

UTILIZATION OF CONTEMPORARY TOOLS IN TEACHING CHEMISTRY – COMPUTERS, COMPUTER PROGRAMS AND INTERNET

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Abstract. Utilization of modern computer aids represents an innovative model and method on which modern chemistry teaching is based. The possibility to apply the innovative methods in teaching chemistry, the use of computers, computer programs and the Internet, are based on the conducted practice and theoretical work in primary schools. Simplification of rules, phenomena, laboratory procedures, and complex molecular structures is based on the simplicity in work, the use and application of computer aids. The aim of the research paper is to point to the advantages of computer programs and the Internet in presentation, practice and explanation of teaching material in chemistry, as opposed to traditional technical means. Moreover, it popularizes, modernizes, develops, and perfects the existing models and methods of teaching chemistry by using computer science and computer aids.

Keywords: chemistry teaching, computers, computer programs, computer teaching aids, Internet, students

Introduction

17th century the creator of didactics and the contemporary school John Amos Comenius¹⁾ (Czech: Jan Amos Komenský) pointed out that the understanding of the outer world is realized through our senses [1]. Having this in mind, one is able to arrive

at the fulfilment of the condition of obviousness. The obviousness in chemistry teaching is accomplished through the display of static models, kinetic perceptions, and the utilization of modern technical advances.

The means and equipment for conducting experiments, diaphotos, multi-layer pictures, models, graphoscopic and magnetic labels, feature film pictures, are among the most commonly utilized teaching aids. For the sake of successful practice of teaching (topics) units, the explanation of terminology and phenomena in chemistry, the choice and use of teaching aids, only the most suitable, simplest and most interesting are to be taken into consideration [2-4].

The book was, and has remained, the central source of knowledge and a way of the enhancement of educational program, which contains the summary of the basic and existing knowledge on phenomena. Precisely due to such treatment of phenomena, most textbooks fail to enrich teaching and teaching process didactically and methodically [5]. Therefore, it is necessary to find an optimal didactic-methodical solution which provides the correspondence between the structure of real student activities in teaching process and program objectives.

Teaching means and problems related to their application in teaching chemistry

Due to the advancement of new techniques and technologies, under a strong influence of computer revolution during the last decade, the traditional source of knowledge, the book, is slowly being pushed behind. Computers, modern teaching aids, have recently assumed their role in school teaching, thus pushing behind traditional teaching means used so far. Nowadays, the use of computers in school teaching is of crucial importance. Computers first appeared in the late 1970s and the early 1980s in specialized schools, such as natural science grammar schools and vocational schools. Those were computers of limited possibilities [6].

The main characteristic of the computer, as opposed to classic teaching aids, is the fact that it unites the following teaching means: the picture, sketch, photo, scheme, television, projectors, films. Since it can easily reproduce a number of media simultaneously (sound, tone and picture), it can justly be referred to as a multimedia means. Its application in teaching chemistry on both primary and secondary school levels is becoming indispensable for a number of reasons.

First, complex molecular structures can be displayed on the monitor, with the possibility of 3D picture, for example, molecules of DNA (deoxyribonucleic acid), RNA (ribonucleic acid), and proteins, instead of calotid (ball) and tetrahedron models [2,3]. Multimedia programs in the field of chemistry, encyclopedia issues, scientific magazines, lexicons, and text-books on the CD, are the accompanying elements of the books and technical literature.

Complex technological processes are shown as a whole, their display is simplified, while drawing plants, machinery and apparatuses are becoming a matter of routine. Schemes and sketches of technological processes and industrial plants may successfully be reproduced on the computer. In addition, the chemical processes occurring within plants are vividly displayed by interrupted lines, often in red or green. Movement of raw materials and half-products is shown by vertical blinking blue lines. This creates an impression of the raw materials moving within plants.

Furthermore, the Internet may be regarded as a lucrative and inexhaustible source of information. It also represents a powerful system of communication among people throughout the world. It enables fast, effective, and cheap exchange of information. Nowadays, it is used by millions of users, with a tendency of constant growth. The number of users in the world doubles every three months.

This global network has been developed out of a military project that was implemented in the USA in the late sixties of the twentieth century. The project was named "ARPANET", the main aim of which was to connect the computers into a unique network which would serve as a means of communication in case of the break-out of the nuclear war [7]. Thus, the invention of the "Cold War" has become a means of cooperation among people all over the world. The Internet as a global world network combines all types of media (radio, TV, telephone), providing immediate and effective exchange of information.

The computer is among the most important technical means for performing calculation, which is applicable to the field of chemistry as well. Complex issues in chemistry, as well as the less difficult ones, may be explained by the use of the computer. The management of industrial and technological processes is based on the application of mathematical (computer) programs. Performing theoretical and experimental calculations in chemistry is based on the application of various mathematical methods, through the use of computer languages (FORTRAN) and their numerous versions adapted to different types of computers until recently used in the field of programming in chemistry. Namely, setting principal parameters of acid and base (expressing acidity and alkaline by volumetric titration) used to be solved by linear equations. Expressing return of organic reactions (addition and substitution of halogens) was based on the application of linear functions and methods of curve fitting. In addition, systems of matrix and integrals were used to define the principal parameters (shape, size, position) of atomic and molecular orbitals. Therefore, programming in chemistry demanded from both students and teachers the knowledge of a number of program languages and certain mathematical procedures (logics rules, special symbols) and operations, when constructing algorithms and solving problems [8]. Due to its complexity and modest practical applicability in chemistry teaching, programming in chemistry was replaced by modern and less complicated computer methods and programs. It has, however, still remained part of technology of chemistry and chemical engineering.

Computers and their application in contemporary teaching of chemistry

The new aspects of the utilization of computer teaching aids in the teaching of natural sciences (Chemistry) are a result of the long lasting work and the conducted practice in the field of Computer Science and Chemistry in primary schools (Primary School "Djura Jaksic" in Jelasnica, and Primary School "Lela Popovic" in Miljkovac, situated on the territory of the city of Nis, Republic of Serbia).

The innovative methods of the utilization of computer aids in chemistry teaching are based on the advantages of the use of the computer. They also facilitate and advance the work of the teacher and the student in both theoretical and practical aspects. The computer offers plenty of possibilities in the theoretical aspect of teaching, as a result of which students are shown various chemical processes, and natural phenomena on the computer, and vividly presented with principal chemical laws as well. The structure of molecules, atoms and crystal systems (cubic system of sodium-chloride, NaCl) is much clearer if shown in 3D on the monitor of the computer instead of a two-dimensional diagram.

Moreover, organic reactions undergoing intricate mechanisms become clearer to students when using computer programs adopted to chemistry teaching. These are programs which show certain phases of particular reactions as well as the entry of the parameters of the development of reaction mechanism (temperature, pressure, various quantities of reactants, catalysts) within organic chemistry (reactions of halogenation, oxidation, reduction, substitution, addition and elimination).

Practical work with the help of the computer represents simplification of procedures when applying chemicals and laboratory equipment during experiments. Arranging the apparatus when conducting experiments becomes easier when performed with the help of the computer. The position and order of the laboratory equipment are clearly displayed on the monitor, the only task of the student being to follow the instructions on the monitor, which leads not only to independence while conducting an experiment but also to enabling students to conduct various more complex experiments. In addition, students may revise and practise certain quantitative analysis methods a number of times, by the use of a so-called computer virtual laboratory in order to optimize caution and precision in work and reduce the number of possible injuries when conducting experiments and using toxic substances, especially when using: sulphur dioxide (SO_2), white phosphorus (P_4), nitric acid (hard acid, HNO_3), sodium metal (Na); nonmetals, red liquid bromine and iodine (Br and I); in volumetric analysis (methods), and titrations with standard solutions of sulphuric acid (hard acid, H_2SO_4) and sodium hydroxide (hard base, NaOH) [9]. Students revise experiments and procedures many times with the help of the virtual laboratory until they reach desired results, simulating conducting an experiment in laboratory conditions.

The position of the computer may be determined by the teacher himself. The computer can be placed on the teacher's working desk in the cabinet, in the facility for

experiment preparation, but certainly not in the laboratory. Not only does it occupy space, but it may also be partly damaged due to the presence of a large number of students and work in groups, mainly lack of caution, and the impact of evaporating and corrosive substances (acids, bases and solvents).

Moreover, the computer may be used by the teacher to serve as a database. In this way, traditional file for storing student dossiers, test scores, seminar papers is not necessary. Lists of laboratory equipment and substances, chemistry devices, teaching aids are constantly available to the teacher.

Computers are also used with the purpose of testing and evaluating students' knowledge of chemistry (mainly of separate units) by the use of tests, composing standard tests, as well as creating procedures when conducting experiments. The teacher is to choose free activities in the field of chemistry through organizing school quizzes, debates and competitions with the help of the computer. Composing and writing standarsized tests on the computer does not take plenty of tim. It is simple and demands the knowledge of basic computer skills, such as creating and utilizing the tools within the Word and Power Point programs.

The use of computer programs in teaching chemistry

Modern chemistry teaching offers a plethora of possibilities in combining teaching methods. It is almost impossible to imagine natural sciences teaching, especially chemistry teaching, which is not based on the usage of the computer and programs adapted to the school and the age of the students. With the purpose of achieving interdisciplinarity in chemistry teaching experience has showed that teaching, methodical and didactic objectives are achieved by using and combining the following programs: Paint, Word, Power Point i Corel Draw. The choice of programs depends primarily not only on the topic and unit to be practised but also on professionalism, methodical and didactic education of the teacher, his master of computer skills, and capability of presenting the students with principal terms and phenomena in chemistry. From the aspect of didactics and methodology in chemistry teaching, completion of teaching units and topics, explanation and simplification of chemical terms, phenomena, and laboratory and technological procedures may be realized by utilizing the above mentioned computer programs.

Paint is one of the many and the simplest programs for computer drawing, with relatively modest facilities, which is, however, quite simple to master and utilize [10]. Precisely due to its simplicity and applicability, this program may be used when practicing the topics: structure of atoms and molecules, chemical reactions and inorganic substances (oxides, bases, acids and salts). Thus, writing chemical symbols and general formulae leads to accuracy and precision in defining the relationship between the number of atoms (in organic chemistry) in the molecule and the position of indexes and coefficient in the formulae (according to the laws of formula writing), for the very

facilities of the Paint enable clear and precise expressing the relation of the number of atoms within chemical formulae. When writing formulae and the symbols of elements, the largest number of errors is caused by copying which is the result of bad visual clarity of the data written on the board. The program Paint reduces the number of errors, increases precision, and offers students the possibility to exercise and combine symbols, indexes, and coefficients (number of atoms and molecules).

The second characteristic of the program Paint is precision and visual clarity of presented structures of atoms and molecules, which corresponds to the levels of abstraction (atom structures may be showed by the use of four levels of abstraction). What is more accessible and graspable to most students is the level of pictures (the third level), rather than the abstract level (the fourth level, characteristic of numbers) [11]. Therefore, when showing structures of atoms and molecules by the use of the level of pictures, students have better score than if the problem of understanding the structure of substances were explained by black-and-white pictures or mathematical model.

The third characteristic of the Paint is directly connected to data transferring and processing in the Word and Power Point programs.

Word is a program the main purpose of which is text processing and work with simple tables and grids [10]. Units such as the periodic table, valency of elements, experimental and laboratory practices, seminar papers and school research projects, are best conducted by the use of the program Word. Simple and fast table formation in Word, the insertion of colors, various signs and variables simplify the illustration and construction of the periodic table and understanding of Mendeleev's periodic law, the position, type and characteristics (physical and chemical) of elements, and the distribution of groups and periods as well. Students become creators of the periodic table. Following periodic's law and according to the model of construction (according to increasing atomic weight), they independently create the magnetic model of the of periodic table.

Moreover, in accordance with the text written in Word (symbols of elements, atomic number and atomic mass) combined with magnetic basis, they are able to design a "mosaic" model of periodic table. By moving magnetic symbols, they compose Mendeleev's periodic table, according to the rule of periodicity. The table of electronegativity (Pauling's table) and chemical symbols are constructed in the same way. Finally, procedures and results of performed experiments in the school laboratory are recorded and presented by students in the form of a laboratory record and report; students independently define the results and products of experiments, thus preparing themselves for independent working. By combining the Paint and Word programs, it is possible to handle seminar papers and school projects, formation of tables, pictures, grids, demonstration of results (theoretical and experimental).

Power Point is one of multimedia computer programs for making presentations, which utilizes a number of media: text, sound, music, speech, pictures, film and video records [10]. It combines certain more or less similar programs, such as Word, Exel and Paint, linking various traditional teaching aids, such as: diaphotos, diaproyectors, multi-layer pictures, model of atoms and molecules, graphoscopic labels, and feature film pictures. It possesses all the characteristics of a modern didactic-teaching means.

Power Point offers a large number of possibilities when choosing and practicing teaching lessons and units in the field of organic chemistry (chemistry of carbon), electronic configuration, structure of crystal systems (cubic, tetragonal, hexagonal, trigonal, monoclinic, orthorhombic and triclinic), formation of covalent and ionic (chemical) bonds, stoichiometric and percentage concentration assignments), principal chemical laws (law of constant composition or Proust's law and law of conservation of matter and energy (Einstein law)), presentations of lessons, seminar papers, projects, school quizzes, and their online publication. Thus models of atoms and molecules, covalent and ionic bonds, carbonic structure of organic molecules, crystal structure no longer represent static models (as it is the case in Paint and Word). In fact, they have become moving pictures and short films, which, along with tone and music support, provide visual illustration for the students of the formation of chemical bonds and crystal systems, atoms and molecules.

As in the case of Paint, when speaking in terms of mathematical models of solving chemical problems and displaying models of electronic structure of atoms and molecule formation, Power Point offers clarity and visualization of displayed phenomena and models, which corresponds to the levels of abstraction, in this case raised one level up (fourth level, the level of numbers).

Introducing specific effects (3D) within Power Point according to standard examples which explain the law of constant composition and the law of conservation of matter and energy (for example: combustion and measuring the mass of the candle, synthesis of iron and sulphur) makes completing stoichiometric (order of procedures), percentage and mass concentration assignments, complex structures, important biological and organic substances clearer and more accessible to students than when explained during traditional practice of the mentioned teaching units (in case of inability to perform an experiment and lack of adequate chemicals and laboratory equipment). Students are given the possibility of choice and creation of technological processes (production of ammonia Haber process, production of polymers, soaps and detergents, refining of oils, creation of atomic energy) [12].

The characteristics of Power Point are principally utilized with the purpose of writing, composing and presenting teaching units by the teacher, solving problems (stoichiometry, chemical processes), quizzes, tests for evaluating students' knowledge, presentation of the subject, its topics and tasks. Hence students create presentations

of research upon a free model, according, however, to given current topics in the field of chemistry, ecology, and biology (saving drinking water and environment, using alternative sources of energy). If necessary, presentations in Power Point are made on the Internet. Among the mentioned programs, Power Point is most frequently utilized in chemistry teaching.

However, there are certain disadvantages of the use of Power Point, which ought to be avoided in work and when making presentations. Most importantly, in order to acquire desired objectives, defined by the type of lesson, volume and complexity of the curriculum, one should mind the balance of the number, size, and variety of images, the choice of music, short and simple (representative) examples, the introduction of certain effects, and short concise texts.

Corel Draw is a program most commonly utilized by designers. It is more complex and possesses plenty of possibilities for computer drawing [10]. In chemistry teaching, it is primarily made use of in drawing complex organic structures (fats, carbohydrates, amino acids and proteins). There are structures of inorganic substances (oxides, bases, acids and salts), atoms and certain molecules which make little trouble to students when drawing. In this case, the choice of Word and Paint is satisfactory. What may be applied to Corel Draw is the third and fourth level of abstraction, since the geometry (spacial arrangement of atoms in the molecule) and the image (structure) of the molecule are connected.

The use of Internet in teaching chemistry

Innovative models and methods of computer utilization are also related to the use of the Internet (teaching television and teaching film [2,4]) in chemistry teaching. The Internet provides students with fast and simple access to a large quantity of information from various fields of science (in this case chemistry). Moreover, computer networking, connecting computers by the Internet, offers rapid and simple information transfer among schools in a city, region, state, and finally in the world.

Teaching television and teaching film are becoming an integral part of the Internet, with the use of adequate technical aids. A chemistry class is organized and conveyed through an internal network which connects computers in a school, city or region. In this case, the role of the teacher is the same as with school television, with the exception of a WEB or digital camera being used for image transmission instead of a common TV camera.

Lectures of recognized local and world experts in the field of chemistry, and other teachers acknowledged in the country and the world, are conveyed in the direct and indirect way. In the case of the direct way, lectures are delivered directly, as with school television. The indirect way is better, for it enables subsequent lecture broadcast, previously filmed with the possibility of coordinating the time of broadcast, which

would be common for the majority of the schools. On the occasion of organizing Internet quizzes, the choice of teaching lessons and units is determined by the syllabus of the subject itself. If this were not the case, the evaluation of results among different schools would significantly differ from standard values. The results are statistically processed and presented by the use of grids and charts in Excel, individually, and by questions, with the purpose of acquiring as realistic as possible an analysis of skills, knowledge, and competence of students. This type of knowledge testing is applied by schools in order to, according to planned activities and within the program of self-evaluation, conduct a research and, on the basis of the results, assess their own work, student and teacher achievements, and launch new types of research (teacher-researcher).

Conclusion

Chemistry is not a favorite subject of students. Negative attitude to chemistry is not characteristic of a particular region or country; quite contrary, this is a matter of attitude of most students in the world. Numerous researches conducted in Europe (in German cities: Bremen, Bonn, Bremerhaven, and places surrounding Bremen) have shown that interviewees (students) fail to understand chemistry due to difficulties resulting from the process of mastering and comprehending certain theories and formulae, by which they are intimidated. Failure in understanding and anxiety result from the complexity of theoretical and abstract models and constructions. According to students, these are in contrast with practical use of the acquired knowledge in chemistry [13]. In addition, it is quite common for students to associate the teacher with the subject, which testifies about emotional factors, subjective opinion, and the age (adolescence) of students.

Contrary to the negative attitude of students towards chemistry, teaching experience has shown that studying chemistry with the help of the computer leads to better results, which is justified by various individual and psycho-emotional skills of students (interests, work, beliefs, talents, and emotional development). Thus students very often suffer from stagefright when answering in the presence of others. Some of them have difficulties in focusing, comprehending and mastering the syllabus, whereas others are afraid of the teacher, which leads to anxiety and negative attitude towards the subject itself.

Consequently, studying with the help of the computer unburdens students and provides them with confidence, for, even when they make a mistake, they will not get a bad mark or be criticized by the teacher. Chemistry teaching organized with the help of the computer motivates and develops imagination with students and their individual affinity for natural sciences. It also stimulates innovativeness in research work. The aim of chemistry and computer science teaching is not only to provide basic theoretic-

cal and practical knowledge but also to enable students to make use of the acquired skills and experiences in various areas and spheres of life.

However, in primary and secondary chemistry teaching, the computer must not be given the role of the most commonly utilized teaching aid, thus neglecting other traditional teaching aids. This principle may be applied in chemistry teaching when it is necessary to give the computer the ultimate role due to lack of other teaching aids. Finally, the task of the teacher is not only to possess the appropriate level of professional, methodical, and didactic education but also to follow the development of technical and computer advances, and successfully apply them.

Possibilities of the Internet have not yet been fully made use of in chemistry teaching. The future of chemistry teaching is closely connected to computer science teaching. The influence of computer revolution on the modernization of school chemistry teaching is enormous. Generally speaking, students' interest in natural science teaching is gradually decreasing, revealing a tendency for stagnation, unlike computer science teaching, which displays constant growth. A stronger influence of computer science on chemistry teaching would certainly lead to the return of students' interest in natural sciences, chemistry being among them.

There is also a question of the specific role, involvement, and position of the teacher in teaching, which is influenced by the utilization of the computer. The role of the teacher in the creative field of work, as a methodologist, motivator, mentor, creator of teaching atmosphere, and above all innovator and researcher, would be putting effort into introducing novel scientific ideas in the teaching process (openness for changes), applying new technical and technological means, combining teaching methods, cooperation and exchange of ideas with colleagues in order to modernize and improve teaching [4].

Bad financial situation and poor equipment in schools is the main factor which further development of chemistry and computer science teaching depend on.

NOTES

1. John Amos Comenius (1592-1670) was a Czech teacher, scientist, educator, and writer. He was a Moravian Protestant bishop, a religious refugee, and one of the earliest champions of universal education, a concept eventually set forth in his book *Didactica Magna*. Comenius became known as the *teacher of nations*. He is often considered the father of modern education <http://en.wikipedia.org/wiki/Komenski>

REFERENCES

1. **Komenski, J.A.** *Velika didaktika*. Zavod za udžbenike i nastavna sredstva. Beograd, 1997.
2. **Nikolajević, R.** *Metodika nastave hemije*. Zavod za udžbenike i nastavna sredstva. Beograd, 1999.

3. **Halaši, R., M. Kesler.** *Metodike nastave hemije i demonstracioni ogledi.* Naučna knjiga, Beograd, 1976.
4. **Herak, J.** *Didaktički temelji početne nastave kemije.* Školska knjiga, Zagreb, 1979.
5. **Havelka, N.** *Učenik i nastavnik u obrazovnom procesu.* Zavod za udžbenike i nastavna sredstva. Beograd, 2000.
6. **Sotheeswaran, S., D. Gaschik.** Computer-Assisted Instruction in Chemical Education in the Asian/Pacific Region. *Chem. Educ. J.* **8**(1), Serial No. 14 (2004).
7. **Rogers, K.** *The Usborn Illustrated Dictionary of Science.* Atlantis, Novi Sad, 2000.
8. **Dickson, T.R.** *The Computer and Chemistry. An Introduction to Programming and Numerical Methods.* W.H. Freeman and Co., San Francisco, 1968.
9. **Kostic, D.A., S.S. Mitic, A.R. Zarubica, A. Gosnjic, M. Stojkovic.** Comparing the Computer Supported Approach versus Traditional "Teacher-Student" One. *Chem. Educ. J.* **11**(2), Serial No. 21 (2008).
10. **Stojanović, M., D. Vasić.** *Osnove informatike i računarstva za 8 razred osnovne škole.* Zavod za udžbenike i nastavna sredstva. Beograd, 1991.
11. **Devlin, K.** *Metematički gen.* Plato, Beograd, 2001.
12. **Llansana, J.** *Školski atlas fizike i hemije.* Kreativni centar, Beograd, 2004.
13. **Woest, V.** *Den Chemieunterricht neu denken: Anregungen für eine zeitgemasse Gestaltung.* Leuchtturm-Verlag, Darmstadt, 1997.

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