fruits, they contain minimum proteins and fats. Mango provides with a huge amount of tryptophan (figure 2) – the ferment which is the precursor of serotonin – "the hormone of happiness".

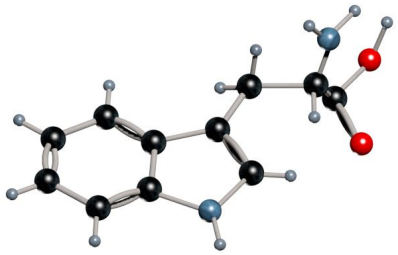

Figure 2. Tryptophan.

Mango is one of the top champions in containing the Vitamin C – ascorbine acid (figure 3). This water-soluble vitamin needs to be supplied to the organism, as far as it does not accumulate or store inside the cells [31, 32]

Mango is also full of folic acid – vitamin B_9 (figure 4). This substance is taken by the organism while building proteins and DNA, and they build new cells [31, 32].

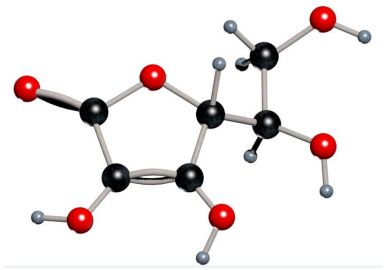

Figure 3. Vitamin C (ascorbine acid).

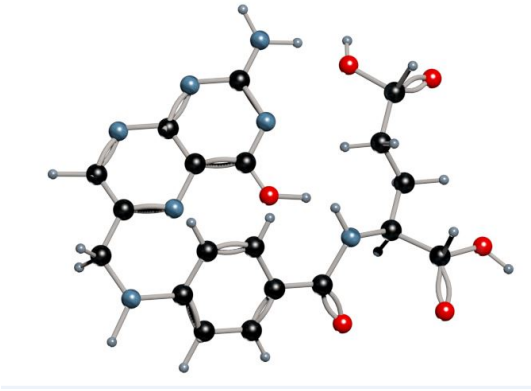

Figure 4. Vitamin B_9 (folic acid).

Vitamin E (figure 5), also contained in mango is fat-soluble. It supports the immune function and is a vital antioxidant.

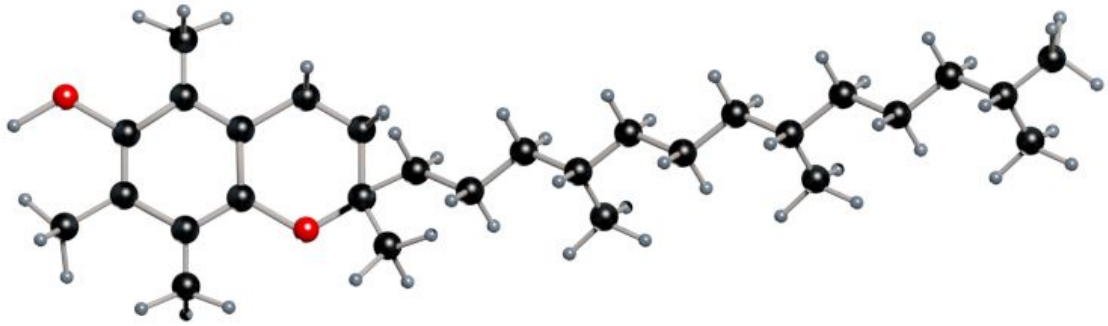

Figure 5. Vitamin E (α-tocopherole).

Mango does also involve vitamin A (figure 6), crucial for eyesight, osseous tissue growth and for reproduction health.

As far as we can see, a brief description of only one fruit gives the opportunity to learn a few vitamin formulas. But, as far as this topic is reviewed by 8^{th} grade students, and vitamins are organic compounds, studying which does only begin during the 9^{th} grade chemistry lessons, it is reasonable to simplify the material, visualizing it with augmented reality. In this way, every

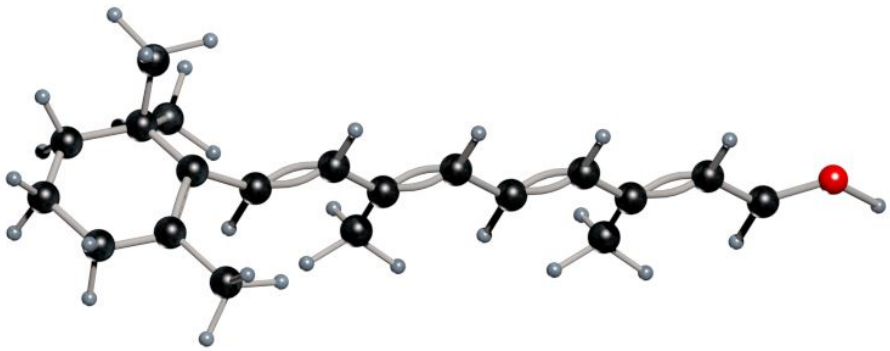

Figure 6. Vitamin A (retinol).

student can view this material on their smartphone or tablet, to "hold" the molecule of vitamin in their hands, which makes the lesson significantly interesting. This approach will help the students analyze the situation, boost their critical thinking and help them make the reasonable conclusions about the value of nutrition products, and the knowledge, received at the lesson will be useful in the grown-up routine.

The augmented reality can be implemented while investigating, for example, the chemistry of happiness. It is a fact that the nature of our happiness is chemical [33]. The happiness is defined as a psycho-emotional state of a total life satisfaction, the feeling of deep comfort and endless joy. The feeling of endless satisfaction is nothing, but a sophisticated chain of biochemical processes, driven by special hormones – "the hormones of happines", produced by the brain [33].

Dopamine, serotonin and the endorphins (figure 7) are considered to be the three hormones of happiness. All of them are produced in the human body and depend on its vital activities, the division of physical and mental stresses, nutrition and health.

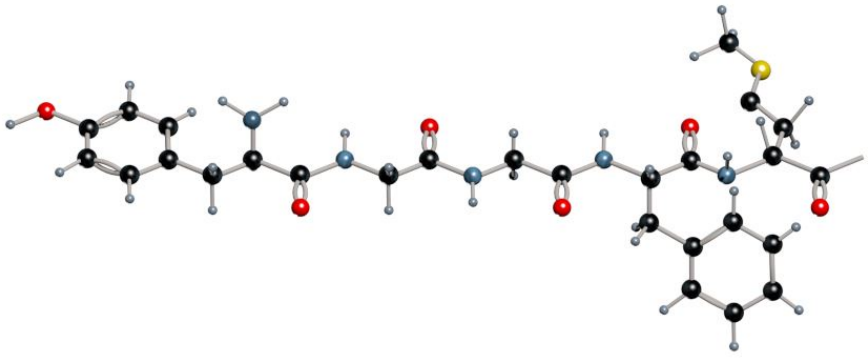

Figure 7. A part of endorphin.

Endorphins are probably the most famous hormones of happiness and satisfaction. Endorphins are a group of poly-peptide chemical compounds, which are produced by neurons of the cerebrum (the brain), similar to opiates in their structure. Endorphins develop inside the neurons of the brain from a substance, produced by the hypophysis – betalipotropin [33].

Serotonin (figure 8) is the hormone, connected with seasonal rhythms [33]. Its production depends on the daylight duration. Serotonin (5-hydroxy-tryptamine) is a neurotransmitter. A biogenic amine, the precursor of which is hydroxylated tryptophan (5-hydroxy-triptophane),

which is to be processed with decarboxylizing pyricoxal phosphate dependant decarboxylase and building a biologically active amine. Serotonin is metabolised in the human body in moments of extasy, its amount is increasing with euphoria and decreasing with depression. 5-10% of serotonin is syntethized by the pineal gland from the vitally important tryptophan amino acid. The sunshine is a must-have for its production, that is why we feel so good during the sunny days [33].

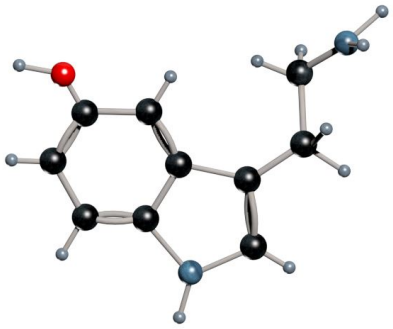

Figure 8. Serotonin.

Dopamine (figure 9) is the hormone of joy and satisfaction, it is also defined as the hormone of motivation, metabolizing in the organism at the beginning of love feeling. It is also the antagonist of PRL (mammotropic hormone) – the hormone of stress and nervousness.

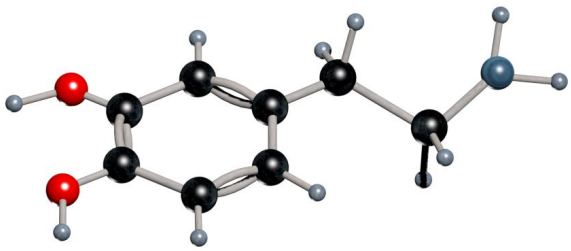

Figure 9. Dopamine.

Dopamine appears like an award for a completed act: the person feels an energy boost, satisfaction from what they have done. That is why this hormone is being connected with motivation. It encourages realization of interesting projects, personal achievements, heroic acts etc [33].

The chemistry of fear is as fascinating. The adrenaline (figure 10) effect (the hormone of fear) on the vascular system is represented by the hormone speeding up the heartbeat, increasing the blood pressure, but at the same time it dilates blood vessels of heart, the muscles and the internals. Operating through the vessel system, adrenaline can touch almost all the functions of all the viscera, and as a result the forces of defending the organism against stressful situations are involved. Nor-adrenaline (figure 11) is the hormone of happiness and relief. This hormone manages the relaxation, relief and normalization of post stress processes. Noradrenaline neutralizes Adrenaline [33].

While explaining the material above, the students attention can be attracted with the right daily routine, analyze they nutrition, discuss about leisure, hobby etc. This approach will allow to learn more about every student, set up an individual approach, simplify the teacher's work during next lessons.

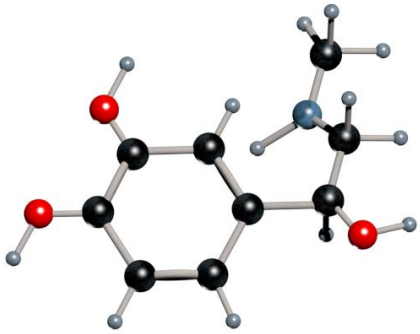

Figure 10. Adrenaline.

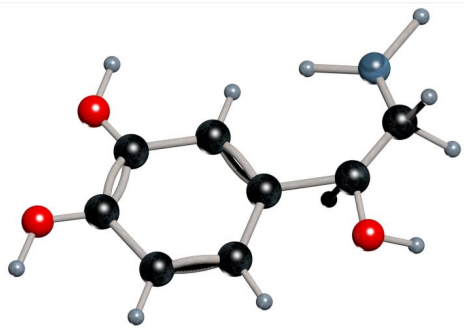

Figure 11. Noradrenaline.

Discussing these everyday, real-life problems, activates the student's semantic activity, motivates for study, develops critical thinking, etc. For example, everybody is familiar with the feeling of pain, which means everyone can share certain opinions, experience. That is why this subject can easily be taken to explain the structure of organic compounds, their features, existing area, effects on the human body. These knowledge are extremely necessary in order to form professional qualities of the upcoming chemistry teachers, as far as in chemistry lab, students and the teacher are permanently exposed to dangerous chemical substances. A careless performance of a practical work or a laboratory experiment, inappropriate safety regulations management can be a result of a critical situation during the lesson. In this case, the knowledge of toxicological chemistry will help the teacher act hard-and-fast to deal with the situation.

The pain system of a human body works with different chemical substances, the structure of which can be viewed in 3D. One of the substances, causing pain is bradykinin (figure 12) – a peptide, that dilates the blood vessels and decreases the blood pressure.

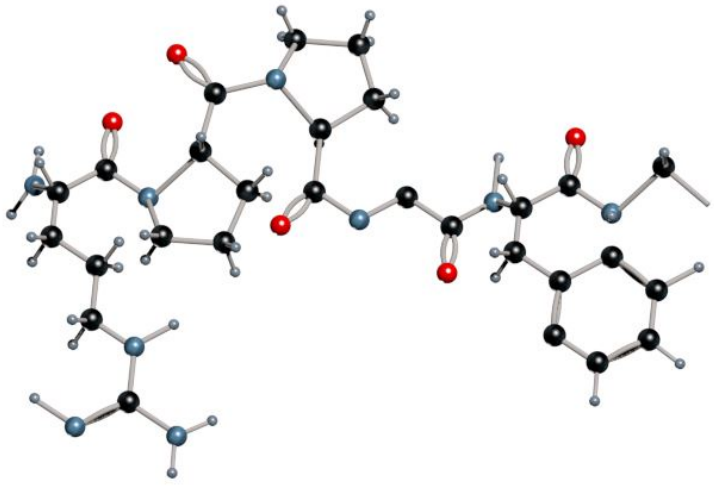

Figure 12. A part of bradykinin.

A 0,5 μ gram of bradykinin causes severe pain [31, 32]. This substance is metabolizes in tissues while they are damaged, or in the blood plasma during the coagulation process.

Histamine (figure 13) is a biogenic substance, that is produced as a result of decarboxylizing the histidine amino acid in the organism [31,32]. Normally, in an organism, histamine is mostly

inactive and bound. During different pathological processes (anaphylactic episode, heat injury, freezing, hay fever, urticaria fever and other allergic diseases), the amount of released histamine increases.

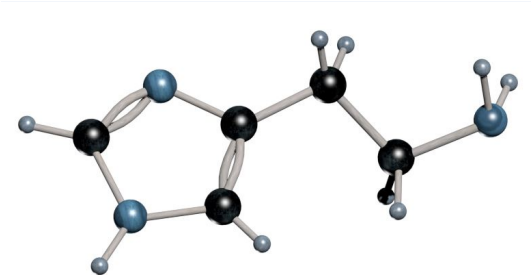

Figure 13. Histamine.

Prostaglandines (figure 14) cause contractions of the unstriped muscles (especially the womb muscles), they have influence on the blood pressure, vascular glands, water-salt metabolism, etc. They are widely used to alleviate the child birth pain, artificial abortion, etc.

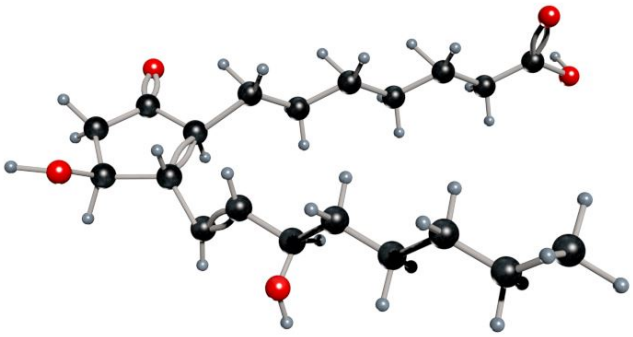

Figure 14. Prostaglandine.

These and many other examples can be used by the teachers during STEM lessons, because the data, given, integrates a couple of subjects in it and includes information and communication technologies. Visualization of the study material makes its reception and memorizing easier. A properly selected demonstration material helps better understand various processes and phenomena, going on in the human body, the structure of chemical compounds and mechanisms of their correlation.

The augmented reality can also be used while studying the nature of bioactive substances, such as chemistry of smell, and also while developing and stand up for a project (Subject 3. Oxygen-containing organic substances: "ethers and esters in cosmetics").

The smell is a specific feeling of certain volatile substances, present in the air, carried by chemical receptor units of scent (chemo-reception), and located in the nasal cavity of humans or animals. We perceive the smells through our sophisticated nasal sense system. The nasal system – is the least investigated system of the human body. Even nowadays, the scientists are still trying to define all the physical specifics of the nasal sense mechanism.

It is known, that the human can only perceive five main smells – mint, camphor, floral, ethereal and musky. All the others are received by combining the main ones.

Osmophores are molecules, which have a smell and are defined by the following features: volatility, low water solubility, good solubility in organic solvents.

Nowadays, the tight interconnection between the molecular structure and the smell of the substance is not established, only particular trending characteristics were noticed.

Fragrant substances with a pleasant smell, usually are representing the following classes of organic compounds: terpenoids, ketones, aldehydes, esters, heterocyclic ring substances (figure 15, 16, 17, 18).

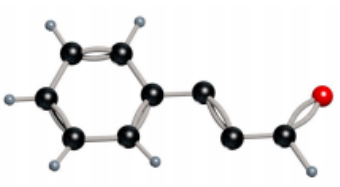

Figure 15. Cinnamic aldehyde.

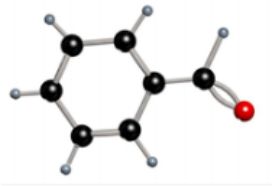

Figure 16. Benzole aldehyde.

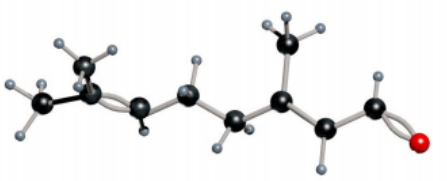

Figure 17. Citral.

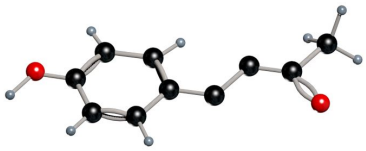

Figure 18. Raspberry ketone.

Depending on which acid and alcohole are involved into the esters, their smells vary.

Isoamyl formiate (figure 19) is the gey component of the plum smell, and isoamyl acetate (figure 20) has the duchess pear flavour.

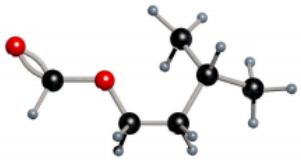

Figure 19. Isoamyl formiate.

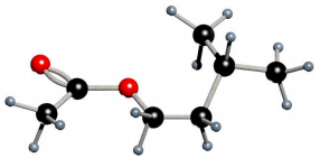

Figure 20. Isoamyl acetate.

Isoamyl valerate (figure 21) and butyl buterate are responsible for the flavours of fresh apple, banana and pineapple.

In this way, mixing and varying the acid and alcohole component of ester, different fruit smells can be modeled. This is the task of Chemistry of Aromatic Substances.

Furthermore, the smell can be consequenced by heteronuclear compounds. In this way, 2-acetylpiridine (figure 22) has the popcorn flavour, 2-methyl-4-methoxypyrazine (figure 23) – the fresht bread crust flavour.

Indole (figure 24) smells like jessamine flowers, maltol (3-hydroxy-2-methyl-4H-pyran-4on) (figure 25) has a fruit-caramel odon.

Unpleasant smells are investigated much less, but for the plants, they do the same task, as the pleasant ones – they attract the insects for pollination. There is a wide-spread belief that the human is more sensitive to unpleasant smells.

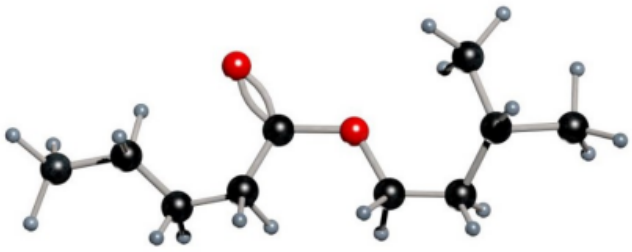

Figure 21. Isoamyl valerate.

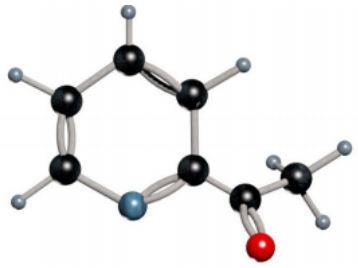

Figure 22. 2-acetylpiridine.

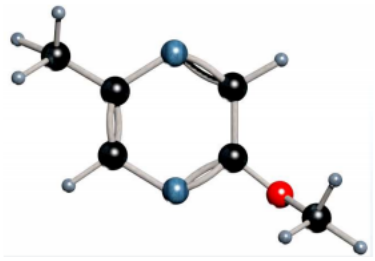

Figure 23. 2-methyl-4-methoxypyrazine.

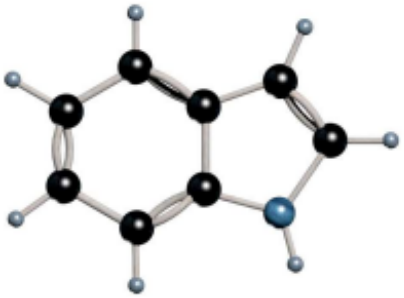

Figure 24. Indole.

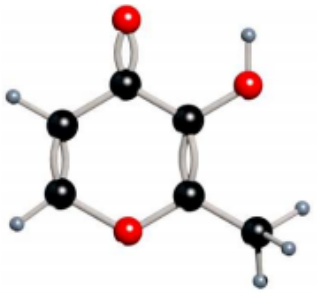

Figure 25. Maltol.

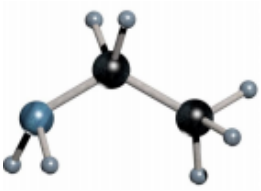

Figure 26. Ethanamine.

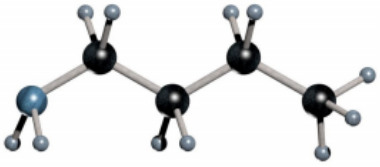

Figure 27. Butane-1-amine.

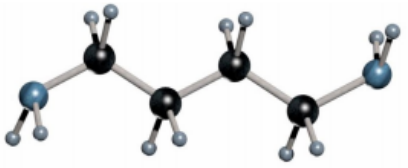

Figure 28. Putrescine.

The major part of the unpleasant flavour among plants is provided by amines (fish smells) (figure 26, 27, 28).

Sulphur-containing compounds (figure 29, 30), like thiols and disulphides have extremely unpleasant, strong smells. Isoamyl mercaptan gives the smell of skunk secretion. Cases are known, when people fainted, breathing in the emissions of these animals.

Disulphides are responsible for the strong smell of some plants, for example garlic and onion. The animals themselves do not have these compounds, but when an onion or garlic is cut, the

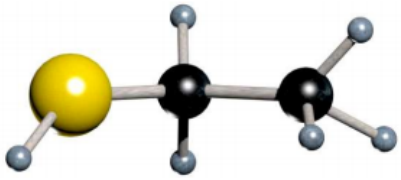

Figure 29. Ethyl mercaptan.

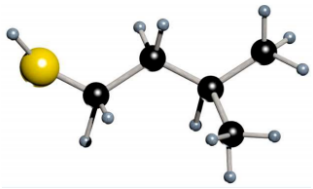

Figure 30. Isoamyl mercaptan.

amino acid cysteine, containing the –SH group, under the influence of ferments is transforming into disulphides with a smell.

While explaining the material above, the students' attention can be attracted on the influence of the structure of chemical substances on smell: the carbon chain length, the nature and quantity of functional groups, the specifics of spatial structure of molecules and the nature of substituting groups in the benzene nucleus; the ability to model different fruit smells (mixing and varying the alcohol and acid components of ester).

As far as the investigated substances are organic, the STEM lessons in the subject, being offered, are suitable for 9^{th}-10^{th} grade students, in order to boost interest while studying organic chemistry. The mobile application, developed, was tested by 9^{th} grade 99 students, and was given positive reviews by 90% of those surveyed.

3. Conclusions

The integrated lessons fascinate with innovation, with capability to involve alternative ideas and original approaches into the school course. The experience proves that the extensive use of information and communication technologies has benefits in achieving the general aims of education, building communication values: the ability to collect facts, contrast them, organize information work, express own thoughts on paper and verbally, think logically, listen and understand the written and verbal language, discover something new, make choices and decisions.

Applying new information technologies in study allows differentiating the study process, taking to consideration their individual features, gives the creative teacher the ability to spread the spectrum of study data presentation methods, allows performing a flexible management of study process, is sociably valuable and up-to-date.

Augmented reality gives the opportunity to visualize the object to the limits, meaning convert 2D images into 3D, and "make it alive". Applying this ICT tool while studying new material gives the students an opportunity to improve their imagination (spatial awareness), "to see" and bring a deeper understanding of the theory, heard, which upgrades its perception and builds certain practical skills, furthermore, it is working on a cellphone, which is an advantage of AR.

Integrated lessons with augmented reality are powerful boosters of the intellectual work of a child. The efficiency of these lessons is higher, comparing with the regular ones, as far as during the study process, the students carry on creative, investigational work, receiving high-quality visualization of study material. This provokes a solid curiosity to the subjects, develops perception activity of the students and is a part of STEM education.

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