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Successful Experiences in Chemistry Teaching in Bulgaria: Role of Interactive Teaching Materials in Teaching/Learning Process

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Abstract

The paper presents successful experience and good pedagogic practices in teaching chemistry at Bulgarian secondary schools in the context of the European educational policy for development of key competences for the young people. Basic strategies, approaches, new teaching methods and technologies as problem-based approach, experimental work, project-based activities and other are discussed as effective way to improve the students' scientific literacy and their motivation to study chemistry. Good practices in Implementation of information and communication technologies in educational process using multimedia presentation, videolessons, and interactive materials are described. The paper pays special attention to the role of Chemistry is all around Network Project, including networking activity and testing of interactive teaching resources, in sharing of successful experience and practice in Chemistry teaching at school.

1. Key competences and their development in chemistry education

The term "key competence" is cearly defined in Key Competences for Lifelong Learning - European Reference Framework as "combination of knowledge, skills and attitudes appropriate to the context" [1].

Key competences in the form of knowledge, skills and attitudes appropriate to each context are fundamental for each individual in a knowledge-based society. Key competences should be acquired by young people at the end of their compulsory education and training, preparing them for adult life, particularly for working life, whilst forming a basis for further learning. The framework defines eight key competences and describes the essential knowledge, skills and attitudes related to each of them [2].

Competence in science refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to draw evidence-based conclusions. Competence in technology is viewed as the application of that knowledge and methodology in response to perceived human desires or needs. Competence in science and technology involves an understanding of the changes caused by human activity and responsibility of individuals.

Essential knowledge for science and technology comprises the basic principles of the natural world, fundamental scientific concepts, principles and methods, technology and technological products and processes, as well as an understanding of the impact of science and technology on the natural world. These competences should enable individuals to better understand the advances, limitations and risks of scientific theories, applications and technolog y in societies at large (in relation to decision-making, values, moral questions, culture, etc.".

Skills include the ability to use and handle technological tools and machines as well as scientific data, to achieve a goal or to reach an evidence-based decision or conclusion. Individuals should also be able to recognise the essential features of scientific inquiry and have the ability to communicate the conclusions and reasoning that led to them.

Attitudes related to this competence are critical appreciation and curiosity, an interest in ethical issues and respect for both safety and sustainability, in particular as regards scientific and technological progress in relation to oneself, family, community and global issues [2].

Modern education defines few basic strategies and instruments for development of key competences in natural sciences including chemistry: context-based real-life problems; project-based learning; hands-on activities; inquiry-based learning; extracurricular activities – competitions, olimpiads, club activity etc.

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Approaches for development of key competences in Chemistry regarding to its experimental nature could be found in:

- work with natural objects - observations, assumptions, searching for proofs, conclusions);
- transfer of information from graphic to verbal phorm and vice versa;
- search, selection and presentation of information on certain topic;
- work with graphs, charts, diagrams
- application of knowledge on unknown objects (i.e., physical and chemical knowledge on biological objects);
- formation of communication skills to present and solve problems;
- comprehension of text (abilities to comprehend and use written text and ability to use characters for practical purposes, the so called functional literacy);
- calculation of values of unknown parameters in a formula;
- device measurements (precise measurement, proper recording of results, incl. units)
- construction of experimental setup, closely following the instructions, resourcefullness and dexterity.

Development of key competence in chemistry is part of a common process of cultivation of natural science literacy among students, which is the basic aim of science education during the obligatory school stage. International studies and assessements as Trends in International Mathematics and Science Study (TIMSS), the Progress in International Reading Literacy Study (PIRLS) and Programme for International Student Assessment (PISA) allowed the identification of the most important factors responsible for the good achievements in school science education. Based on the experience of European countries with best achievements, following factors could be defined: teacher's high social status; good school athmosphere; the science education is directed toward formation of key competences; enough number of classes especially for chemistry; the stress of school education in Chemistry, Biology and Physics is put on experimental work and development of practical skills [3].

2. Successful experience in Chemistry teaching in Bulgaria and ways for its popularization

Good Bulgarian practice in teaqching Chemistry at school. There are many examples of good teaching practice used in Bulgarian schools for development of key competences in chemistry in the context of the strategies defined above.

Solving real scientific problems is an approach which helps teacher to overcome students' low motivation and to attract their interest in natural sciences. According to chemistry teachers, ignoring the scientific research approach in natural sciences leads to rote memorization without any possibility of application in everyday life [4]. The ambition of institutions responsible for the school chemistry education is to apply this approache not only on school but on national level also – for example, the National contest for key comepences in natural sciences [4], the model of problem-based learning in teaching chemistry at school developed in Comprehensive High School – Mirkovo [5], the model for building of specific competence on chemistry and environmental protection created and experimented by teachers in National Highschool of Science „Academic Lyubomir Chakalov" – Sofia [6] etc.

Experimental work is an approach which is very highly appreciated by chemistry teachers - combined with the *problem-based learning,* experimental work gives very good opportunities for solving of experimentally-logical problems with research character, which leads to more lasting knowledge and skills of students. That is proved by the result from experimental testing of a pedagogical model, developed and implemented in chemistry laboratory exercises for work with substances in 9^{th} grade of Comprehensive High School "P. Beron" - Pernik [7].

Extracurricular training in chemistry in various forms - club activities, school projects, and others - is an effective way to extend students' knowledge and to develop deeper interest in natural sciences. The practice of *school projects* is well developed in Aprlinov National Highschool – Gabrovo [8]. As a form of partnership between schools with different profiles and level of chemistry learning, it was applied in chemistry and biology training process at Vocational High School of Electronics and American College Arcus - V. Tarnovo.

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Such an interschool collaboration allows the integration of students into a new school environment but also gives the opportunity to students from schools with insufficient or no laboratory base (which are most of the schools in Bulgaria), to participate in experimental work in chemistry which increases student's interest in the subject [9]. An example of successful experience in Chemistry club activity was presented during the International Conference on Training Issues of Chemistry Teachers (2013, Gabrovo) by chemistry teachers from Vocational High School of *Mechanical and Electrical Engineering* – Sevlievo [10].

Enriching the learning content with scientific achievements - there are a number of ways to implement the science in the educational content, to make knowledge practically oriented and the way of its presentation - more attractive**.** A very successful practice has been developed over the last few years in Private American College in Sofia. It is performed as "live scientific show" combining science and art in teaching of complicated chemical issues [11]. The most successful practice in implementation of science in chemistry school education was developed through the "university – business" collaboration, and was successfully applied at school – it is a common initiative of BASF (Bulgaria) and the Faculty of chemistry and pharmacy of Sofia University called *"Portable chemistry laboratory for students Chemgeneration Lab"*. The laboratory travels to schools in Sofia and the country where under the guidance of the hosts - outstanding students of the Faculty of chemistry and pharmacy, students are able to make some experiments, corresponding to the school educational content [12].

Implementation of contemporary ICT in the learning process is an approach used by Bulgarian teachers in their efforts to restore the students' interest toward natural sciences and chemistry at every stage of their training by number of teaching instruments - application of multimedia products and interactive materials for visualization of specific problems of curriculum content in chemistry [13-15]; development of interactive materials by teachers, using their own skills in ICT sphere [16]; e-learning, self-education and self-control [17]; efficient control over knowledge absorption.

Popularization of good teaching practice. Development of competency and natural science literacy is a long process in which teachers play the main role - they have to provide conditions for its effective implementation through innovative approaches. Teacher training and permanent development of new skills are key factors for the successful performance of this role. Sharing of good practices and successful teaching experience is a way to help teachers in their activity and happens with the joint efforts of state institutions, universities involved in teachers training, business and other (mostly private) organizations.

As state institution in charge with the organization and implementation of the educational process at national level *Ministry of education and science (MES)* works on the research and popularization of the good teaching practices in all spheres of education, including science – by national forums, journal, specialized printed editions, websites.

The most significant forum for exchange of professional experience and good teaching practices in chemistry education in Bulgaria is the *National Conference of Chemistry Teachers*, which takes place every two years thanks to the joint efforts of MES, Sofia university „St. Kliment Ohridski" and the Union of Chemists in Bulgaria - apart from chemistry teachers from across the country, it involves university professors and experts from institutions in charge with the national policy on science and chemistry education.

The Ministry publishes the only national weekly newspaper on education and science "Az Buki" [18] and nine science journals - each of them presents successful educational practice, including in chemistry education: *Chemistry: Bulgarian journal of science education* [19]; *Educational Journal "Strategies of the Educational and Scientific Policy*" [20]; Educational Journal "Pedagogy" [21] etc. Last year the Ministry published Digest with good practices for interactive education [22], which summarizes teachers best practices in interactive teaching, as a result from workshops organized in Bulgarian schools under the motto „School – student's desired territory".

As a step to implement the e-learning as educational practice in Bulgarian schools MES developed *National education portal* [23] – it is an important web-based form offering platform for sharing successful teaching experience.

Bulgarian universities, providing education of chemistry *teachers* offer also ways to exchange pedagogical experience organizing university, national or international scientific forums and conferences. Opportunity for exchange of successful experience and good practice in teaching chemistry at school is *Autumnal scientific-*

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educational forum, organized by the Department for information and teachers' qualification of Sofia University. Papers presented during the forum are full length online accessible by electronic journal „Lifelong education", published on the Department's Portal [24].
MICROSOFT Bulgaria supports *National network of innovative teachers (or Teacher.bg)* - the portal aims to improve the teachers' qualification and skill in implementation of ICTs in educational process and also to share the best examples of teaching practice in their applicaton at school [25].
The role of Chemistry is all around Network Project. Popularization of successful teaching experience and practices is a way to help the chemistry teachers in their efforts and contributes to restore the students' motivation to study Chemistry. In this sense Chemistry Network Project plays important role because trough the project network it helps established pedagogical experience and good practice to be shared with chemistry teachers from large number of schools within European countries. The whole networking activity during the last project year was dedicated to this thematic area. Workshop on Successful experience and good practice in teaching chemistry at school within the national network allowed teachers and experts to discuss innovative approaches and good practice in chemistry teaching in the other European countries and the possible application in the Bulgarian school system.
Beside the workshops on national level and the international virtual meetings, there are also opportunities for exchange of successful experience and good practice provided by international conferences within the activities of the project International Conference on Training Issues of Chemistry Teachers (Bulgaria) and *International Conference on Successful Experiences and Good Practices in Chemistry Education* (Portugal) where successful experience in application of ICTs based products in chemistry classes at Bulgarian secondary schools was presented [26-28].

3. Role of interactive materials and ICT in Chemistry teaching/learning process: what the experiment says?

One of the main questions which educational specialists face at all levels is *whether the application of ICT can change the quality of teaching in the particular learning environment of Bulgarian secondary schools*. In response to this question experimental testing of interactive teaching materials based on ICTs, as a part of Chemistry Network Project activities, was performed in the chemistry classes in Bulgarian secondary schools.
The strategy of experimental testing was discussed with chemistry teachers and experts involved in the project activities. The materials to be tested were carefully identified by chemistry teachers on the basis of clear defined criteria like school profile, level of students' knowledge, available technical equipment. Following factors limited the choice of teaching resources for testing in chemical classes: language of the teaching resource; level of students' basic knowledge; lack of laboratory equipment; lack of computers and other supporting technical equipment; level of teacher's competence to use ICTs.
Students' opinion about the effect of tested resources on the way of understanding of learning content, and teachers' conclusions about their applicability in the chemistry training at Bulgarian school were studied at the end of the testing process.
Nine interactive teaching resources have been chosen to be experimentally tested in the real Chemistry teaching/learning process at 6 schools involved in the project activities – among them 5 project partner schools and 1 associated school. The testing procedure was performed by 11 chemistry teachers - 9 from the partner schools and 2 from the associated school. 175 students 8 – 10th grade from Bulgarian secondary school attended the testing: 162 in regular chemistry classes and 13 in research club activity.
Resource "The world of chemistry (Carbon)" [29] was tested at Aprilov National High School – Gabrovo with 24 students, 10th grade, specialized English language education. Teachers find the reasons to choose the resource in the easy and understandable way to present basic knowledge, and special effects and animations enable simulation of processes, dangerous for real lab visualization. Learning topics were to show the chemistry in the real life and thus, to rise the students motivation. Students find the material interesting, easy to understand and efficient - it stimulates the curiosity to the world around, to the meaning of chemical knowledge in everyday life and to forming of proper attitude towards health care and environmental protection. Teacher's conclusions is that the use of material influenced positively the

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chemistry education - the topic is directly linked to applications, including industrial and environmental problems announced through opinions of representatives of academic and industrial sphere. The resource also offers efficient approach to mastering chemistry knowledge through improving of English language.
Resource "Explore & Discover Chemistry!" [12] was tested at two secondary schools: Vocational High School of Electronics – V. Tarnovo, with 18 students, 9th grade, education in ICTs and Private Specialized High School "American Arcus College" – V. Tarnovo, with the participation of 18 students, 9th grade. The resource has been choosen because it enlarges the students' basic knowledge, allows integration of science in educational content and visualization of 3-dimensional structures, and combines learning with entertainment. The experimental testing aimed at enhancing students' motivation by presenting advances in science and technologies, at developing notion about environmental sustainability. The results obtained by the students' questionnaires show that students like the idea of team working with students from other schools. *Concerning the resource's content* the most liked are electronically presented animated models. Teacher's conclusion is that the resource ensures utilization and interpretation of educational content by stimulating the student's cognitive activity. It provides the student with motivation and willingness to learn. The resource is easily accessible and promotes students' self study also.
Two interactive teaching resources - *"PhET"* [30] *and "National Education Portal"* [31] - were tested at Vocational High School of Electronics and Chemical Technologies – Pleven, with 28 students, 9th grade, specialised education in Chemical Products and Technologies. Topics related to the first resource were*:* Chemical equations balancing; Isotopes and atomic mass; Atom and molecule structure. Use of e-lessons in chemistry classes – theory and practice was the learning topic related to the second one. Reasons to choose the teaching resources were: educational content is suitable for both theoretical and practical classes; possibility to visualize chemical processes with simulations. In addition to that "PhET" allows presentation the content in amusing and understandable way, and "National Education Portal" is in Bulgarian language. Following learning topics have been defined during the "PhET" testing: generation of simple atom models; visualization of chemical bonds*;* development of stereo-imagines about molecule structure. Students tested with great enthusiasm the simulations – they enjoyed learning chemistry by using computers. Teacher's conclusion about the tested interactive simulations is very positive: they are easy to use and of a good scientific value; through them, the teacher can receive feedback, whether the learning content is absorbed; when used appropriately by the teacher, they can increase students' interest in studying the subject; through these simulations, by having fun the students can demons*t*rate and apply what they have learned; they are very suitable in lessons for exercise and summary, as well as new knowledge with difficult theoretical concepts, which are presented through them in a very accessible and understandable way /e.g. atomic structure, chemical bonds, etc/.
Another interactive resource based on the *National Education Portal (Alkanes)* [32] was tested at Vocational High School of Electronics – V. Tarnovo. Eighteen students 9th grade, specialized education in ICTs attended the experimental classes. According to the chemistry teacher the resource covers a great part of educational content relating to alkanes, visualizes the bonding between carbon atoms and allows visualization of burning process – that is why the teaching resource has been chosen. The experimental lesson aimed at developing knowledge about alkanes and helping students in analyzing of chemical properties through chemical experiment. The evaluation of testing results shows that students' reaction has been definitely positive - they like the diversified lesson in different learning environment like computer lab. Most of them have recognized the role of self-study and self-examination of knowledge in the course of the lesson. Students' attention has been strongly attracted by the demonstrations watched also. Teacher's conclusions about the tested resource are also positive - it increases student's skills for visualization of content and understanding of concepts, helps to develop self-study skills for the designation of a given formula, to draw patterns in chemical formulas, to associate properties with application, to transfer acquired knowledge and skills in a new unfamiliar situation.
Two interactive teaching resources were tested at Vocational High School of Electrotechnic "M. V. Lomonosov" – G. Oriahovitza: *Virtual chemical laboratory* [33] and *A Química das coisas* [34] with the participation of 48 students, 10th grade, specialized education in System engineering. Teachers involved in the testing have a long pedagogical practice in teaching chemistry. The Virtual chemical laboratory is a

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resource developed in Bulgarian so it allows easy working and has education content developed according to the requirements of MES. Tested topics, related to the resource were "Sulphuric acid" (Chemistry content for 8th to 10th grade) and "Compounds of aluminium". Experimental learning aimed at developing of skills for performing of chemical experiment and working with scientific resources and handbooks. Students liked working with the product - most of them have used the website after the school classes, at home also. They have been interested in mastering new knowledge in chemistry.Teacher's opinion is that the resource is very well structured - it offers a wide range of options for the organisation or the teaching process by presenting the learning content in various methodological units. The teacher has also observed that the activity and interest of students increases when they find themselves in a position to take independent decisions and apply them in solving scientific problem.

Experimental testing of *A Química das coisas (Chemistry of things)* tried to give students scientific answer about some chemical processes related to human health: why ethyl alcohol is protoplasmic poison and what happens with ethanol inside human body; is ethyl alcohol food, how does it affect the human body. Reasons to choose the teaching resource were the rich education content and availability of equipment for implementation of the resource in the learning process. Students liked the work with the resource because beside the educational effect it has emotional effect, too. The teacher finds the resource useful because it allows: systematization and summary of the matter, expanding and improving knowledge; individual learning of something new in relation to the lessons learned in class and aspiration to clarify more thoroughly the studied phenomenon; use of knowledge, skills and habits obtained during the lesson in other situations.

Chemistry teachers from Vocational High School of Mechanical and Electrical Engineering – Sevlievo experimentally tested two interactive resources: *Chemistry Online* [35] *and Learn Chemistry* [36]. Two groups of students attended the testing: 26 students, 9th grade, specialized education in Computer Engineering, taking an intensive English language course; 13 students, 8-10th grade, members of „Research laboratory"club.

Testing of *Chemistry Online (Trends in the Periodic Table)* aimed at enlarging students' knowledge about the chemical elements. Students like the resource as all the notions and relations which they consider difficult and abstract are explained in an interesting and user friendly way. The lesson helped them to understand the relations in the periodic system and they are willing to use it in other chemistry lessons. Teacher's opinion is that the resource conveys great amount of information and facilitates the study of the theory for the atomic construction and the chemical elements. The combination of videos, pictures, experiments and interesting facts about the substances make the resource interesting for students. But they also realize that in spite of its advantages, the resource has been successfully applied in the real training owing to the students' linguistic and computer skills also, as well as to the modern labs at school.

"Interactive Periodic Table" and "Chemical elements (metals and non-metals)" were topics related to *Learn Chemistry tested with a mixed group of students* 8-10th grade, invovled in club activity. Learning topics have been defined by chemistry teacher to be developing of skills in formula writing and determination of chemical bonds. Although different level of chemistry knowledge is a limitimg factor, results obtained by the experimental testing are more than positive. Students like the website having special preferences to videos, simulations and experiments - according to them, these materials increase the interest in chemistry, contain synthesized and interesting information and facilitate the study of lessons. Experiments produced largest discussions among students during the training process – they consider experimental work interesting as it contributes to the exploring of the real world. According to the teacher's opinion the website is very attractive and very well structured - it offers a wide range of materials and enables teachers to share and exchange ideas and materials. It contributes not only to the development of competences in natural sciences but also the ones of digital and linguistic skills. The resource application could be only limited by the need of good command in English**.**

In summary, the reaction of the students involved in the teaching resources testing could be defined as *very positive*. They were "interested in mastering new knowledge", "enjoyed learning chemistry by using computers, electronically presented animated models, simulations", videos. According to them, these materials increase the interest in chemistry, contain synthesized and interesting information and facilitate the study of lessons. Students consider chemical experiments as the most interesting because they contribute to

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the exploring of the real world. Using these teaching resources, many of them recognize the role of self-study and self-examination of knowledge in the course of the lesson.
Based on the summarized teachers' considerations, few important points should be marked:

- Use of interactive teaching resources has a positive influence on implementation of objectives of chemistry education. ICTs based educational products ensure utilization and interpretation of educational content by stimulating student's cognitive activity and provide with motivation and willingness to learn;
- Many of the resources help students to develop self-study skills for the designation of a given formula, to draw patterns in chemical formulas, to associate properties with application, to transfer acquired knowledge and skills in a new unfamiliar situation etc.;
- The combination of videos, pictures, experiments and interesting facts about the substances and processes make the resources interesting for students.
- Without ignoring the role of the real experiment, based on the testing results, chemistry teachers appreciate also the place of the simulations in the training process:
    - Interactive simulations are easy to use and of a good scientific value;
    - Through them, the teacher can receive feedback, whether the learning content is absorbed.
    - When used appropriately by the teacher, they can increase students' interest in studying the subject.
    - Through these simulations, by having fun the students can demonstrate and apply what they have learned;
    - They are very suitable in lessons for exercise and summary, as well as new knowledge with difficult theoretical concepts, which through them are presented in a very accessible and understandable way

Besides of the quality of the experimentally tested interactive teaching resources, their successful implementation in the real educational process depends in large degree on the students' linguistic and computer skills, teacher's ICTs skills as well as on the modern equipment at the school.

4. Conclusions

Achievement of scientific literacy and development of key competences of students become one of the main objectives in natural sciences and particularly Chemistry training in Bulgarian school education. This is a product of a long process whose quality and final results are influenced by factors as quality of educational plans and programs in terms of their volume and content, modern and adequate technical support, implementation of ICTs in educational process.
Crucial for the successful implementation of this objective is the leading role of teachers and their skills to present the educational content in attractive and understandable way, to involve students as active participants in the educational process, to develop their scientific and innovative thinking, and ability for team working. To perform this role Bulgarian chemistry teachers apply innovative approaches as problem-based approach (solving of context-based real-life problems), experimental work (hands-on activities), project-based and inquiry-based learning.
To make these approaches effective and to improve the quality of Chemistry education, teachers implement ICTs in school educational practice – multimedia, interactive teaching materials, e-learning etc. – to make the complicated chemical content more understandable, to stimulate students' activity and to direct their interest toward chemical science. The utility of interactive ICTs based teaching materials was prooved by the results obtained during the experimental testing of selected by the chemistry teachers resources in the real process at Bulgarian secondary schools. The common opinion both of chemistry teachers and students, attended the testing is that the implementation of ICTs in Chemistry education and use of interactive teaching resources facilitates students in understanding of complicated educational content, helps chemistry teachers in their pedagogic activity and contributes to restore the students' motivation to study Chemistry.

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