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## Teaching Chemistry at School: Bulgarian Innovative Practice

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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. Problem-based approach, experimental work, project-based activities and other innovative teaching methods and technologies are discussed as effective way to improve the students' scientific literacy and motivation to study chemistry. Chemistry teachers' experience in implementation of information and communication technologies (ICTs) in the educational process using multimedia presentation, videolessons, interactive materials and other, is described. The paper pay attention on the ways of popularization of the successful experience and practice in Chemistry teaching at Bulgarian schools also.*

### 1 Key competences and science literacy

The intensive development of technologies and processes of globalization position education as a determining factor for the building of knowing, enterprising and innovative young people with skills for adjustment and professional development. This leads to the need of application of new methods and technologies in the teaching practice aimed at the development of skills and competence for the young people to deal in a competitive environment. The most important of them are united in several groups, defined as key ones and can be found in *The European Qualifications Framework* [1,2]. The competence approach dominates as an efficient instrument – it offers large possibilities for personal development and practical implementation of the trainees and is preferable to the conventional approach for the accumulation of knowledge among students through offering the knowledge in the form of finished information.

In the field of natural sciences which form a knowledge of phenomena and processes, the development of key competence is part of a common process of cultivation of natural science literacy among students which in recent years follows a negative tendency of continuous deterioration. The education in physics, chemistry and biology offers a number of opportunities for its forming through solving tasks and problems in real context (context-based real-life problems), experimental work through „doing“ (hands-on activities), project-based learning, inquiry-based learning, extracurricular and club activities, competitions, olympiads etc.

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 [3].

### 2 Approaches for development of key competences and their application in chemistry education



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Being an experimental science, chemistry gives exceptional opportunities for development of key competences among students which are grounds for the development of other useful for their professional realization skills. According to A. Tafrova [3], these opportunities have to be searched for in work with natural objects (observations, assumptions, searching for proofs, conclusions), transfer of information from graphic to verbal form 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, resourcefulness and dexterity).

A model for building of specific competence on chemistry and environmental protection was created and experimented by teachers in National Highschool of Science „Academic Lyubomir Chakalov“. It is based on the curriculum of chemistry and environment protection for 10 grade and aims at developing skills, such as:

- *Knowing* basic principles, laws, patterns and concepts in chemistry
- *Readiness* for scientific explanation of chemical processes and phenomena;
- *Skills* for use of scientific data and evidence
- *Skills* to perform observations, measurements, recording and analysis of the data
- *Skills* for planning of chemical experiments and construction of equipment and tools for conduction of experiments;
- *Skills* to identify problems in environment and find solutions and prevent new problems;
- *Skills* for research and select proper information;
- *Digital competences* – use of multimedia technologies in order to extract, estimate, store, create, present and exchange information;
- *Analysis* of information (reading comprehension)

The technology of competence forming and defining includes the application of a number of didactic materials and research of the results of the model implementation. According to the authors, „the attitude of students towards mastering key basic competences changed in a positive direction under the influence of the applied competence approach“. They are aware and motivated to continually improve their achievements, to search for reasons for problems and to create and use algorithms for solving them, to cooperate with others for the accomplishment of mutual goals [4].

*Solving real scientific problems* is an approach which stimulates students to search for and find problems, to lay down questions and suggest ways to solve them, to analyze strengths and weaknesses of each of them and make reasoned choice [5]. According to chemistry teachers ignoring the scientific research approach in natural sciences leads to rote memorization without any possibility of application in everyday life. This in turn leads to students' low motivation and lack of their interest in natural sciences.

A method of using a problematic approach in teaching chemistry in school to assist the acquisition of useful knowledge and the formation of key skills in students was applied in chemistry lessons on organic chemistry according to the 9th grade syllabus. The research was conducted with 15-16-year-old students in two classes. One of the classes was the control group, while the other one was the experimental group. During the research the students from the test group received problems every week by e-mail. They had to submit the solutions within seven days. Each problem was aimed at forming certain skills and had a specific way of presenting the solution and the way in which it was

reached. A test was conducted at the end of the research. The test contained 8 problems divided into three groups, aimed at assessing the level of attaining certain key competencies.

The research results allow authors to come to the conclusion that “applying even elements of problem-based learning affects positively the formation of important skills and motivation for studying in students”. But they also faced some problems during the experiment - students desire to receive feedback on the proposed solutions as soon as possible, which leads to necessity of in time and regular control of their work by the teacher. The problem is that most of the Bulgarian teachers do not have the habit of fast and timely revision of student work, regardless of the resources. So to be the experimented method effective the change should not be in the methodology, but rather in the attitudes and way of thinking of teachers [6].

Solving problems which illustrate or are related to phenomena and processes of real life increase students' motivation and interest in studying chemistry, prove its relevance in everyday life and convince students of the benefits of studying chemistry. A good practice in this respect is the National contest for key competences in natural sciences which is held annually ever since 2009 among students from 5<sup>th</sup> to 11<sup>th</sup> grade of Bulgarian school [7]. It aims to stimulate students in acquisition of key competences in natural sciences, including chemistry – to express their own opinion considering important for the society issues, to develop innovative thinking, to present original ideas, to demonstrate key competences in solving problem in unknown conditions. In the field of chemistry the contest includes solving and public presentation of problems, demonstrating of key competences as knowledge about basic principles of the nature, critical viewpoint and assessment of the science advance, and its influence on the individual and the society. The participants should demonstrate knowledge on materials, substances and mixtures, natural and chemical processes, measurement devices, organization of scientific experiment, health and ecological culture etc.

Some of the problems in the external evaluation tests and state exams are also of the same kind. Their answer requires knowledge not only in one but in several subjects as well as team work and communication.

The other approach is *the experimental work* – the chemical experiment is irreplaceable as a means for acquiring research approach, developing skills and enriching the scientific literacy. Teachers who have the ambition to develop and apply the active teaching in the training process through problem-based learning, research approach, studying through discovering and making and other ways for developing key skills, appreciate its role as an extremely efficient tool in their chemistry teaching practice. Combining of the two discussed approaches – using practically oriented problems in experimental laboratory work - leads to development of pedagogical model, based on the idea that it is necessary to follow the path from theoretical knowledge to its application in different situations. Such a model was implemented in chemistry laboratory exercises for work with substances in 9th grade of Comprehensive High School “P. Beron” (Pernik) [8]. Experiments included have a practical implementation. A part of them are selected from the curriculum content and are supplemented with others, also useful and interesting to students. They help to build skills for work with substances, also for selection of substances in everyday life - food, detergents, mineral water, alcohol consumption, use of synthetic fibers and plastic. All developed problems give the students options for additional work on a topic selected by them and its presentation through posters, papers etc. Survey conducted among the students, gives information about the attitude and way of perception of the implemented laboratory work – most of them find laboratory work very useful, because it helps to memorize the curriculum content easier. The laboratory work motivate them to search for information also. Most of the students have discovered experiments which can be used in everyday life.



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The teachers' opinion is that the model gives very good opportunities for work on experimentally-logical problems with research character, which leads to more lasting knowledge and skills of students. At these classes they are more focused, express opinions, suggestions and construct scientific hypotheses [8].

Irrespective of which of the two elements of chemistry education at school are concerned – theoretical lessons or laboratory experiments, teacher faces one major problem: how to engage the attention of students, to make the lesson more interesting and more easily understandable, to convince students of the usefulness and applicability of chemistry in everyday life and to motivate them to study. Solving of that problem is a complicated task which challenges the whole teacher's potential – scientific, creative, pedagogical, technological. In days of technological development some of the conventional teaching methods and pedagogical approaches seem to be not efficient. Textbooks and notebooks officially approved by the Ministry do not provide serious help as they are often theoretical and the matter is presented in alien for the young people language.

Efforts of teachers and experts to overcome this disadvantage of chemistry education are implemented in several main directions. The first one of them is the *use of contemporary ICT* in the learning process. For example the use of interactive multimedia allows the visualization of chemical content – substances, chemical reactions and related definitions, quantitative and qualitative measurements etc. The interactive multimedia presentation could be successfully developed for one lesson or for group of thematically close lessons [9].

One of the main questions which educational specialists face at all levels is about the sense of *the e-learning* and whether the application of ICT can change the quality of teaching in the particular learning environment of Bulgarian secondary schools. In response to the question a model for e-learning of chemistry and environmental protection in 9th grade and e-multimedia resources (modules) for information provision (multimedia presentations, electronic versions of tests, instructions etc.) have been created in order to overcome the low efficiency of teaching chemistry in high school. The model was experimentally implemented in chemistry classes in Sofia high school of bakery and confectionery technologies. The diagnostic research conducted after the study aims at identifying positive changes in learning achievements and motivation of students when using the proposed model in the training process. The research took place in two stages – preliminary study and actual study on two of the studied sections – „Hydrocarbons“ and Hydroxyl derivatives of hydrocarbons“. Four groups of students participated in the experimental study. Groups' composition is identical in terms of gender, social status of the family, ethnicity etc. and also performance (up to the beginning of the experiment): the first group studies using the e-learning model; the second and the third group study combining traditional method + e-learning in theoretical and experimental work, and the fourth group is a control group which is trained using the traditional method without the use of ICT. The results of the creativity test conducted after the end of the training intended in the study show that the biggest difference between the results of the preliminary and final test belongs to the group which was trained using entirely e-model; lowest growth belongs to the group which was trained following the traditional model. These results give reasons for the author to conclude that the proposed model for e-training helps to improve the educational achievements of students, has a positive effect on motivation for studying and development of creativity and offers a flexible approach to solution of problems of low performance in chemistry and environmental protection training [10].

In modern pedagogical practice a big part of teachers are oriented towards the application of a number of multimedia products and interactive materials for visualization of specific problems of curriculum content in chemistry, process simulation, self-study, estimation and self-





estimation of knowledge. According to them, the use of interactive materials and ICT in the learning process provides not only for the diversification of presentation of learning content but also for the implementation of efficient control over knowledge absorption. Some of the teachers use their skills in ICT sphere to create interactive materials.

Such an innovative product is the electronic handbook on Chemistry and environmental protection, an algorithm for its use in the educational practice as well as the results of the pedagogical research on its application in the study of the section Initial review in 8th grade of secondary specialized language school. It is a software product for review, self control and self evaluation. The content of the handbook is structured as per the sections in the curriculum and Chemistry and environmental protection textbooks. Each of the topics includes key words, short explanations of the key words, examples and test problems. In author's opinion the use of electronic handbook gives options for independent studying, increases the interest in the subject Chemistry and environmental protection through the use of computer, enables easier summarizing and systematizing of knowledge, stimulates cognitive interest, activity, independence. It also contributes to the development of self control and quick self evaluation and development and acquiring of mental and active competence. The results of the experimental use of the handbook in the training process show that an extremely favorable atmosphere is created in classes and the work is much more effective. The given handbook is interesting, attractive and useful for students and motivates them to acquire new knowledge and skills. The model presented is fully applicable to any school subject [11].

A way out of this tangle is the Chemistry lessons in the educational platform Ucha.se [12]. The videos interpret understandably basic Chemistry knowledge which lies in the obligatory syllabus from 7 to 10 grades. They are short – the matter is presented in 10-15 min, using also jokes, interesting stories or situations close to the students' life. There are over 150 videos created for Chemistry. The platform users especially appreciate the video exercises where they can apply skills in solving different tasks. In the different grade sections there are lots of tests by which students can check their level of knowledge after certain unit or before forthcoming exam in school. The statistics show that users - students, university students, teachers, parents, even people of various ages find the learning from video-lessons effective and entertaining. In a one and a half year the videos have collected more than 2.5 million watches - this proves the need of such education. This way of learning has many advantages: learning from video-lessons is effective and entertaining - it's not torturing and students learn with pleasure; the platform is very communicative – there is possibility for asking questions, commenting problems, online chatting and asking question in real time; video-lessons are particularly useful for students which absent from school and cannot study the lessons from the textbooks on their own. In the future subtitles will be inserted in the videos in order to be accessible by children with hearing impairment. The platform will offer also special forum for sharing successful experience in teaching Chemistry (presentations, video materials etc.) of Chemistry teachers from the whole country [13].

Enriching the learning content with scientific achievements in the field of chemistry is an approach which expands the awareness of students and builds their lasting interest in science. Scientists and university teachers support chemistry teachers in its implementation. Last few years a very successful practice combining science and art in teaching of complicated chemical issues was developed - it is "live scientific show". Such a show "On the edge of science and art" was demonstrated during *International Conference on Training Issues of Chemistry Teachers* in June 2013, in Gabrovo. The author of the show is a Science communicator and Chemistry teacher in Private American College in Sofia at the same time. That innovative approach allows of complicated Chemistry and Physics



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issues to be presented to students in attractive and understandable way using simple and amusing experiments and so called “scientific toys”.

Similar approach is used by the creators and participants in the Portable chemistry laboratory for students Chemgeneration Lab – a common initiative between BASF and the Faculty of chemistry and pharmacy of Sofia University „St. Kliment Ohridski“. The purpose of this laboratory is to create an opportunity for experimental work in chemistry for students from 6th to 12th grade with declared interest in chemistry. The laboratory travels to schools in Sofia and the country and unfolds in the host schools. Within one session of 1-2 hours up to 15 students are able to make some experiments, corresponding to their age and under the guidance of the hosts - outstanding students of the Faculty of chemistry and pharmacy. Experiments are selected in a way that they are both fun and spectacular and as safe as possible. After the implementation of the experiments the host explains the observed phenomena and show their relation with the learning content taught at school. Over the last year the laboratory visited a number of schools in the country and the interest towards it continues to grow – this is also proved by the schedule which is full for the next year [14].

*School projects, club activities and other extracurricular training in chemistry* are successful forms of work for the development of natural science literacy and a tool for cultivating skills for teamwork. According to M. Nikolova, chemistry teacher from Aprilov National High School – Gabrovo and its professional experience in development of scientific school projects, the project work allows students to cultivate many new competences that will benefit their future development - to develop ability to deal with scientific information; to extend their knowledge of chemistry and to develop deeper interest in natural sciences; to apply ICT in demonstration of scientific results; to appreciate the importance of natural sciences for everyday life; to learnt how to work in a team and make good friendships etc.[15].

The practice of developing school project, applied as a form of partnership between schools with different profiles and level of chemistry learning adds more positives in favor of the efficiency also as an educational tool - interschool partnership allows the integration of students into a new school environment, shows new ways of learning and develops abilities for teamwork. This is a conclusion made by teachers in American College Arcus and Vocational School of Electronics, V. Tarnovo based on their common work to develop a school project which involves students from both schools. This partnership has another positive effect within the environment of the Bulgarian secondary school: it 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 students' interest in the subject [16].

The need to develop key skills and cultivate scientific literacy among students is a major task of Bulgarian high school education and is indicated in the project for new State educational requirements and curricula content and programs in chemistry and environmental protection comply with it.

### **3 Popularization of successful experience and good practice in Chemistry teaching**

As an institution in charge with the organization and implementation of the educational process at a national level, the Ministry of education and science (MES) works on the research and popularization of the good teaching practices in all spheres of education, including science. Bulgarian universities, providing education of teachers, including chemistry teachers, offer also ways to exchange pedagogical experience in teaching Chemistry.





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### 3.1 Conferences and forums

The most significant forum for exchange of professional experience and good teaching practices in chemistry education 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 teachers and experts from institutions in charge with the national policy on science and chemistry education. In 2013 the conference was held for 45th time with the active participation and as a part of the activities under the project Chemistry is all around Network. More than 120 teachers presented good practices and problems within conference thematic sessions „Scientific literacy and chemistry education in secondary school“ and „Topical problems and European perspectives of chemistry education in secondary school and university“ as:

- Reflective practices for empowerment of learning
  - Using the results of modern scientific research in chemical education
  - The role of the research approach in science education
  - The role of Teamwork and competition-lesson
  - Application of multimedia products and software as *Envision*, Chemgeneration Lab, Video lessons in the electronic platform Ucha.se etc. in chemistry education as an approach for modern chemistry education in Bulgaria and way to stimulate students' interest in chemical experiments
  - Improving of secondary students' scientific literacy through e-learning
  - School scientific projects and Science on stage European festival as instruments to develop scientific knowledge
  - Application of ICT in chemistry education through the viewpoint of chemistry teachers;
  - School partnerships, informal club and after-school activities as a pedagogical approach to increase the interest in natural sciences and efficient instrument for development of scientific literacy.
- Teachers discussed with experts from MES how these practices and the results from them could be applied in the new State educational requirements and Programmes of study in Chemistry and environment protection school subject.

*International Conference on Training Issues of Chemistry Teachers* was held on 26 June 2013 in Gabrovo. The conference was organized by Technical University of Gabrovo in close collaboration with Research Laboratory on Chemistry Education and History and Philosophy of Chemistry – Faculty of chemistry and pharmacy, Sofia University, and Aprilov National High School – Gabrovo, under the Chemistry is all around Network Project. The conference aimed to turn into a forum of discussing the methods of teaching chemistry at school, competences of chemistry teachers in using ICT for enhancing students' interest towards Chemistry lessons, opportunities for experimenting different approaches and methods for teaching and learning Chemistry, ways for implementation of the most recent findings in the field of chemistry science and chemistry teaching. The 3th thematic area was dedicated to the methodology, modern approaches and good practices in teaching specific Chemistry topics –incorporation of science in the Chemistry teaching/learning process using ICTs applications as video-lessons, simple and amusing experiments, “scientific toys”; different forms of team work as school scientific projects, club activity etc. All conference papers were collected and full length published in Conference Proceedings and as PDF on Conference website [17].

Another opportunity for exchange of successful experience and good practice in teaching chemistry at school is *Autumnal scientific-educational forum* organized by the Department for information and teachers' qualification of Sofia University. Thematic area covered by the two editions of the event is



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directed to the teacher's competence and to the need of continuous development of new ones. Since 2011 the forum has become annual and allows Bulgarian teachers and University professors sharing experience and good practice in school education. Papers presented during the forum are full length online accessible by electronic journal „Lifelong education“, published on the Department's Portal [18].

### 3.2 Scientific journals and other printed editions

*Az Buki National Publishing House for Education and Science* of MES publishes the only national weekly newspaper on education and science „*Az Buki*“ and nine science journals, each of them presents successful educational practice including in chemistry education among large number of students, teachers and experts - as it is mentioned on the publisher's official website, potential readers of the journals are about „19 600 people employed in the system of education, about 615 600 students in more than 2090 high schools, approximately 47200 teachers and principals, 21,100 people encompassed at University faculty institutions of higher and special education [19].

*Chemistry: Bulgarian journal of science education*. The goals announced on the journal's webpage closely relate to present education policy in natural sciences and chemistry: „This journal provides a room for sharing and discussing ideas, news and results about new ways of teaching as well as of presenting new experimental and theoretical aspects of chemical science. „Among the goals of the journal is to bridge the gaps between the educational research and the school practice. All educational levels - from the early science education, secondary education, vocational education to the tertiary education and the lifelong education, are on the focus. Enhancing the interest of students by combining multidisciplinary approaches amalgamating the science with its fundament - history and philosophy of science, is persistently pursued by the journal“ [20]. The journal offers large number of thematic areas for publishing and sharing of experience: Education - Theory and Practice; New Approaches; Teaching Efficiency; Teaching Experiment in Science; Advanced Science etc. The articles appearing in this journal are indexed and abstracted in Chemical abstracts and SCOPUS.

*Educational Journal „Strategies of the Educational and Scientific Policy“*. The journal aims to orient the pedagogical body from all educational system levels for applying innovative educational practices and their relation with the scientific policy of Bulgarian MES. The topic of the magazine for 2013 is dedicated to estimation in school education - the lack of appropriate methods and tools for evaluation in school system so that not only theoretical knowledge is properly assessed, but also the obtained practical knowledge remains one of the most significant problems of the educational system. The magazine publishes not only analysis of international and Bulgarian scientific researches in the sphere of school evaluation, data from international benchmarking concerning Bulgarian students (Program for international student assessment – PISA, European survey on language competence – ESLC, Teaching and learning international survey – TALIS and others) but also a special section for ideas from the practice, suggestions and feedbacks on the assessment [21].

*Educational Journal „Pedagogy“* is theoretical and methodological journal, which combine knowledge and information on all areas of education at all educational levels - from pre-school education to learning through life. Main topics of the journal are Philosophy of Education, Theory and Experience, Good Educational Practices, Research, Foreign Educational Tradition and Contemporary Experience etc., so the journal allows sharing of innovative ideas, insights and research achievements and good teaching practices among wide number of teachers, researchers and pedagogical experts [22].

*Electronic journal „Lifelong education“* It is published by the Department for information and teacher qualification and for 10 years now through its column „Good pedagogical practices“ it has been





providing teachers with the opportunity to discuss problems and share ideas while searching for approaches to qualified and sustainable secondary education. The journal publishes the full text of reports from the annual Autumn scientific and educational forums, organized by the Department [23].

In 2013 the Ministry organized a number of workshops in schools across the country under the motto: „School – student’s desired territory“. At these seminars, teachers had the opportunity to present their experience in the interactive teaching, extracurricular and club activities and all activities which contribute to the increase of attractiveness of students’ education and motivation. Best practices were presented in a *Digest with good practices for interactive education* [24]. The three sections of the digest, „Didactic and innovative methods and technologies“, „Self management, extracurricular and club activity“ and „Limitation of dropout and incentives for school attendance“ present professional searches of teachers in three major for the teaching practice directions: use of ICT in the education process; club activity, extracurricular activities and work on projects as a means of stimulating the personal expression of students; creation of more and more attractive opportunities for expression, stimulation of participation in the educational process through individual approach to every student as a way to prevent dropouts.

### 3.3 Websites and portals

There are also web-based forms offering platform for sharing successful teaching experience. One of them is the National education portal, developed by the MES as a step to implement the e-learning as educational practice in Bulgarian schools [25]. Other one is Teacher.bg or National network of innovative teachers, supported by MICROSOFT Bulgaria - 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 application at school [26].

## 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 long process which 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. Popularization of the 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.

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