Chemistry Education
in the Light of the Research

the monograph edited by:
Paweł Cieśla, Małgorzata Nodzyńska, Iwona Stawoska

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INTRODUCTION

Chemistry education lies somewhere in between the chemistry as a science as well as pedagogy and psychology. It is a specific knowledge which includes the theory concerning the ways of teaching on a different levels of studies. Chemistry education as a science should be continuously developed base on research widely carried out. Chemistry teaching at school should follow the achievements in the scientific research. The didactic of chemistry plays a role of mediator in translating the recent discoveries in the field of chemistry into the content that is easy to understand by young people at school.

The chemistry education departments should cooperate in order to strengthen the role of didactic of chemistry as a science. It follows that the primary role of the groups is to conduct researches concerned on the various branches of chemistry education. Research in the teaching of chemistry should cover areas which are presented in the following diagram (Fig. 1).

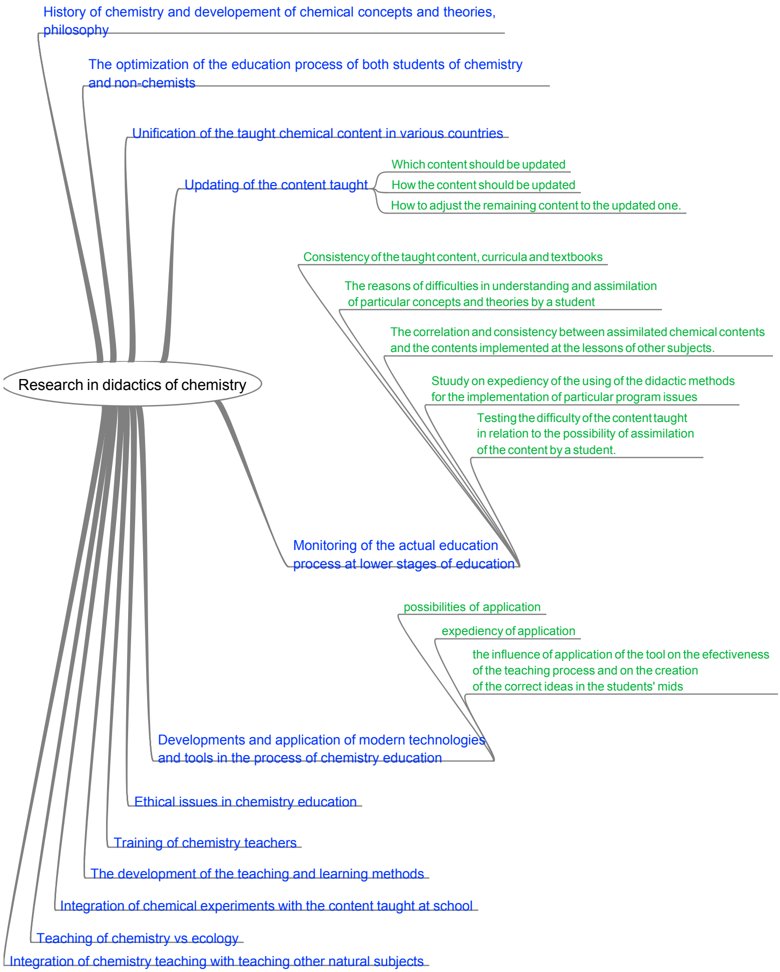

Figure 1. Directions of the research in chemistry educations.

The results of the research should be published in books or journals of international level, unfortunately nowadays, many important researches has local, minor character and often is limited to the participants of thematic seminars or conferences.

In Chemistry education proces the special interests should also be paid to the teachers' training process. In many universities teachers are trained in chemistry, almost in the same way as well as chemists who undertakes work in an industrial laboratories. The only difference is the block of pedagogical and psychological activities, which is absolutely insufficient to prepare for the role of teacher.

This monograph is not a "book with prescriptions", with planned lessons, lectures or laboratories but rather a compendium of various techniques which goal is to obtain a success in teaching. The book also includes the recent results of the research in various fields of chemistry education carried out in many countries

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THE REPRESENTATIVE LEVELS IN CHEMICAL EDUCATION

Valéria Campos dos Santos; Agnaldo Arroio

Introduction

The complex and abstract nature of chemistry makes learning and teaching of the subject difficult for students and teachers (Johnstone, 1991, 1993; Nakhleh, 1992; Gabel, 1998; Treagust and Chittleborough, 2001).

The formation of most of chemical concepts and explanations of chemical phenomena rely on understanding microscopic world that is connected with the phenomenological world, both of which are communicated through the use of symbols. Thus, the conceptual understanding in chemistry includes the ability to represent and translate chemical problems using macroscopic (observable), molecular (particulate), and symbolic forms of representation (Gabel and Bunce, 1994).

Because of this complex nature of chemistry, Johnstone (1991, 1993, and 2000) proposed a model of thinking in chemistry that consists of three modes, addressed as “levels of though”: the macro, the sub-micro, and the symbolic. This multi-level way of thinking can be represented by the corners of a triangle (Figure 01) where the sub-micro and symbolic modes were put at the base of the triangle, and the macro mode at the apex.

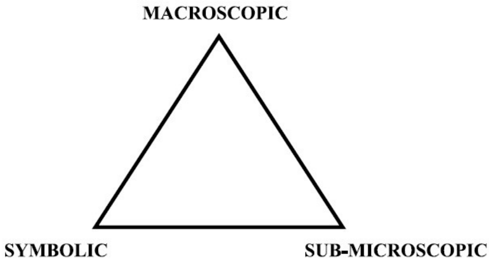

Figure 01. The three representational levels in chemistry (Johnstone, 1991).

Likewise, Gabel (1999) says that chemical phenomena, which are studied at the macroscopic level, can also be studied at the sub-microscopic level, but are generally described at this level in order to solve some complicated problems. The same occurs with the symbolic level. However, students are apparently able to understand complex ideas when asked to express the relationships between all the representational levels (Jansoon, Coll and Somsook, 2009).

In this respect, the utilization of visual tools at teaching chemistry is required to promote visualization capacities and understanding of the representations. The use of pictures, concrete models, photos, graphics, diagrams, computational programs and other kind of visualizations tools has increased strongly on the last years in science education. Studies about the use of these tools on the learning of chemistry have been carried out in order to prove that they can improve student’s representational capacity and understand of chemical phenomena since it can illustrate ideas that words cannot describe.

On the basis of the difficulties faced by students and chemical professionals at the teaching-learning of chemistry using the representative levels and the necessity of studies at this topic, this study aims to review and perform a theoretical discussion about the studies on the representative levels and its contributions for the chemistry education.

Methodology of research

The literature review was carried out in this article to aim to convey the reader what knowledge and ideas have been established on the representative level in chemistry education topic. The articles were chosen more on representative levels in chemistry issues and those that were related to science education and teacher education, the keywords for selection were chemistry representation, representative level, visualization, teacher education program, visual abilities and science education. The articles selected were from 10 different journals as showed at Table 01.

Table 01. Journal search results

Journal
Chemical Education: Research and Practice in Europe
Chemistry Education Research and Practice
International Journal of Environmental & Science Education
International Journal of Science Education
Journal of Chemical Education
Journal of Chemical Educator
Journal of Computer Assisted Learning
Journal of Research in Science Teaching
Journal of Science Educational and Technology
Science Education
University Chemistry Education

Results and discussions

Performing a literature review can be seen a major concern around the difficulties and abilities of both, high school students and undergraduate students, on understand chemistry in all the representational levels. Thus, many studies present methodologies and tools, such as, computer programs that can help these students in obtaining a complete learning of chemistry. Some studies are also conducted in order to analyze the influence of teacher's interventions on student learning. Nevertheless, few studies emphasize teacher trainings to work in all the representational levels.

Some researchers have shown that to chemists and chemical educators is required operate across the various levels quickly and easily, but students face a lot of difficulties to operate at all the representational levels. This fact was also observed by Rappoport and Ashkenazi (2008) when they have studied the way students use and connect the representational levels when solving conceptual problems, using a think-aloud interview protocol.

Hinton and Nakhleh (1999) examined the mental representations of chemical reactions used by six students who achieved above-average grades in a college freshman chemistry class at a large Midwestern university. The study revealed that the participants did make at least some use of each of the three representations, but some of them were able to make associations just with macroscopic and symbolic levels.

Some strategies can be used by teachers and students in order to integrate the three levels of representation: students need to confront a variety of problems (Gabel, 1999); learn how to connect abstract representations (Wu, Krajcik, & Soloway, 2001); teachers have to encouraging students to work with various representational and symbolic models (Bodner and Domin, 2000); present to students opportunities to develop and test their produced models (Justi and Gilbert, 2002) and expose to students abstract phenomena that are difficult to interpret or visualize at the sub-microscopic and symbolic levels (Johnstone, 1991).

In order to solve the problems associated with the difficulties faced by students in understanding and move between the triplet representational levels, researchers have been proposed methodologies of in class work. The use of models in science education is seen as a good methodology for a complete understanding of the phenomena. According to Grosslight et al. (1991), modeling ability is the ability to traverse the three levels of chemical representation of matter.

Multimedia tools are also used to help students in understanding and move between the triplet representational levels. The growing interest of educators in visual literacy is conditioned by the newly emerging communication and visualization technologies, which are supported by the development of computer graphics, animations, and simulations (Ferk et al., 2003).

Although the importance of the teachers' role on the students' full appreciation of the chemical content, we still see a lack on scientific studies related to teacher training for help students to understand the chemistry for completely, moving between all the levels. Therefore, we emphasize the need to direct research on the topic visualization highlighting the importance of the teachers' training for the learning of chemistry in all representational levels.

Conclusions

The outcomes obtained from a literature review have shown that this topic has raised the interest of many researchers in science education. However, there is still a predominance of works around the students' difficulties and methodologies to improve their visual capacities to understand chemistry in all representational levels.

The use of models and multimedia tools in chemistry classes has been helping to increase the performance of students on operating all representational levels but, researchers emphasize that the teacher's role is still very important for the students' success. Nevertheless, there is still a lack on scientific studies related to teacher training for help students to understand the chemistry in all the levels. Thus, we emphasize the necessity of works showing the role of teachers on the chemistry lessons in all the representational levels.

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CHEMISTRY EDUCATION AT ELEMENTARY SCHOOLS IN THE CZECH REPUBLIC: TARGET SKILLS AND POPULARITY OF THE SUBJECT

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Background

As it has been shown (Budiš, 1996; Pavelková, Škaloudová and Hrabal, 2010), chemistry in the Czech Republic has been one of the less popular subjects at elementary schools for a long time. Our aim was to check this situation during the ongoing educational reform and to find out how much pupils` wishes correspond (about target skills in chemistry) with chemistry subject matter.

Methods

Elementary school pupils answered two questionnaires. **The first of them** was responded in the end of January 2010 by 866 elementary school pupils (8th grade). It contained (among others) the following questions: *1) What is your favourite subject? 2) What is your less favourite subject?* The results were compared to an analogical research undertaken earlier by Budiš (1996) with pupils of the same age (January, 8th grade). According to the frequency of pupils` proposals we determined the order of popularity (unpopularity) of individual teaching subjects.

From May to June 2011, 984 pupils (tab. 03) answered **the second questionnaire.** Among others, it contained the question: *What chemical skills would you like to acquire?*

Results and discussion

In **the answers to the first questionnaire** we can see a great shift of chemistry towards more favourite subjects. While in the year 1996 it was assessed among popular items at the last 13th place, in 2010 was the 6th site out of 20 teaching subjects (tab. 01). We can read changes in positions of other teaching subjects from tab. 01 as well.

As for the less favourite subject (tab. 02), in 1996 chemistry was the 3rd less favourite subject. Unlike this, in 2010 it was only the 6th less favourite. The other teaching subjects mentioned in the answers are given in tab. 02, too.

As it follows from data in tab. 01 and tab. 02, the initial (opening) position of chemistry has shifted to more favourite subjects (approximately three times in both questions) since 1996. In our opinion it is a result of a change in the way of teaching chemistry. In comparison with 1996, much more experiments (that are considered to be the most interesting part of chemistry for elementary school pupils) are used at school nowadays. An apparent contradiction showing that Pavelková, et. al., 2010 had found chemistry to be one of the least favourite subjects even in the years 2001-2007, can be explained by the fact that Pavelková, et al., 2010 had investigated older pupils than we did. It has been shown (Cídlová, Petrů, and Bayerová, 2012) that relationship of pupils towards chemistry turns to unpopularity rapidly within the first two years of its study.

In the second questionnaire we focused on the question *What chemical skills would you like to acquire*? We asked pupils of different age and two kinds of school (elementary school, eight-years grammar school). For more information about respondents see tab. 03.

The answers to this question were made freely, without any list of offers. The suggestions of the respondents were classified into groups with similar kinds of answers. For the results see tab. 04. The total number of pupils (respondents) was taken as 100 %. As the respondents could give none, one or more suggestions, the sum of percents in columns in tab. 04 is not equal to 100 %.

As it follows from tab. 04, the desire to be able to perform chemical experiments dominates. With increasing age of the respondents this wish drops down substantially. With a large gap, this

Tab. 01: The answers to the question No. 1 (*What is your favourite subject*?).

1996		
Teaching subject	**Proposals` percentage (%)**	**Order of popularity**
Physical Training	20,0	1
History	16,0	2
Geography	13,3	3
Art	10,7	4
Informatics	8,7	5
Music	6,0	6
Civics	5,3	7
Science	4,0	8
English Language	3,3	9-12
Czech Language	3,3	9-12
Mathematics	3,3	9-12
German Language	3,3	9-12
Chemistry	***2,7***	***13***

2010		
Teaching subject	**Proposals` percentage (%)**	**Order of popularity**
Physical Training	26,6	1
Informatics	13,3	2
Art	8,1	3
Mathematics	7,5	4
Science	7,2	5
Chemistry	***6,8***	***6***
Geography	5,6	7
English Language	5,4	8
History	4,7	9
Czech Language	3,8	10
Music	3,8	11
Physics	3,4	12
Health Education	1,8	13
Civics	1,4	14
Environmental	0,2	15-19
Media Education	0,2	15-19
Work Activities	0,2	15-19
Family Education	0,2	15-19
Cooking	0,2	15-19
German Language	0	20

Tab. 02: The answers to the question No. 2 (*What is your less favourite subject?*).

1996		
Teaching subject	**Proposals` percentage (%)**	**Order of unpopularity**
Physics	27,3	1
Mathematics	23,3	2
Chemistry	***22,7***	***3***
German Language	8,0	4
Czech Language	7,3	5
English Language	6,0	6
Geography	5,3	7

2010		
Teaching subject	**Proposals` percentage (%)**	**Order of unpopularity**
Mathematics	28,0	1
Czech Language	17,8	2
Physics	12,9	3
English Language	10,2	4
History	8,6	5
Chemistry	***7,9***	***6***
Geography	5,0	7
Russian Language	2,7	8
Science	2,5	9-10
Physical Training	2,5	9-10
German Language	1,8	11-12
Art	1,8	11-12
French Language	0,9	13
Music	0,7	14-15
Career Choice	0,7	14-15
Work Activities	0,2	16

Tab.03: The number of respondents in various groups of pupils that answered the second questionnaire (*What chemical skills would you like to acquire*?).

	elementary school		**eight-years grammar school**	
	grade	number of respondents	grade	number of respondents
just before the beginning of chemistry study	7th	169	1st	159
one year after the beginning of chemistry study	8th	223	2rd	127
the end of elementary school	9th	180	4th	126

desire is followed by the wish to know symbols of chemical elements and their position in the periodic table, to be able to build chemical equations, to be able to prepare explosives and to be able to use chemical curriculum in practice. For the rest of the suggestions see tab. 04. It is obvious from tab. 04, that older pupils gave much less suggestions per pupil in comparison with younger ones. It shows indirectly the rapid decline in the pupils' interest in chemistry during the first 1-2 years of their chemistry study. The decrease in interest concerns almost all the skills listed in tab. 04, with the exception of environmental protection and preparation of pharmaceuticals, where the pupils' interest increased or remained approximately the same.

A surprisingly small percentage votes for the ability to use school knowledge in practice might be due to immaturity of the respondents and their idea that practical use of chemistry is

Tab. 04: Pupils´ responses to the question What chemical skills would you like to acquire? For more information about groups of respondents see tab.03.

suggestion of a chemical skill	**percentage of the answers** (100 % is the number of the pupils)			
	grade of elementary school (or eight-years grammar school)			**average per pupil**
	7th (1st)	8th (2nd)	9th (4th)	
to perform chemical experiments	39,0	43,4	11,4	32,0
to know symbols of the elements and to know their position in the periodic table of elements	16,4	7,1	1,6	8,5
to build chemical equations	5,5	15,4	2,6	8,1
to be able to prepare explosives	7,3	8,6	4,3	6,8
to be able to use the chemical curriculum in practice	9,5	5,4	4,9	6,6
chemical nomenclature	0,6	11,4	0	4,3
to be able to prepare drugs	0,0	6,3	5,9	4,1
environmental protection	2,8	3,4	3,6	3,2
chemistry as a means of entertainment	3,0	3,1	0	2,1
safe work with chemical substances	0,6	4,6	0,3	1,9
preparation of solutions, calculation of their composition	0,3	3,7	0	1,4
to be able to prepare pharmaceuticals	2,7	0,8	2,3	1,9
explanation of chemical phenomena and processes	1,2	2,3	0,3	1,3
to be able to do everything what is possible to learn in chemistry	3,1	3,1	0,3	2,2
calculations based on chemical equations	0,9	1,7	0	0,9

a subject matter of further education. But this does not explain the fact that this desire drops with the age of pupils. As for the low number of suggestions of safe handling with chemicals, pupils probably have the impression that safety training before each laboratory training, safety alerts contained in laboratory work instructions and handling instructions on stock bottles with chemical substances are sufficient. It might also be the reason why the wish to manage this issues is in the end of elementary school (the end of 4th grade of eight-years grammar school) much lower than in the very beginning of chemistry study. Unexpected front location of wishes to know symbols of chemical elements and their position in the periodic table and to be able to build chemical equations is probably due to the fact that pupils expect more school chemical education in their near future, for which the skills mentioned above are really necessary, whereas non-chemical and non-educational life practice is for them so far away in the meantime that they do not think about it. It might be interesting to compare this fact with older respondents´ ideas about the same question.

Conclusions

The introductory attitude of upper elementary school pupils to chemistry improved during last 14 years, maybe due to using more chemical experiments at school. It is consistent with the results received by the 2nd questionnaire from which it follows that pupils want first of all to be able to perform chemical experiments and after it, with a large gap, they want to get some other chemical skills. The wishes what chemical skills should the pupils obtain at elementary school change and decrease rapidly during the beginning of chemistry study as well as the popularity of chemistry rapidly decreases within these two years. The majority of the students` main wishes is contained in Educational Framework or in the most frequently used chemistry textbooks (with the exception of preparation of explosives and drugs, of course). As for building chemical equations, it is a very difficult subject matter, for which pupils can be taught general rules just exceptionally. This problem needs much more attention to be solved in the future.

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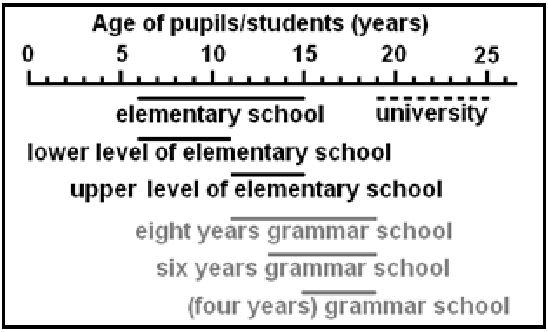
Appendix

A simplified explanation of terms related to the Czech educational system (used in this article):



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TPCK DEVELOPMENT AS PART OF CONTINUING CHEMISTRY TEACHERS´ EDUCATION IN THE CZECH REPUBLIC

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Introduction

Current social changes require much more effort from each individual than in the past. Everybody should be able to accept the changes and adjust to them actively. The worries relate to loosing jobs because working structures with firmly defined roles are missing, man has to change the job, position, field and profession for several times within the working time. Flexible, initiative and creatively thinking individuals are strongly required by the society in this uncertain and unstable environment. This should be a challenge for the current system of education, mainly for teachers and their new roles (Blížkovský, 2000, Vašutová, 2001).

That is why our analyses focus on increasing teachers´ information literacy in the field of general chemistry education in relation to the subject taught which the newly accepted didactic terminology called TPCK – Technological Pedagogical Content Knowledge. A group of lecturers teaching the course "ICT in the chemistry instruction" was monitored, the materials prepared by them were analyzed with the aim to optimize the learning content and forms of further teachers´ education in this field. A set of the Internet-supported lessons for chemistry teaching on the lower secondary school level was designed and created and methodological and technical recommendations were provided and tested.

The TPCK Model under Evaluation of Teachers – Lecturers of the "ICT in Chemistry Instruction" Course

Characteristics of new roles of chemistry teachers on the lower secondary school, which include the ICT implementation in the process of instruction, require new teachers´ competences. How these new trends are reflected in the latest didactic reality in the Czech Republic – it was one of the research objectives (compare to e.g. Zounek, Šeďová, 2009). The sample group was created by teacher community participating in the SIPVZ project at the Department of chemistry didactics, Faculty of Education (which was renamed Faculty of Science in 2010), University of Hradec Kralove since 2006, i.e. lecturers of the further education course "ICT in the chemistry instruction" (Bílek, 2005a, 2005b) participated in the research. We analyzed their experience, opinions, products of teaching activities (individual training plans, proposals of ICT-supported teaching units) and discussions with the aim to define realistic requirements on new ICT competences of chemistry teachers which would be reflected in the "ICT in chemistry instruction" course. The analysis also included teachers´ proposals and plans of ICT-supported chemistry lessons, defining of methodological recommendations and technical incentives for schools of different level of equipment. From this point of view we prioritized the Internet implementation (see below).

The research activities monitoring preparation and follow-up activities of the "ICT in chemistry instruction" course aimed at following fields:

1. Analysis of individual topic plans of the "ICT in chemistry instruction" course created by teachers – future lecturers.
2. Analysis of proposals of type chemistry lessons with ICT-support (future lecturers´ attestation works).
3. Questionnaire monitoring lecturers´ activities one year after receiving the lecturer's certificate.
4. Recommendation towards improvements of the "ICT in chemistry instruction" course.

The analyses provided facts which to some extent influenced the process of forming the TPCK content under the Czech conditions of pre-gradual preparation and further education of chemistry teachers on lower secondary school level, which are currently organized by various institutions without the SIPVZ co-ordination.

In 2005/2006 thirty-two teachers working on various levels and types of schools were awarded the certificate of the "ICT in chemistry instruction" course lecturer, i.e. they were certified for running (tutoring) the courses. In following years their activities were monitored so that the feedback (mainly the relevance and efficiency of the course) for further reflection could be provided to the educational institutions dealing with preparation of new lecturers. The lecturers´ proposals, products, experience, opinions, designed topics and comments should help optimize the course and provide prognosis of further development of the ICT implementation in the general chemistry education. They are monitored both in the role of course tutors and teachers – leaders in the process of the ICT implementation in the chemistry instruction. The emphasis is paid to the problems they have to solve at workplace relating to running the courses, to the interest, efforts and willingness to learn something new from the participants´ side etc.

Each lecturer provided written approval with anonymous publishing analyzing the course-related materials under random coding.

In the analysis of the individual topic plans (ITP) following criteria were applied: planned face-to-face (present) lessons; implementation of the distance form of work and its type; time devoted to single compulsory chapters: I. Office software for chemistry teachers, II. Internet and its application in chemistry lessons, III. Chemistry didactic software, IV. Modeling and simulations in chemistry and V. Computer-supported school chemical experiment; links to the recommended "ICT in chemistry instruction" manual in the ITPs (Bílek, 2005); total extent of the ITPs and interesting items within the course instruction. The proposed model of instruction was structured into five face-to-face meetings of total 20 hours and 10 hours of independent work in the distance form using WWW and e-mail communication. The distance form included various activities including work with www-search engines and web pages, communicating by e-mail, discussions (55 %) and e-mail conferences (19 %). The entire LMS (Learning Management System) was not frequently available for lower and higher secondary schools which was why only 13 % of future lecturers included this type of e-learning in the proposed course.

Each lecturer also prepared a plan of the ICT-supported chemistry lesson on any topic, methods, forms and the course of lesson reflected the topic and equipment of the institution. Thirty-nine plans were included in the research which were analyzed in the quantitative and qualitative way on the following criteria: topic of the lesson, topic field, type of institution/year, time devoted to the topic, learning content (chapters I – V), forms, methods, type of lessons (teaching units), the extent of the unit and inspiration.

Tab. 01 Sample teaching units (lessons) according to the discipline (%)

Learning content in general chemistry	44 %
Learning content in inorganic chemistry	33 %
Learning content in organic chemistry	23 %

Tab. 02 Sample teaching units (lessons) according to the TPCK field (%)

Office software	41 %
Internet	26 %
Learning programmes (didactic software)	36 %
Modeling and simulations	33%
Computer-supported experiment	15%

Tab. 03 Sample teaching units (lessons) according to the organizational form of instruction (%)

Collective	13 %
Group	64 % (... within the group instruction 36 % prefer pair work)
Individual	23 %

Tab. 04 Sample teaching units (lessons) according to the phase of instruction (%)

Motivation	22 %
Explanation	47 %
Consolidation	19 %
Diagnostic	13 %
Application	34 %

Tab. 05 Sample teaching units (lessons) according to the phase of instruction (%)

Search for information	27 %
Presentation of information	11 %
Computer managed instruction	13 %
The use of software tools for pupils´ activities	13 %
Modeling of pupils´ activities and objects of instruction	23 %
Experimental activity support	13 %

As the above presented analyses show lecturers prefer the ICT-supported instruction mainly in groups (including in pairs), despite 25 % of them requires one computer with the Internet access per pupil. Working with the Internet and its wide use (virtual laboratories, simulators of experiments etc.) is steadily increasing. The proposals of lessons were worked out in details, which demonstrate lecturers´ positive and responsible approaches to studying the course.

One year after finishing the course "ICT in the chemistry instruction" we were interested how the lecturers work in the role of trainers, what problems (organizational and methodological) they cope with, what experience they received from the interaction with their learners-chemistry teachers. This field was monitored by the questionnaire method.

The lecturers answered the questions at the time, when totally 171 participants had been trained - 85 lower secondary (basic) school teachers, 34 grammar school teachers, 47 teachers of other types of secondary schools and 5 of other schools. Teachers mostly enrol the course because of receiving new ideas, methods and widening their knowledge. They have enough experience in using the office software and the Internet (see tab. 06), rather little experience was detected in using the didactic software and computer modeling, and hardly any experience was discovered in PC-supported measurements. The participants were mostly interested in the ChemSketch software, learning programmes (LangMaster and Terasoft) and didactic software, they were least interested in the PC-supported experimental activities (approx. 19 % lecturers provided this activity in the form of excursion), which is the result of insufficient equipment of PC rooms and little teachers´ experience. Most of participants (71 %) included the distance form of instruction in their plans, mainly in the form of e-mail communication and work with web pages. As for the lecturers, one third of them includes the ICT into their instruction while working with office software (42 %), the Internet (24 %), chemistry didactic software (16 %), modeling and simulations (14 %) and computer-supported school chemical experiment (4 %). Nearly all lecturers expect step-by-step widening of the ICT in the chemistry instruction but relating to financial support and further education in this field. Half of the lecturers evaluated the course by the questionnaire provided by the local training centre, 30 % of them applied their own questionnaire, others by the questionnaire which was available on the "e-Gram Portal" (former SIPVZ portal), in discussions and asking questions. The courses were evaluated positively by participants-chemistry teachers, a longer time period would be appreciated. The lecturers were surprised by their willingness to learn, hard work, interest in the course content and new ideas despite their level of computer literacy differed considerably.

Tab. 06 Evaluation of participants experience in single types of ICT support of chemistry instruction

Type of support	Position of the Likert scale 1 – 4	Evaluation
Office SW	1.92	Good experience
Internet	1.71	Good experience
Didactic SW	2.43	Sufficient or hardly any experience
Computer modeling	3.21	Hardly any experience
Computer supported measurements	3.64	No experience

Proposals, Plans and Evaluation of Learning Units Implementing the Internet in the Chemistry Instruction on the Lower Secondary School Level

Resulting from the above presented analyses of the Internet support of chemistry instruction on the lower secondary school level and from our experience six groups of "chemistry lessons with the Internet support" were distinguished:

1. Search for information:

- search for sources,
- search for answers to the questions with the help of information sources,
- search for materials for seminar works or projects (the topic fields are set only, e.g. Metal properties, The use of metals etc.).

2. Presentation of information

The teacher uses presentation for explaining the matter, as well as animations, images, video-sequences etc.).

3. PC managed instruction

The learners work with the learning programme (explanation of a new topic, practising, revising, evaluation etc.).

4. The use of software tools for learner's creative activities

The use of programmes for creating formula, molecules, devices, text documents, tables, figures, presentations etc.

5. Modeling of learning objects and learner's activities

- simulation replaces experimental activities (virtual laboratories),
- simulation of experimental activities before and after the real experiment (models and virtual laboratories).

6. Support of experimental activities

PC-supported measurements (remote laboratories, remote measurements).

This structure included 38 learning units (lessons) which were piloted within the chemistry instruction on the lower secondary school level (Bílek, Zemanová, 2007). Following topics were appreciated to be the most interesting and attractive: "Air - the bubble of life and the greenhouse effect", "Chemical reactions around us", "Titanic of the heavens", "Tradition of the Czech glass", "Halogen-derivates of Hydrocarbons – Freons", "Fermentative processes in brewing industry" and "Sorting and recycling plastics". The process of instruction was run under the conditions of average level of computer equipment for the pupils´ independent work. Pupils worked with worksheets which we consider to be very efficient and contributive for the smooth course of instruction (motivation, pace, pupils´ individual abilities); having discussed the results pupils hand in them to teacher at the end of the lesson.

We did not indent to apply the pedagogical experiment and research the efficiency of the Internet-supported learning unit plans, as it is usually done. We focused on description of lessons with different approach to Internet use. Below the description and results of two different approaches to the topic "Tradition of the Czech glass" are presented. We did not run the pedagogical experiment as well as because of the reason that the proposals in our methodological manual (Bílek, Zemanová, 2007) are not provided in the form of algorithmic directions for mechanical applications to the instruction but they are complex proposals for the chemistry teachers on the lower secondary school level, and it depends on their inventions and experience what (procedures) they will choose. Thus the data received from the pedagogical experiment would be strongly influenced by our subjective approach to the process of instruction, either with the Internet support, or without it, and the contribution to the pedagogical practice of other teachers would be considerably weak. The above mentioned lesson, as well as other lessons in which other proposals were applied, were taught in two parallel classes (group 1 – 16 pupils, group 2 – 18 pupils), with different type of Internet support in each one. Group 1 was finding answers to five questions on the topic "Tradition of the Czech glass". Pupils worked individually using various search engines, wrote the answers down and cite the source. The group discussion followed where they presented the results, evaluated them peer-to-peer and filled the missing data and information. In group 2 pupils were randomly (by drawing lots) divided in five groups of three or four. A topic relating to the "Tradition of the Czech glass" was assigned to each group. Pupils were to prepare brief information on it for the other learners. They were provided with several WWW addresses to choose from. Finally, the results were presented to other learners and results evaluated in the discussion. Both groups (classes) worked with worksheets of different concept, i.e. reflecting the process of instruction. Identical features of the process in both classes (groups) were as follows: average marks in chemistry in half of the school year; the topic "Oxides nomenclature" had been gone over; the classroom and time period for the Internet-supported instruction (computer lab, 1 hour = 45 minutes); worksheets for recording the results of pupils´ activities; presentation of results and discussion summarizing new information. The groups (classes) differ in following features: organizational form of instruction, (individual/group); method of search on the Internet (any search engine/limited offer of www pages relating to the topic); teacher's approach (walking in the class, helping to find adequate web pages if needed/teacher only repeated the set questions to pupils) and final activities (discussion after presentations of selected pupils/discussions after presentations of group deputies).

Results in both groups (classes) differed considerably. In group 1, which worked in the "free, unlimited mode of searching on the Internet, more than half of pupils did not answer all questions, more than half of them did not provide the source of information. When discussing the topic, pupils read the answer only without trying to understand the meaning and interrelations within the topic. This was also proved in written answers which often did not fully relate to the question. The working environment in the group 2 was more active and noisy, when the roles in groups were divided, course of single activities planned etc. But the work ran quietly and results were much better. The written answers were worked out in details (approx. one A4-page) with one third of pupils, half of them wrote form about half of A4-page (average performance), one pupil's work was unsatisfactory, one group provided information randomly, without interrelations, as they found them on the Internet.

Pupils in the group 1 seem to have been more involved in searching adequate www addresses, and they did not have enough time for the "chemistry learning content“. Neither the teacher was able to help them to understand and solve the topic. Crucial problems were detected with children with special needs (LMD, dyslexia, dys-orthography etc.). Despite they answered fewer questions, searching the www addresses was very difficult for them, they were lost in the texts and often did not succeed in finding the answers. Working in groups is considered very efficient because pupils can support each other, do different activities, discuss the results and problems with other group members at the end of lesson. It was clearly seen in the 8.B class the Internet inspired and supported the co-operation within groups. The results proved that nearly all pupils

(90 %) used the offered www addresses, which contributed to better final results. The evaluation of single members within groups was more difficult because their work deal was not identical.

As observers in the teacher´s role we can confirm that excellent and average pupils in both groups worked hard, with efforts, trying to reach good results. Numerous of pupils proclaimed problematic surprised us, mainly by their participation in group work. Generally, some problems appeared in work with text, i.e. with presentation of results. This activity can be repeated and problems gradually eliminated. The feedback, i.e. pupils´ discussion is also a firm part of the lesson. The teacher should emphasize that not all information on the Internet is true and that is why each item should be considered, critically evaluated, compared to other sources etc. Efficient work with information means thinking about it and understands the meaning, content, relations.

Conclusion

The Internet support for the chemistry teaching on the lower secondary school level could be recommended, mainly in setting assignments with primary offer of checked www addresses. It may work as the support of concentration on the core of the topic and motivation to meaningful search for new information even on new www addresses. This approach fully corresponds to topical trends of Internet applications in the chemistry instruction in the world, e.g. so called WebQuest (Bílek & Ulrichová, 2006). Above all, we can definitely validate the chemistry instruction in the computer room to be highly motivating for pupils, it attracts their attention and inspires them for other chemistry and Internet related activities. Pupils´ frequently asked questions "when will we have such Internet-supported lesson again", were the cogent evidence. On the other side it should be emphasized that teacher's preparation for such type of instruction is demanding because all pupil's activities should be carefully planned from the point of learning content, ICT and methodology. The quality ICT-supported instruction will appear only if the lesson is well planned and prepared, firmly organized by the foresighted teacher, aiming at reaching pre-defined objectives in planned steps, otherwise it is the "playing with computers and surfing on the Internet" only.

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EXPERIMENTS WITH NATURE-BASED COLOURS

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Introduction – chemistry education and the Framework "FEP EE"

The chemical experiments realization is a quite essential and one of the most attractive part of chemistry education lectures in which the students can develop and improve their practical and communicative competences. Actually, the chemistry (and other science subjects as well) education system in Czech Republic is being basically covered by the relatively new mandatory programme called "Framework Education Programme for Elementary Education", abbreviated as "FEP EE".

This Framework strictly divides subject matter in chemistry education into 7 individual areas called as follows:

Tab. 01: Division of subject matter into 7 individual areas according to the Framework

Area No.	Name of the Areas belongs to the Framework
Area#1:	Observation, Experiment and Chemical Safety
Area#2:	Mixtures
Area#3:	The Particulate Composition of Substances and Chemical Elements
Area#4	Chemical Reactions
Area#5:	Inorganic Compounds
Area#6:	Organic Compounds
Area#7:	Chemistry and Society

This mandatory Framework was officially published in 2007 by the Authority VÚP Prague [1] and majority of Czech elementary schools had to start their education in full accordance with this Framework in the school year 2007-08.

Pedagogical Research – definition, objectives, methods

The pedagogical quantitative research started in the year 2009 and is closely connected with newly implemented Framework. It was focused on the teacher's (i.e. demonstration) and pupil's experiments realization in the particular areas of „FEP EE" in the chemistry lessons at the Czech elementary schools, its frequency, preferred or neglected topics and other related features.

The general objective of each pedagogical research is to find out ways how to improve the function and results of complete educational process. The main factual objectives of this pedagogical research were defined and discussed in the initial phase of research preparation and are summarized in the table below.

As the most effective tool how to send out, receive, collect, validate and evaluate data the electronic questionnaire concept was chosen. It was created using open-source program LimeSurvey™ [2], which provides on-line electronic form publication as well as classic paper output with printed questions and answers options. In practice, both forms of questionnaire were applied: online form located on the website [3] as well as classic paper form delivered by post.

Tab. 02: The pedagogical research executed - essential points (area, topic, target group, objectives, outcomes)

The research preparation - essential points		Essential points – specification in detail
1.	area of the research	Framework Education Programme for Elementary Education (FEP EE).
2.	topic of the research	What Theory says and the Practise clearly shows.... Teacher's (so-called demonstration) experiments realization and pupil's experiments realization in the particular areas of "FEP EE" at Czech elementary schools
3.	targeted respondent group	The teachers of chemistry at Czech elementary schools
4.	objectives of the research	Main objectives are to find out : teacher's attitudes to chemical experiments performing preferred or neglected topics/areas for experiments identification of the areas of "FEP EE" where is lack of simple, impressive and safe experiments frequency of both experiments realization identification of reasons why some experiments are not realized
5.	expected outcomes of the research	Have a true over-view of major aspects connected with the realization of chemical experiments on the elementary schools. Look up, suggest, design or improve suitable teacher's and pupil's experiments for those areas of "FEP EE" , in which the executed research showed low realization of experiments. Direct support of increasing chemical experiments realization at Czech elementary schools.

Fig. 01: Screenshots of the home web page where on-line questionnaire is located on

The questionnaire was sent out into 185 elementary schools which were chosen by random selection from the reference database managed by the Ministry of Education of the Czech Republic [4].

Pedagogical Research – evaluation, practice outcomes

The return rate of executed questionnaire survey was found as 65.4 % (above common standard), other results of questionnaire evaluation were discussed and published [5, 6], detailed presentation of the results would be out of the topic of this contribution. In short, the statistic evaluation of received data has shown (among others) there is a lack of pupil's experiments in the Area#7 called „Chemistry and Society".

That is why there was taken a decision to create and test out a short one-week pupil's project which will be able to cover this Area#7 of the Framework and combine together subject matter and practice procedures belongs to the affected Area. And more, this project can be considered as a cross-sectional one combined Chemistry, Biology, Physics and Environmental Education together.

The Project – basic characteristics

The Project "Experiments with Nature-based Colours" is focused on pupils at the elementary school. It has been developed with regard to the quite essential theses for school experiments performing – using safe, cheap, commonly available chemicals and eye-catching results of experiments. Activity target is to introduce pupils to chemical and physic characteristics of colours. The practice is effectively connected with theory. Pupils will obtain new communication, professional and problem-solving competencies in this one-week project.

The main goal of this project is to introduce pupils to the physical and chemical properties of pigments (i.e. separation of nature pigment mixtures, their reactions in acid or basic environment, mixing the colours and colour filters). Biological part of project is focused on plant's pigments and food colouring using natural pigments.

This Project is designed as approx. one-week long and consists of theoretical phase and practice part connecting several school subjects.

Phase 1 – Theoretical preparation of project

Pupils are looking for information concerning natural colours, suggest possible sources of natural colours indoors resp. outdoor and investigate the basic literature to find some experiments.

Phase 2 - Experiments Preparation (Biology)

Pupils are working in pairs or small groups (max. 4 people). They pick up about 5 plants around the school or during the environmental excursion. They look for colour plant in preference. Children take photos of these plants.

Fig. 02: Photos of some common plants which were picked out by pupils

After then they fill in the prepared table in work-sheet (using information from books, textbooks or internet).

Tab. 03: Table in the work-sheet

No.	Czech name	Latin/English title of plant	Site-location - Colour part of plant (bloom, body, fruit) / colour	
1	denivka	Hemerocallis fulva	garden	yellow-brown bloom
2	růže	rose	park	red bloom
3	ostružina	blackberry	garden	red-black fruit

If the pupils finish their work, they can paint corns of rise using curry or peel of onion. The best student can find animals' perception of colours.

Phase 3 – Realization of Experiments (Chemistry)

Pupils put plant's pigments on piece of filtration paper and observe their reactions in several drops of common acid (vinegar) or basic (washing-powder) mixture – they take photos of reactions. Brown origin juice from Hemerocallis fulva (in the middle) changes own colour to red in acid (on the left) or discolour to green in basic solution (on the right).

Pupils make chromatography of chlorophyll contained in all green plants. Spinach leafs

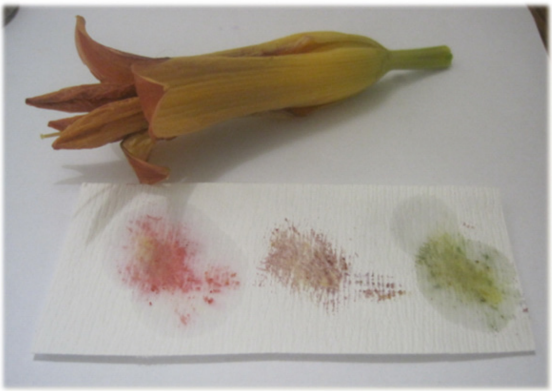

Fig. 03: Photos of discolour origin juice from plant

are suitable for this experiment. Firstly leafs are grinded with sand and ethanol is added in. The natural pigments contained in spinach are firstly dissolved in ethanol. Then half volume of benzine is consequently added into mixture and a piece of filtrate paper is put into the mixture. After 15 minutes pupils are observing separation of various types of natural colours [7]. The best students can prepare an indicator rate of solution from juice of red cabbage.

Phase 4 –Realization of Experiments (Physics)

Groups of pupils are preparing visible spectrum on transparent foil. They cover various colour line (or coloured objects) by their pre-prepared spectrum on transparent foil. The colour line or object is hidden under the same colour of spectrum only.

Pupils can also make a rotating spectrum disk from the paper circle which is coloured and fixed on the pinwheel. Pupils can blow on the pinwheel and look at the illusion.

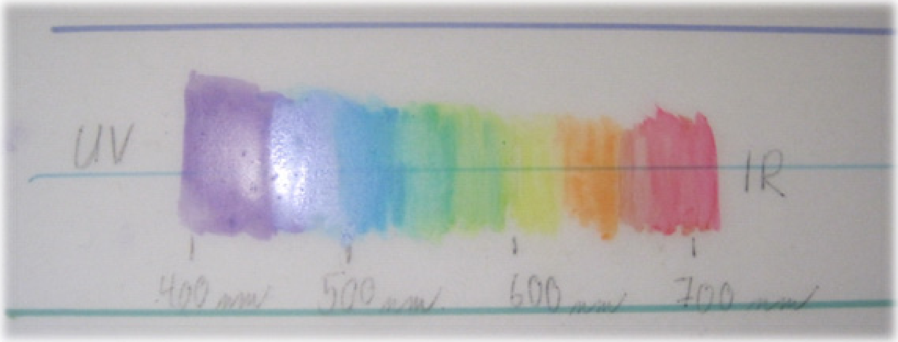

Fig. 04: Light-blue line under visible spectrum made by pupils

Anyway, students can find and prepare some other optical illusion or experiments from the source [8]. Children can manually make various colour filters or use pre-prepared flash animation. For example, pupils at Czech elementary schools can use flash animation called “Color room” or similar ones produced by Czech company Pachner s.r.o. [9]. They can change white, red, green and blue light of the bulb on the ceiling and pupils are observing the changes of object’s colour.

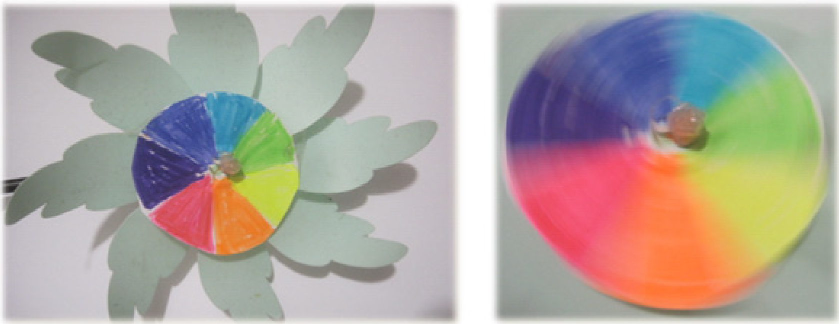

Fig. 05: Spectrum disc - blow on the pinwheel and look at

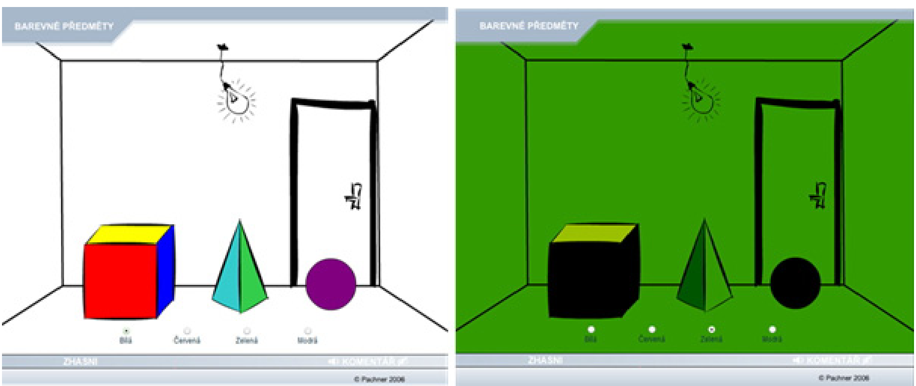

Fig. 06: Original flash-animation “Color Room” – before and after using the green filter (on the right)

Phase 5 – Results Discussion, Evaluation of Experiments, ICT Support

Pupils are working in the same groups and preparing their presentation about their previous practice lessons. After completing the particular worksheets prepared in advance by the teacher, all pupils discuss the results of realized experiments. They can produce a wall-poster for other pupils at school. Student can prepare newspaper article or publish their presentations on the student's website.

Conclusions

Educational process joins more school subjects (biology, chemistry, physic, ICT, environmental education). From the Chemistry education point of view this project helps to extend pupils' experimental activities in the Area#7 of the Framework called "Chemistry and Society". Production and application of nature pigments are an important part of day-to-day life.

Pupils cooperate and learn themselves about pigments, colours and light. They prepare education tools and utilities themselves during the project and use separating method chromatography to determinate parts of pigments.

The project outcomes are work-sheets, posters and PowerPoint presentations. All kinds of outcomes can be used for repetition and proper understanding of basic subject matter. Pupils will organise the meeting with other pupils from the school or public and shortly present the key points of experiments. The impressive multimedia presentations containing photo documentation or other attractive points from the project will be prepared by the pupils.

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FROM SER TO STL: TRANSLATING SCIENCE EDUCATION RESEARCH INTO SCIENCE TEACHING AND LEARNING

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Introduction

Has several decades of science education research (SER) had any effect on the way science is taught and learnt in school and university? The answer would have to be - yes, to some extent, but very little compared to the effort, money and time put into science education research (SER) over the last 40-50 years and particularly in the last 20 years. SER has become a large enterprise, with many research groups around the world, several science education journals, large numbers of research papers being published, and many reports and books. In many ways it is a field of academic study that has come of age. However, its impact on science teaching and learning is still in question. Bucat (2004) said: "Research has not had the impact on science teaching that we would have hoped. Furthermore, science education research seems to be looking for direction. Much of chemical education research has used subject matter simply as a vehicle to develop domain-independent pedagogical theory." He went on to say: "The advances have not in general been translated to the classroom, and Chemistry education seems unsure of its direction."

John Hattie (2008) in his influential book Visible Learning says this: "How can there be so many published articles, so many reports providing directions. So many professional development sessions advocating this or that method, so many parents and politicians inventing new and better answers, while classrooms are hardly different from 200 years ago? Why does this bounty of research have so little impact?"

This issue of lack of impact raises the question as to what is the primary purpose of science education research (SER). Is it to understand better the problems of teaching science to learners of different ages, abilities and interests so as to improve things or is it an academic pursuit, important for academic standing and careers, and largely independent of what goes on in the classroom, lecture theatre and laboratory? We could contrast these two approaches as the pragmatic and applied versus the theoretical and pure, similar to the situation that applies in science itself, or in any other academic discipline. There is always a tension between applied and pure research. The emphasis on pure versus applied/theoretical versus pragmatic varies from one country to another, and from one research group to another. I am firmly in the applied/pragmatic camp, as I believe that the purpose of science education research should be primarily to understand the processes and problems involving in teaching and learning science, with a view to changing and improving the way we do it. One could argue that research that does not effect change in teaching in the long run is pointless, at least from the point of view of the practitioner – the teacher or lecturer - but also from the point of view of the paymaster, often governments, who want to see research informing policy. However, this does not mean that pure research is not important in itself or may not end up being applied and affecting practice, even if that was not its original intention. Likewise applied research must usually have some theoretical basis even if its main focus is to change practice. McIntyre (2005) discusses the different types of knowledge produced by research on the one hand, and used by teachers on the other hand and suggests "that there is a very large gap between the kind of knowledge that good scholarly educational research can at best provide and the kind of knowledge that teachers most use in good classroom teaching." I have previously discussed this topic in general (Childs, 2007) and in relation to improving chemical education (Childs, 2009).

The gap between educational research and practice

Many people over the last 100 years or so have talked about the gap between educational research and practice. In 1996 Hargreaves complained that "teaching is not, at present, a research-based profession. I have no doubt that if it were, teaching would be more effective and more satisfying." (Hargeaves, 1996)

Greenwood and Abbot (2001) identified four factors for the gap between research and practice:

- the separateness of the research and practice communities;
- the limited relevance of educational research as perceived by practitioners;
- the failure of researchers to produce usable interventions; and
- the limited opportunities for meaningful professional development by practitioners.

McIntyre (2005) pointed out the contrast between the type of knowledge research provides and the type of knowledge teachers use: propositional (knowledge that) versus pedagogical knowledge (knowledge how); a focus on coherence and truth rather than practicality; a focus on the theoretical and general rather than the pragmatic and the local; and an impersonal versus a personal view of knowledge. To summarise, teachers and researchers are divided by the language they speak and the knowledge they value.

Broekkamp & van Hout-Wolters (2007) reviewed the literature on the gap between educational research and practice, and they identified four basic problems: that educational research

- yields only few conclusive results;
- yields only few practical results;
- practitioners believe that educational research is not conclusive or practical;
- practitioners make only little (appropriate) use of educational research.

The presence of the gap was also supported by a questionnaire given to 160 people in the Netherlands, including teachers, researchers, policy makers and teacher trainers, and the results "suggest that there is not only broad consensus about the existence of a gap, but also that the respondents – a diverse group of people involved in educational research and/or practice – agree on the particular problems and causes of the gap." (Broekkamp & van Hout-Wolters, 2007)

A survey of the research literature by Burkhardt & Schoenfeld (2003) suggested four models for overcoming or minimising this gap:

- The Research Development Diffusion Model (RDD model), where practice-oriented research expands on fundamental research,
- The Evidence-Based Practice model (EBP model), like the RDD model, describes the systematic application of research results in educational practice based on evidence for successful methods.
- The model of Boundary-Crossing Practices (BCP model) describes the value of combining tasks from different professional domains e.g. a teacher-researcher.
- The model of Knowledge Communities (KC model) assumes that links between research and practice are established in professional networks, involving teachers and researchers..

Broekkamp & van Hout-Wolters (2007) commented: "In the literature, the four solution models are often contrasted. The RDD model and the EBP model, which emphasize, respectively, the importance of "translation" of research results and the application of strong research evidence in practice, are considered to be based on a one-sided influence of research on practice. The BCP model and the KC model, which both emphasize the importance of collaboration between researchers and practitioners, are considered to be based on interactive influences of research and practice." One complaint about the application of research to teaching and learning by teachers is that it is too one-sided and unidirectional: the experts telling the teachers what to do. The collaborative or cooperative model, where teachers and researchers work together, is a healthier and more productive model.

In a recent commentary for teachers on 'Making use of evidence. Bridging the gap between research and practice', Andrew Morris (2011) summarises the problem: "Vital though this connection between research and practice may be, in the field of education it still remains relatively weak – a few references in initial training, occasional links in CPD, perhaps an isolated case of action research. Research may find its way into academic journals and government guidance but rarely into the hands of school and college practitioners."

More recently John Oversby has dealt with this topic in his RSC Science Education Award lecture, ‘Mind the gap’ (Oversby, 2012a) and in the ASE Guide to Research in Science Education (Oversby, 2012b). It is clearly still a live issue and the gap still remains to be bridged.

The dangers of fads and fashions in education research

The view that educational research is of no use to the teacher is a view with a long pedigree, going back to John Dewey and later authors. It has long been a complaint of education that it is driven by the latest fashion. In a recent article in Newsweek (Begley, 2010) entitled ‘Second Class Science: Education gets an F’, the author attacks the record of educational research in providing evidence of what initiatives, curricula or approaches actually work in the classroom. She quotes a researcher (Cobern et al, 2010), who recently compared direct instruction versus inquiry-based teaching in a controlled intervention and concluded: “Some claims for inquiry methods regarding understanding the nature of science are not sufficiently well supported by evidence.” Similar evaluations of the research evidence on other popular educational strategies, such as class size or educational expenditure (Barber and Nourshed, 2007) and learning styles (Coffield et al, 2004) have not provided strong evidence supporting the favoured strategy. These are salutary lessons that all some strategies that are enthusiastically adopted as the latest ‘silver bullet’ are neither correct nor useful and we should check out the evidence supporting some particular strategy before rushing to implement it. Otherwise education will driven here and there by the latest wind of educational fashion, as Chaddock nicely explains: “Teachers call it the “reform du jour,” and for many, it’s the biggest challenge at the start of any school year. That’s when the latest idea for how to improve student performance kicks in.” (G.R. Chaddock, 1998)

The individual teacher has no means of evaluating the effectiveness of a particular strategy. John Hattie (2008) has conducted an evaluation of 138 strategies in his book Visible Learning, based on over 50,000 individual studies and 800 meta-analyses measuring achievement. He uses the size effect value (SE) to compare studies and those with a value > 0.4 are inthe zone of desired effect. A value of +1.0 (or -1.0) corresponds to 1 SD gain (or loss). His top 20 strategies are given in Table 01. The interesting thing is what is missing from this list. Inquiry-based learning comes in with a SE of 0.31 and is 86/138. Top of the list is student self-report grades with a score of 1.44. Gender has a Size Effect of 0.12 i.e. it is negligible. The importance of this study is that it provides a measure of the effectiveness of various strategies, independent of their publicity or fan-base. These data should help us to choose which strategies to use and which to avoid, because they are unsupported by evidence of success. It should be noted that this evaluation was not subject-specific i.e. it is about the general use of the various strategies, not their use in science education.

There has been a great cry in recent years for evidence-based teaching and effective practice. The aim of the Institute for Effective Education based at the University of York, set up in 2008, is to ensure that education is not based on fads but rather evidence. “The Institute for Effective Education (IEE) will develop, test and evaluate ideas on how to improve education. They will find out what works in teaching and learning, and why. The Institute, which will be both international and independent, will create a hub of evidence for education innovation by using innovative approaches and scientific evaluations similar to those in medicine.” (Morris, 2007) The incoming Director of IEE Robert Slavin identified in an interview where he saw the problem lay in improving education in UK schools: “Our problem isn’t a lack of knowledge about how children learn, or what effective teaching methods are,” he says. “Our problem is a lack of knowledge about how to help teachers apply research-proven methods every day.” (Slavin, 2008)

The influential Teaching and Learning Research Project (TLRP) in the UK ran from 2000 to 2009 and under its auspices were four projects run by the Evidence-based Practice in Science Education (EPSE) Research Network (2000-2003) (see TLRP, 2009), which were:

Project 1: Exploring the impact on teachers’ practices, and student learning, of providing research-based diagnostic tools.

Project 2: Developing and evaluating short teaching sequences informed by research evidence.

Tab. 01: Top 20 meta-analyses on factors affecting achievement (Hattie, 2009)

Rank	Domain	Influence	SE
1	Student	Self-report grades	1.44
2	Student	Piagetian programs	1.28
3	Teaching	Providing formative evaluation	0.90
4	Teacher	Micro-teaching	0.88
5	School	Acceleration	0.88
6	School	Classroom behavioural	0.80
7	Teaching	Comprehensive interventions for disabled students	0.77
8	Teacher	Teacher clarity	0.75
9	Teaching	Reciprocal teaching	0.74
10	Teaching	Feedback	0.73
11	Teacher	Teacher-student relationships	0.72
12	Teaching	Spaced versus mass practice	0.71
13	Teaching	Meta-cognitive strategies	0.69
14	Student	Prior achievement	0.67
15	Curricula	Vocabulary programs	0.67
16	Curricula	Repeated reading programs	0.67
17	Curricula	Creativity programs	0.65
18	Teaching	Self-verbalisation/self-questioning	0.64
19	Teacher	Professional development	0.62
20	Teaching	Problem-solving teaching	0.61

Project 3: Establishing the extent of ‘expert’ agreement on what people should know about the nature of scientific knowledge and the procedures of scientific enquiry, and exploring how this agenda might be taught effectively.

Project 4: Documenting and analysing science education practitioners’ views on the influence of research on their everyday practices.

A number of useful publications came out of this project on how to transfer the evidence obtained from research into the science classroom and laboratory.

Why does so much SER fail to change STL?

What are the reasons why the findings of SER, whether pure or applied, often fail to make any impact in the classroom and lecture hall, the very places they are meant to illuminate, affect and change? There are many reasons for this and I would like to discuss some of them now.

a) The academic rat-race: Most research is done by third level academics whose careers and promotion are determined by the number and quality of the papers they produce, whether they teacher educators or specialist researchers. What matters most in academia are the Impact Factors of the journals papers are published in, rather than their impact in the classroom. Credit is given just as much for research with no possible application as for research which actually changes and improves teaching and learning. Also academics at third level may be far removed from the reality of teaching a subject, particularly if they are in an education department: they are thus doubly –distanced fom the reality of the situation they are researching. There is increasingly a culture of publish or perish in universities, driven by short-term targets, and more concerned with research income than scholarship. Even "Funded projects have been driven mainly by goals of contributing to the accumulation of scholarly knowledge; disseminating this knowledge to practitioners as materials, directives, or rules had been see as a secondary responsibility of the investigators." (Sabelli and Dede, 2001) The world can look different from the ivory tower of the university and the goals and pressures of academics are often very different from those of the harassed teacher in the classroom, where survival is the name of the game.

b). The shortness of initial teacher training (ITT): Whether ITT for science teachers is based on a concurrent model (teaching subjects, education, pedagogy and teaching practice combined in a 3-4 year bachelor degree) or a consecutive model (education, pedagogy and teaching practice covered in 1-2 years after completion of a subject-based bachelor degree), there is relatively little time for dealing with the results of SER and relating them to the classroom. In addition to courses in general education, such ITT courses have varying amounts of Pedagogical Content Knowledge (PCK), where SER interfaces with subject content knowledge (SMK) in relation to the pedagogical knowledge (PK) needed for specific teaching situations. Given that students have little exposure to SER before entering ITT, they are likely only to get a superficial and limited treatment during ITT. In the limited time available for PCK there is always more to be covered than time allows. In Ireland the one year Post Graduate Diploma in Education (PGDE) has just been increased to two years, but the length of the four year concurrent degrees for second level teachers has not been increased. In trying to fit in all that the trainee science teachers need to know in the time available: it is like trying to fit a litre of beer into a half-litre mug.

c). The communication gap with teachers: There are several aspects to the problem of communicating SER to teachers.

- The language used in academic papers is often riddled with jargon and statistics, and is impenetrable to non-specialists;
- Journals are expensive and often inaccessible to teachers unless they are open access internet journals like CERP;
- In academic research much of the communication and networking is done in conferences, and teachers do not often attend such conferences.
- Conferences for teachers on the other hand, often focus on more practical matters with less emphasis on SER.

d). The (ir)relevance of much SER: Academic articles are often unrelated to the situation and problems faced in the classroom and thus do not seem relevant to practising teachers. Teachers and lecturers are busy people and their main concern is with their students and what they have to teach. They look for information and materials that can easily be adapted to their own teaching situation. Much SER is not seen to be directly relevant to teaching or requires too much translation or adaptation before it can be used. As a result practitioners do not find it useful or worth the effort and time to see whether it is useful. The gap between much academic SER and its application in the classroom is too large for many practitioners to see its relevance. In fact, they may view much educational research as not worth reading as it is irrelevant to the real world they work in.

e). The lack of involvement in SER by teachers: Most research is done by university-based academics and their postgraduate students, or teacher educators, and only a small proportion of whom are practising teachers. Researchers and teacher educators are most commonly based in education departments, not science departments (although Germany is an exception) and this weakens both their connection with subject teachers and with science subjects. The lack of involvement by teachers in SER means that they do not have a stake in it and are detached from it. It is seen as something other people do to them rather than something they participate in themselves. Research (or scholarship) is seen as research on practice rather than research of (or with) practice. If teachers are the subjects of, rather than participants in, research, then they are less likely to be committed or consider themselves as stakeholders or partners.

f). The lack of time and expertise by teachers: Teachers are busy people with full timetables and do not have the energy, the time, the access or the expertise to make themselves familiar with what is happening in SER and to see what is relevant to the classroom. Their main concern is survival in the classroom and professional development comes second in the day-to-day pressures of the job. By comparison, academic life is less demanding and there is less understanding of the pressures teachers are under. Teachers do not have funds to attend science education conferences, often held at times to suit third level academics not school teachers.

f). The failure to influence policy makers: The education system in most countries is centrally controlled by the Ministry of Education. Government policy thus determines the curriculum and assessment, as well as monitoring teaching quality by inspection. Teachers are required to teach the prescribed curriculum and prepare students for external assessment, and these determine to a large extent the pedagogy adopted by teachers. If the curriculum and the assessment are not informed by research but by other influences e.g. political pressure, influence of higher education, then the education system will be deficient. In addition teaching materials, such as textbooks, are prepared to suit the curriculum and the assessment and may not reflect the findings of SER in the way the content is presented. If the science curriculum and assessment are not research-informed then SER will have no practical influence on teaching and learning, as teachers will teach to the curriculum as interpreted by textbooks and dictated by the external assessment. Teaching to the test in the race for better grades and higher ranking in school league tables will result in an impoverished education, a dumbing down of examinations and a failure to prepare students for higher education.

g). Lack of subject-teaching experiences by researchers: Sometimes researchers may not have had experience actually teaching a science subject, either currently or in the past, in the classroom or lecture room, and may be coming from a general educational background. This lack of first-hand experience of teaching science, necessarily means a lack of understanding of the problems in teaching a particular subject, whether at second or third-level. PCK, where pedagogy meets the subject, requires some knowledge of the subject to be effective. Science Education researchers who lack personal experience of teaching a subject will be less well equipped to communicate with practising teachers and will lack credibility and that first-hand knowledge necessary to understand the problems of teaching a subject.

Dealing with these issues

In this section I will consider each of the issues raised above and suggest ways they can be dealt with or alleviated.

a). The academic rat-race: publish or perish

Much academic research is done to fulfil research quotas and meet the demands of a 'publish or perish' culture in universities. The research may be irrelevant to the classroom and to the needs of teachers, and most of it will never be read, but it is essential for one's CV and for promotion in an academic environment. Writing general articles or even books for teachers is not as valued as research papers in high impact journals. The needs of the teaching profession are prostituted on the altar of academic respectability. It is as if the value of a GP were measured by his research output rather the number of patients successfully treated. The balance must be redressed so that science education researchers are encouraged and rewarded for working with and communicating with teachers on a variety of levels, rather than just with their peers in academic journals. Academics should be encouraged to write for and speak to teachers directly.

b). The shortness of initial teacher training (ITT)

'No time, no time' might be the slogan that describes most initial teacher training courses, whether they be 1 year postgraduate courses (consecutive model) or 3-4 years bachelor degrees (concurrent model). The time available in either the consecutive model or the concurrent model for PCK is usually limited, as it is squeezed out by the time devoted to education (general pedagogy) and teaching practice, and in concurrent degrees also by science courses. Learning how to teach science often takes up very little time in ITT courses, so that students have little time to be exposed to and to read the wealth of SER that is available and investigate its relevance to the teaching of science. Even if they have heard of a topic, there is usually inadequate time to explore its application to science teaching. Consequently new teachers go back into the school system with an inadequate knowledge of PCK and consequently tend to revert to what they themselves experienced: as in the old maxim – 'teachers teach not how they were taught to teach but how they were taught'. Given the time constraints, the aim of ITT should be to help new teachers be flexible and adaptable and to help them think and improvise, rather than giving them all the answers. (Childs and Hayes, 2012) Rather than giving them solutions to today's problems, we should be giving them the tools to solve both today's and tomorrow's problems. If student teachers can see something of the value of SER, if they can find their way around the literature and see a few examples of how SER can be applied in the classroom, then they will be more likely to use it themselves in the future to inform their own teaching.

A better strategy would be to increase the length of teacher training courses by one year (as the Irish government has just decided to do for the consecutive courses). However, length is in itself not a solution and a Master's level programme, including a research element, would provide both the necessary length and depth. The McKinsey Report on successful school systems (Barber and Nourshed, 2007) identified the quality of teachers as one of the most important factors in the quality of school systems. The top performing systems were very selective in choosing the best trainee teachers, and often educated the teachers to Master's level. Making teaching an all Master's level profession would raise the quality, improve the pre-service training, and also help to introduce them to the use of SER in STL. "While initial teacher training provides teachers with the critical skills to succeed in the classroom, a master's degree builds on those by encouraging teachers to follow critical, reflective, inspirational and innovative approaches to education and to take risks." (Noble-Rogers, J., 2011)

The main recommendation of the ETUCE report on Teacher Education in Europe (ETUCE, 2008) was that, to meet the challenges of the 21st Century, teaching in Europe should be an all Master's level profession.

ETUCE advocates an initial teacher education at Master's level that:
Provides in-depth qualifications in all relevant subjects, including in pedagogical practice and in teaching transversal competences

• Is research-based, has high academic standards and at the same time is rooted in the everyday reality of schools
• Includes a significant research component and produces reflective practitioners
• Gives teachers the skills needed to exert a high degree of professional autonomy and judgment in order to enable them to adapt their teaching to the needs of the individual group of learners and the individual child or young person
• Offers the right combination between theory and pedagogical practice and benefits from partnerships between teacher education institutes and schools
• Encourages mobility of teachers within the different levels and sectors of the education system, provided that adequate re-qualification is acquired. (ETUCE, 2008)

c). The communication gap with teachers

A major problem is the communication of SER to teachers. Teachers often do not have the language and skills to decipher the academic jargon in inaccessible and expensive journals, describing work which is not directly applicable to their own situation. An effort needs to be made to digest and translate appropriate SER into a language teachers can easily understand, in journals or websites they have easy access to, and to choose and relate the findings of SER to classroom practice. The National Centre for Excellence in Mathematics and Science Teaching and Learning at the University of Limerick (www.nce-mstl.ie) is trying to do this by publishing 4-page Resource and Research Guides in science and mathematics, which aim to convey and summarise information for teachers on specific topics. The Association for Science Education in the UK has a regular Research Focus feature in its magazine, Education in Science, dealing with Science Education Research, which reviews specific areas of interest to teachers. (http://www.ase.org.uk/journals/education-in-science/) The accessibility of research is also being addressed by online journals with free access, such as Chemistry Education Research and Practice, published by the RSC (http://pubs.rsc.org/en/journals/journalissues/rp). John Oversby has developed an effective teacher's focus group PALAVA in Reading in the UK, which meets regularly to discuss research and to encourage teachers to apply research and conduct research in their classrooms. (Oversby, 2012a) Similar groups involving local chemistry teachers and university academics working in chemistry didactics have been run for several years from the universities of Dortmund and Bremen in Germany (Eilks & Ralle, 2002). These are good examples of involving science teachers as partners with SER researchers.

d). The (ir)relevance of much SER

Teachers don't want to read about research which is not relevant to them and their immediate needs. The teacher often has a very narrow focus: does the article relate to my subject, is it relevant to the students I am teaching (age, level, curriculum) and is it likely to be useful? If not, then the teacher is likely to ignore the work as not being relevant. It is thus important for researchers to liaise with teachers and to identify problems and issues of relevance to teaching. Often teachers would like a specific solution to a particular problem e.g. how to teach X better, or how to deal with a particular problem in the classroom i.e. they have a very applied, local and pragmatic view of what is relevant. It is important that researchers seek to show the relevance of what they do to actual practice, even if the research is theoretical and non-specific. Teachers are too busy to waste time reading and trying to understand research which is not relevant to them and their students.

e). The lack of involvement in SER by teachers

Linked to the point above, teachers do not feel that they have any ownership of much SER. It is seen as something done to them rather than for them. They may be bombarded by questionnaires or requests for information from outside, without any personal involvement in the aims, design or implementation of the research. No-one likes to be a guinea pig, even with informed consent, and there is a need to change the model so that teachers are involved at all stages of the research. If teachers have a say in what problems are worth studying and how to go about the investigation, then they will be more committed and more involved in both the conduct of the research and in the use of the findings. The welcome shift towards classroom-based Action Research is an example of this approach. This can be started during ITT by having student teachers involved in action research e.g. in the University of Limerick as part of a final year project many trainee science teachers do school-based, action research as part of their undergraduate degree.

SER needs to be seen as a partnership between researchers and practitioners, what Sabelli and Dede (2001) have termed 'integrated co-development'. They make the valuable point that the reflective interplay between research and practice must be bi-directional, not uni-directional (from researcher to teacher) as it often is at present. In chemical terms, we are looking for something more like dynamic equilibrium between teachers and researchers, with teachers involved as equal partners in the enterprise.

A co-development approach requires cooperation and collaboration between researchers and teachers to identify problems and research strategies, so practitioners have a real stake in the conduct and outcomes of research. Sabelli and Dede (2001) give an example of a five year SER project in the USA on the systematic usage of scientific models in high school, and they have this to say: "The co-design and co-analysis by the participating practitioners of our educational interventions is essential for enabling the large-scale integration of alternative curriculum. The involvement can lead to a sustained process of innovation in science education that persists after our specific curricular studies have finished.”

f). The lack of time and expertise by teachers: Unless teachers are given the time for professional development during their career, or even during the working week, they will be able or encouraged to keep up with the latest SER. There should be an obligation for time to be allocated for this in the teaching week as well as in a structured CPD programme. Teachers need to be equipped with the tools and expertise to use and become involved in SER and this must be done after initial qualification. Resources and time need to be allocated to this aspect of the teacher’s professional development, and they should be encouraged to become involved in SER themselves.

g). The failure to influence policy makers: Too often the voice and expertise of the SER community has not been heard or utilised by policy makers. For example, an Irish government Task Force was set up in 200 to look into the problem of low enrolment in the physical sciences. The membership of the Task Force represented various political and academic groups, but no-one involved in science teacher education or science education research was included, until representations were made. In the same way until recently, the membership of syllabus committees reflected traditional constituencies and lacked expertise in SER. The science teacher training and the science education research communities, which are not always identical, should be represented on policy committees, task forces and syllabus committees dealing with issues of science education.

h). Lack of subject-teaching experiences by researchers: It should by a sine qua non that science education researchers have themselves had experience of teaching science, whether at second or third-level, either currently or in the recent past. Ideally they should have a stake in teaching science as well as researching the teaching and learning of science. There is a lot to be said for the science didactics (or pedagogy) groups to be located in science departments as in many German universities, rather than in education departments, as is the case in the U.K., or at least for the relvant academics to have a foot in both departments. There can often be a lack of sympathy for the particular problems of teaching a specific subject within an education department, just as there can be a lack of understanding of education in a science department.

Some Irish examples

As part of a sustained programme of Action Research involving undergraduates, postgraduates and practising teachers, the Chemistry Education Research Group at the University of Limerick has being trying various models of incorporating the findings of SER into the improvement of the teaching and learning of Chemistry in Irish schools over the last ten years. Three examples of this work are described: TY Science; ITS Chemistry -Introducing Thinking Skills into Chemistry; and Organic Chemistry in Action!

a). TY Science

Transition year is a year in the Irish school system between the junior and senior cycles. It is an optional year and is offered by ~75% of schools and taken by just over 50% of the age cohort. The year has no set curriculum and no examinations and only broad guidelines. This allows schools and teachers great freedom to design their own curricula and to teach science in a different way. However, teachers are hard-pressed and most find it difficult to design their own materials or to adopt a new approach. Recent research by Hayes (2011) has shown that 67% of science teachers actually teach material from the senior cycle science curricula, contrary to the guidelines. The TY Science project was started in 2003 with the aim of developing science materials for the Transition Year, and was based on a view of science teaching supported by SER findings. The teaching materials have an STS-focus and are context-based; they focus on student activity and inquiry; and they aim to develop a range of skills –in ICT, communication and the laboratory. The design criteria used are given in Table 02.

Tab. 02: Design criteria used in producing TY Science modules

1. Build on the previous Junior Science course.
2. Develop practical and laboratory skills.
3. Develop the scientific method and related skills.
4. Develop IT and communication skills.
5. Involve hands-on activities and active learning.
6. Be related to everyday contexts with an STS focus.
7. Develop scientific literacy.
8. Be interdisciplinary involving aspects of Biology, Chemistry and Physics.

The TY Sciences modules were developed in conjunction with final year science education students and evaluated in Irish schools by teachers and trainee teachers, and to date has involved 14 trainee teachers (Table 03). The materials were revised in the light of the feedback and made available at low cost to teachers. To date 14 modules have been developed (Table 3) and have been very well received by teachers. However, a formal evaluation of their long-term use and impact has yet to be done. This project is also a good example of how trainee teachers can be involved in small-scale curriculum development (Childs et al., 2010).

Tab. 03: TY Science modules (with date and author)

- Forensic Science (2004) Sindy Meleady
- Cosmetic Science (2004) Audrey O'Grady
- The Science of Sport (2004) Maria Sheehan
- Science of Survival (2007) Rebecca Moran
- Environmental Science (2007) Sarah Hayes
- Issues in Science (2009) Ciara Hayes
- Science and Medicine (2009) Karen Murphy
- Space Science & Technology (2009) Walter Mahony
- Food Science (2009) Anne O'Dwyer
- Waste not, want not! (2011) Hannah McDonnell
- Power to the people (2011) Nicholas Ryan
- Smart Materials (2012) Martin Sheehan
- The science of toys (2012) Joannah Kennedy

b). ITS Chemistry -Introducing Thinking Skills into Chemistry

ITS Chemistry was developed as part of a PhD project by a practising teacher (Maria Sheehan), in order to evaluate whether including ideas from SER in the teaching of the particulate nature of matter and the mole, could improve students' thinking skills, remove misconceptions in this area and improve understanding. A teaching package was developed, comprising Student Workbooks, a Teacher's Guide and resource materials (Sheehan and Childs, 2011). Figure 01 shows the design of a typical lesson.

The materials were tried out in the author's school and in 5 other schools. After completion of the material the student's understanding was assessed using a diagnostic instrument, and a test of cognitive level, and compared with five control groups who had been taught the same material in the traditional way. The students in the experimental schools showed significant cognitive gains and a better understanding of the material.

Figure 02 shows the significant difference in grades after the intervention of the experimental group compared to the control group. This intervention project showed the value of using SER to inform and change classroom practice.

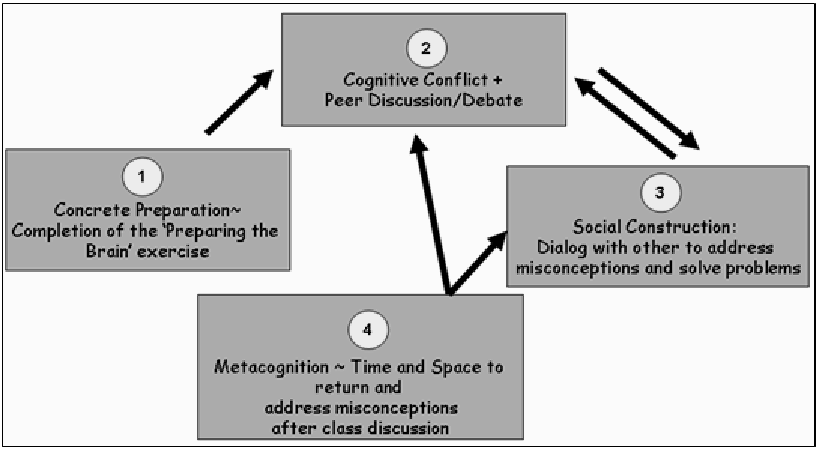

Fig. 01: The structure and key design features of a typical 'ITS Chemistry' lesson showing the incorporation of ideas from SER (Sheehan and Childs, 2011)

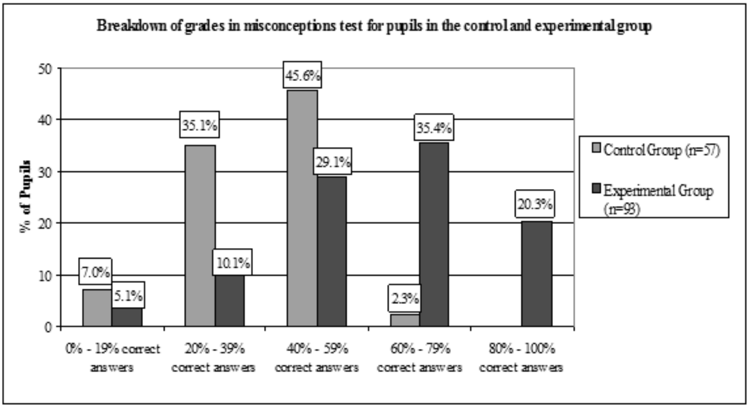

Fig. 02: The comparison of the experimental and control group on the diagnostic test (Sheehan and Childs, 2011)

c). Organic Chemistry in Action!

Organic chemistry has been identified as a major area of difficulty in Irish schools and universities, as well as in other countries. An intervention project, Organic Chemistry in Action!, was developed by a newly-qualified teacher (Anne O'Dwyer) as part of a PhD project, based on the CER literature on the difficulties and misconceptions in introductory organic chemistry. The materials used a number of design criteria (Figure 03) based on SER and aimed to improve the understanding of organic chemistry by a carefully designed set of teaching materials. (O'Dwyer and Childs, 2011a and 2011b).

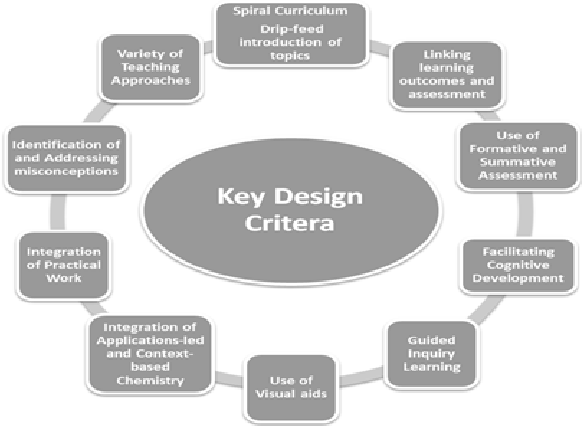

Fig. 03: Key design criteria based on SER in Organic Chemistry in Action! (O'Dwyer and Childs, 2011)

The materials were tested in 9 schools, with the cooperation of the teachers, and at the end of teaching the materials the views of the teachers and students were obtained, and the performance of the students was assessed on a diagnostic test. Students in a control group of 10 schools, who had covered the same curriculum content, were also tested using the same diagnostic instrument. The aim was to find out if the teaching informed by CER produced students who understood the material better and had fewer misconceptions than the control group. The results of this intervention project were positive and showed the value of this approach. (This work is discussed in more detail in another paper in this conference.)

Conclusion: teaching must be research-informed

Teaching involves a dynamic interplay between the curriculum (often defined externally by governments), the pedagogy (how teachers teach and the resources they use) and assessment (how the curriculum objectives are assessed). Although this should represent an integrated system, this is not always the case and often assessment is the tail that wags the dog and determines how the curriculum is interpreted and taught. There should be coherence between the learning outcomes defined by the curriculum, the teaching and learning strategies employed to deliver these outcomes, and the design of the assessment instruments. This paper seeks to make the case that each of these dimensions of teaching and learning should be research-informed (Figure 04).

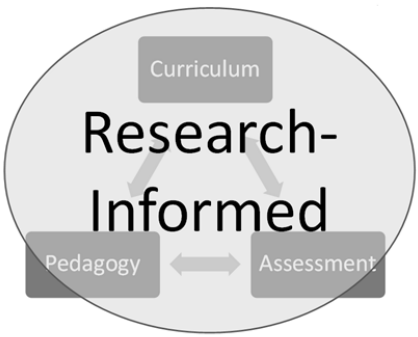

Fig. 04: Research informed teaching and learning

There is strong pressure from the EU following the influential Rocard Report of 2007, A Renewed Pedagogy for the Future of Europe (Rocard, 2007) through its FP-7 Science and Society projects, and by the International Association of Science Academies (IAP, 2010) and by the ALLEA, All European Academies (ALLEA, 2012) that IBSE is the way to go and the panacea for all science teaching ills. A plethora of IBSE projects has been launched in Europe, often with several similar projects running in the same countries, and there seems to be no attempt to assess how these projects relate to each other and how the findings can be disseminated more widely outside the projects. There is surely a need for a research project to do a meta-analysis of all these projects and come to some assessment of their value. The ALLEA Report (ALLEA, 2012), although promoting IBSE, recognises that it "..seems appropriate to devote some research time on developing methodologies that are better suited to measure and compare the success, or otherwise, of IBSE approaches." Where this has been done (Coburn, 2010) there is no clear superiority of inquiry-based teaching over direct instruction. It would seem unwise to put all our pedagogical eggs in one IBSE basket, when experience has shown that no single approach works for all pupils in all situations and a variety of pedagogical strategies should be employed.

The TLRP EBSE Research Network project in the UK identified that the "Widespread use of research evidence in the classroom seems to depend on at least two factors:

- tangible and useful outcomes, such as curriculum materials and teaching approaches, resulting from transformation of research findings into practical strategies;
- the presence of a professional culture which encourages both exploration of research and changes to practice." (Bartholomew et al, 2003)

In other words, SER must be clearly seen by teachers to be of practical use in the classroom, and it must be supported by a professional culture which favours the transfer of SER into STL: this must start in the teacher's initial training and continue throughout a teacher's career.

The National Science Teachers' Association in the USA (NSTA, 2010) has produced a position statement on The Role of Research on Science Teaching and Learning (see Appendix 1). The following declaration is made about the use of research on science teaching and learning and the role of researchers:

- researchers communicate about research in ways that can be understood and embraced by science educators, administrators, policy makers, and others in the science education community;
- researchers make research readily accessible by disseminating it to teachers and other decision makers using many forms of communication, including practitioner journals, professional conferences, and websites;
- researchers recognize and state the limitations of their research;
- researchers and consumers of research discuss, critique, and apply findings;
- school researchers have ample administrative support, time, and resources to conduct research in the classroom, share their findings with colleagues, and implement results to improve student learning; and
- science educators embrace a culture of inquiry grounded in research that focuses on examining practice and improving student outcomes.

If we are to allow SER to inform STL there must be good communication between teachers and researchers, and the formation of a collaborative partnership. There must be an integration of ideas and approaches supported by SER into teacher training and CPD; into curriculum design; into teaching materials and textbooks; in pedagogy and especially in assessment. All these aspects of teacher preparation and practice should be research-informed in order to bring about systemic change in the way science is taught. In almost every country, science teaching is driven by assessment, particularly if this is a high-stakes, terminal state assessment. Unless the final assessment is aligned with learning outcomes, which in turn are informed by SER, then the new insights obtained from SER will never be fully implemented in the classroom. The onus is on science education researchers to communicate their findings to teachers, to work closely with teachers and involve teachers in their research. Systemic change takes place from the roots upwards and not by tinkering with the branches. Too much SER to date has been small-scale, short-term and limited in scope and one has doubts that this approach is able to bring about the necessary systemic change in STL. It is also not enough to convince science teachers of the value of SER – in the real world, we also have to convince politicians and educational administrators.

The principal goal of education is to create [people] who are capable of doing new things, not simply of repeating what other generations have done—[people] who are creative, inventive, and discovers. The second goal of education is to form minds which can be critical, can verify, and not accept everything they are offered. Jean Piaget (1964)

Some recommendations:

1. Every aspect of science teaching and learning (STL) needs to be informed by science education research (SER) – curriculum, pedagogy and assessment.
2. We need to evaluate the effectiveness of new teaching and learning strategies by reviewing available research – and not just jump on the latest bandwagon.
3. Science teaching and learning is complex and multidimensional and there is no 'silver bullet' to solve our problems – we need a mix of strategies, tailored by the teacher to suit his/her specific situation.
4. We need to develop partnerships between researchers and teachers in order to transfer SER into STL effectively and bridge the gap.
5. Teaching should become a Master's level profession across Europe.
Trainee teachers should be exposed more to SER and be involved in research themselves.
CPD should be life-long and introduce and involve teachers in SER.
6. Science education researchers should have current or past experience in teaching science at either 2nd or 3rd level, in order to understand first-hand the problems of teaching science.

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Appendix 1

The Role of Research on Science teaching and learning (NSTA, 2010)

Declarations

Regarding the focus of research on science teaching and learning, NSTA recommends those conducting research
• examine questions that are relevant to enhancing science teaching and learning for all learners;
• address areas that have not have been investigated, or investigated insufficiently, and have the potential to improve what is known about science teaching and learning; and
• extend theories of science teaching and learning in order to contribute to a coherent body of knowledge.

Regarding the practice of research on science teaching and learning, NSTA recommends those conducting research
• draw and build upon previous research that may exist in the area of study;
• focus on longitudinal studies that build on promising areas of research and link to a larger body of work;
• form collaborations and partnerships among those involved in science education (e.g., teachers, administrators, college faculty, informal science educators) as they examine science teaching and learning;
• demonstrate, when possible, the degree to which student learning is affected;
• engage in rigorous peer review that challenges the status quo and values varying perspectives on research pertaining to science teaching and learning;
• view everyday experiences as opportunities to conduct research that yields findings to improve teaching practices and student learning;

• support the participants in research with ample professional development to enhance their ability to design, conduct, interpret, and apply science education research; and
• share research results with the wider science education community inside and outside the classroom.

Regarding the use of research on science teaching and learning, NSTA recommends
• researchers communicate about research in ways that can be understood and embraced by science educators, administrators, policy makers, and others in the science education community;
• researchers make research readily accessible by disseminating it to teachers and other decision makers using many forms of communication, including practitioner journals, professional conferences, and websites;
• researchers recognize and state the limitations of their research;
• researchers and consumers of research discuss, critique, and apply findings;
• school researchers have ample administrative support, time, and resources to conduct research in the classroom, share their findings with colleagues, and implement results to improve student learning; and
• science educators embrace a culture of inquiry grounded in research that focuses on examining practice and improving student outcomes.

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CHEMISTRY EDUCATION AT PRIMARY AND SECONDARY GRAMMAR SCHOOLS IN THE CZECH REPUBLIC: TARGET SKILLS FROM THE POINT OF VIEW OF PUPILS AND GRADUATES

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Introduction

The question, what the pupils should be taught, is one of the key problems of subject didactics. Our aim was to find out the opinion of elementary and grammar school pupils and that of the graduates. The problems of target skills were analyzed more in detail by a questionnaire investigation realized between elementary and grammar schools teachers.

Methods

A questionnaire survey No. 1 was performed among elementary and grammar school pupils and among graduates from chemistry training (university study was not included). For respondents see tab. 01. Another questionnaire (No. 2) was answered by teachers working on different levels of education (tab. 02).

Tab. 01: Numbers of respondents in various groups. The average age in the graduates` group was 41 years (from 19 to 83 years). It contained all levels of finished education (elementary, grammar, tertiary - e.g. university).

	elementary school / four-years grammar school		eight-years grammar school	
	grade	number of respondents	grade	number of respondents
before the beginning of chemistry study	7th	169	1st	159
1 year after the beginning of chemistry study	8th	223	2nd	127
the end of elementary school	9th	180	4th	126
the beginning of four-years grammar school	1st	61	5th	75
the end of chemistry study at grammar school	3rd	78	7th	56
finished school education in chemistry	graduates	122		

Tab. 02: Numbers of respondents - teachers.

		The level of education commented on		
		the end of lower elementary school	the end of upper elementary school	the end of chemistry training at grammar school
Workplace of the teacher	lower elementary school	12	–	–
	upper elementary school	16	47	38
	four-years grammar school	–	43	43
	six-years grammar school	–	4	4
	eight-years grammar school	–	28	28
	university	3	3	3

Results and discussion

The answers to the first questionnaire research carried out between pupils and graduates are summarized in tab. 03. This text deals only with one question taken from each of the questionnaires: Pupils: *Concerning chemistry, what would you like to learn?* Graduates: *Concerning chemistry, what are you interested in nowadays?* The questions were open, without any proposals. The respondents could give none, one, two or more answers.

As we expected, the answers of graduates were focused on practice much more than those

Tab. 03: Pupils` responses to the question *Concerning chemistry, what would you like to learn?* Graduates` answers to the question *Concerning chemistry, what are you interested in nowadays?* "G" stands for graduates.

Suggestion of a chemical skill	Percentage of the answers (100 % is the number of the pupils)					
	grade of elementary school			grade of 4-years grammar school		G
	/ or grade of eight-years grammar school					
	7th/1st	8th/2nd	9th/4th	1st/5th	3rd/7th	
to perform chemical experiments	39,0	43,4	11,4	15,8	20,2	0,8
to know symbols of the elements, to know their position in periodic table of elements	16,4	7,1	1,6	2,9	0,7	0
to build chemical equations	5,5	15,4	2,6	5,1	0,7	0
to be able to prepare explosives	7,3	8,6	4,3	19,9	18,7	0
to be able to use the chemical curriculum in practice	9,5	5,4	4,9	5,2	3,6	3,3
chemical nomenclature	0,6	11,4	0	2,2	2,8	0
to be able to prepare drugs	0,0	6,3	5,9	1,5	0,7	0
environmental protection	2,8	3,4	3,6	2,9	0,7	13,9
chemistry as a means of entertainment	3,0	3,1	0	0	0	0,8
safe work with chemical substances	0,6	4,6	0,3	4,4	6,4	0
preparation of solutions, calculation of their composition	0,3	3,7	0	0	0	0
to be able to prepare pharmaceuticals	2,7	0,8	2,3	6,6	4,3	0
explanation of chemical phenomena and processes	1,2	2,3	0,3	2,2	0	0
to be able to do everything what is possible to learn in chemistry	3,1	3,1	0,3	3,6	2,9	0
calculations based on chemical equations	0,9	1,7	0	0	0	0
everything that is important	0	0	0	2,9	2,9	2,5
various chemical disciplines	0	0	0	0	2,8	0
to know what is produced from which raw materials	0	0	0	0,7	1,5	2,5
to know more about nutrition	0	0	0	0	0	13,9
to know more about cleaning and washing	0	0	0	0	0	7,4
prevention and First Aid	0	0	0	0	0	7,4
to know more about beauty salon, drugstore and hairdressing products	0	0	0	0	0	3,3
production of alcohol	0	0	0	0	0	1,6
to know more about toxic substances (artificial, natural)	0	0	0	0	0	1,6
to be able to help their own children in chemistry study	0	0	0	0	0	0,8
water resources, water types and their use	0	0	0	0	0	3,3
problems of fuel	0	0	0	0	0	3,3
properties and use of chosen inorganic substances	0	0	0	0	0	1,6
chemistry of plant growing	0	0	0	0	0	1,6

of pupils. But, on the other hand, graduates gave smaller number of answers per respondent than pupils and their answers were not so much diverse as those of pupils were.

It is obvious from tab. 03 that for ***elementary school pupils*** the interest in chemical experiments strongly dominates. ***Grammar school (four-year) pupils*** in addition to it want to be able to prepare explosives. Moreover, they mentioned professional interests. Their desire to be able to work safely with chemical substances is slightly stronger than that of primary school pupils. However, older pupils gave much more negative unconstructive responses (not shown) than the younger ones. The ***graduates*** nearly do not mention experiments. The majority of them proposed specific requirements of certain practical issues (environmental protection, food chemistry, detergents, cosmetics, ...).

Tab. 04: Groups of skills from questionnaire for teachers. Italics indicates problems of chemical experiments (in detail described in tab. 05). Bold font means refusal or nearly neutral rating. Top row: average. Lower row in parentheses: interval of 95 % confidence. Statistical methods were used according to Meloun and Militký (2002).

	Pupils should	**the end of**		
		lower elementary school	lower elementary school	grammar school
1.1	identify scientific topics (problems) and to determine their relationship to other natural sciences	2,52 (2,38;2,66)	2,13 (2,04;2,22)	2,79 (2,73;2,85)
1.2	link a chemical problem identified with previous knowledge	2,36 (2,13;2,59)	2,22 (2,10;2,34)	2,83 (2,75;2,92)
1.3	formulate and ask questions	2,07 (1,87;2,28)	1,78 (1,67;1,90)	2,54 (2,44;2,64)
1.4	establish a plan (a process) of work individually / in groups	2,31 (2,29;2,53)	**1,59 (1,50;1,68)**	2,25 (2,16;2,33)
2.1	collect information from text and graphic material	2,11 (1,98;2,23)	2,34 (2,27;2,41)	2,82 (2,78;2,87)
2.2	*collect information by observation and experimentation*	*2,03 (1,92;2,14)*	*2,15 (2,09;2,20)*	*2,71 (2,68;2,75)*
3.1	sort information according to established criteria	2,03 (1,89;2,17)	1,96 (1,89;2,03)	2,64 (2,58;2,70)
3.2	process information according to established criteria (in writing and graphically)	1,90 (1,79;2,00)	2,25 (2,19;2,30)	2,77 (2,74;2,81)
4.1	evaluate work / experiment	2,02 (1,87;2,17)	1,97 (1,90;2,05)	2,59 (2,53;2,65)
4.2	formulate responses and conclusions	1,81 (1,68;1,94)	1,91 (1,83;1,98)	2,61 (2,55;2,67)
4.3	present results	2,35 (2,24;2,46)	2,29 (2,23;2,36)	2,77 2,72;2,81)
Outliers between average values (method of internal walls)		0	0	0
Normal statistical distribution of average values (Jarque-Bera test)		yes	no	no

Chemistry teachers at different kinds of schools (tab. 02) answered another questionnaire that investigated their opinion about target *heuristic* skills of pupils in chemistry or similar target skills in the subject Science in the end of lower elementary school.

They were asked to chose to which extent (definitely disagree = 0, disagree = 1, rather agree = 2, definitely agree = 3) they consider skills from a list to be necessary for the completion of lower level of elementary school, upper level of elementary school and grammar school. For questions and average answers (calculated from numbers mentioned above) see tab. 04. The average of rating scale was 1,5. Larger values implied agreement with the suggestion, lower values meant opposition to the suggestion. The results follow from tab. 04. The main interest of authors of this text was focused on skills related to performing of chemical experiments - paragraph 2.2 in tab. 04 (for questions and answers see tab. 05). Observation and experimentation are not considered by teachers to be more or less useful than other skills proposed the list in the questionnaire.

Teachers agreed nearly with all the suggestions for all three key points of education (the end of lower elementary school, the end of upper elementary school, the end of grammar school). The only exceptions were "Pupils should design an experiment independently" (refusal for elementary school) and "Pupils should suggest appropriate methods and tools for realization of the experiment" (nearly neutral rating for elementary school). The same suggestions are outliers in the results for grammar school (exceptionally low rating, too).

Tab. 05: Questions from the questionnaire for teachers and their average answers. Empty field means that this question was not included. Gray colour indicates outliers. Bold font means refusal or nearly neutral rating. Top row: average. Lower row in parentheses: interval of 95 % confidence. Statistical methods were used according to Meloun, et al. (2002).

		the end of		
	Pupils should	lower elementary school	upper elementary school	grammar school
2.2.1	observe objects and phenomena intentionally	2,32 (2,10;2,55)	2,31 (2,18;2,45)	2,75 (2,64;2,87)
2.2.2	describe the objects and phenomena observed	2,43 (2,20;2,66)	2,35 (2,21;2,49)	2,79 (2,69;2,89)
2.2.3a	work with basic chemical devices (scales, measuring cylinders, pipettes, beakers, storage tanks, ...)		2,42 (2,27;2,57)	2,87 (2,79;2,95)
2.2.3b	work with basic protective equipment (lab coat, gloves, goggles etc.)		2,62 (2,48;2,76)	2,87 (2,77;2,97)
2.2.4	prepare chemical substances for experiments (to measure weight and volume of liquid and solids), ...		2,22 (2,06;2,39)	2,73 (2,60;2,85)
2.2.5	prepare solutions (to measure and mix required quantities of substances ...)		2,00 (1,84;2,16)	2,75 (2,65;2,86)
2.2.6	perform basic stoichiometric calculations (quantities of materials needed for the preparation of a solution, the amount of reactants or products according to the chemical equation, ...)		1,91 (1,75;2,07)	2,83 (2,75;2,92)
2.2.7	perform experiments according to instructions	2,32 (2,12;2,52)	2,45 (2,30;2,61)	2,83 (2,74;2,92)
2.2.8	design an experiment independently	**1,36 (1,09;1,63)**	**1,36 (1,21;1,51)**	2,22 (2,08;2,36)
2.2.9	suggest appropriate methods and tools for realization of the experiment	**1,68 (1,42;1,94)**	**1,52 (1,37;1,68)**	2,31 (2,18;2,45)
2.2.10	record the results of observation and experiment	2,07 (1,85;2,29)	2,44 (2,30;2,58)	2,88 (2,81;2,96)
Outliers between average values (method of internal walls)		0	0	2
Normal statistical distribution of average values (Jarque-Bera test)		no	no	no
Normal statistical distribution of average values after exclusion of outliers		–	–	yes

Conclusions

For ***elementary school pupils*** the interest in chemical experiments strongly dominates. ***Grammar school pupils*** in addition to it want to be able to prepare explosives. Moreover, they mentioned some professional interests. Their wish to be able to work safely with chemical substances is slightly stronger than that of primary school pupils. The majority of ***graduates*** proposed specific practical issues (environmental protection, food chemistry, detergents, cosmetics, ...) and nearly no "chemistry for fun". There are no outliers between ratings (given by teachers) of *general* heuristic chemical skills at any of all the key points of education and teachers agreed with all of the suggestions. The only exceptions (refusal or neutral rating) are in the group of experimental skills (2.2): "to design an experiment independently" and "to suggest appropriate methods and tools for realization of the experiment". The same suggestions are outliers in the results for grammar school (extremely low rating). Observation and experimentation are approximately in the middle of rating.

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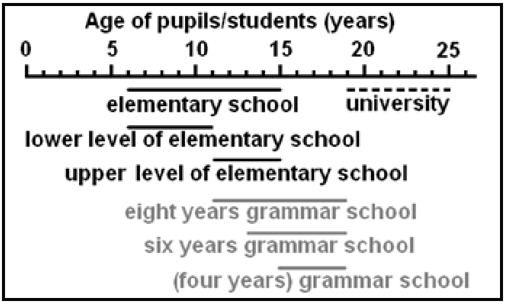
Appendix

A simplified explanation of terms related to the Czech educational system (used in this article):



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INQUIRY-BASED ACTIVITIES IN THE TOPIC OF POLYMERS

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Introduction

The European Union is currently financing, via the 7th frame research programme, international projects which concern themselves with the problematics of education and teaching of mathematics and science. One of them is the project ESTABLISH (European Science and Technology in Action Building Links with Industry, Schools and Home) (Finlayson et al., 2011). As a part of this project, we are preparing inquiry-based activities for the given themes: Polymers around us, which is being prepared by Charles University in Prague and UPJŠ in Košice.

Our contribution aims to introduce the inquiry-based activities we created and to show how they improve the teaching of chemistry with the pilot sample of students. These activities are suggested in concord with the principles of inquiry-based education (Abd-El-Khalick, 2005; Franklin, 2000) in such way to lead the students through the educational cycle from stating the problem and expressing the hypothesis to the experimental verification and its theoretical explanation. This means we focus on the purposeful processes of forming the questions, critical experimentation, judging the alternatives, examining and verifying, reaching conclusions and forming coherent arguments. To interpret the educational activities, we have used various methods, for example the discussion methods, problem education, group and cooperative education or project education.

Methods of research

The theme was processed in the form of three subunits, consisting of 28 inquiry-based activities in total (Ganajová, Šmejkal, Čtrnáctová, 2012).

Subunit 1: Plastic contains the activities Kinds of packaging plastic materials and their labelling and Properties of plastic materials (10 activities in total).

Subunit 2: Plastic waste contains the activities Resolubility of waste in the environment, Separation of waste, Influence of acid rains on plastic products and Recycling plastics – using project-based method (5 activities in total).

Subunit: 3 Polymers contains the activities Materials around us and what plastics and polymers are, Preparation of polymers, influencing their properties, Properties of polymers, Identification of polymers, Application of polymers, Estimate and discuss some information regarding polymers and Pointing out the importance of polymers in everyday life (13 activities in total).

The activities we have prepared are focused mainly on directed and limited inquiry (Mayer, 2004; Okemura 2008). For example, the activities that are concerned with properties of polymers and plastics have the teacher lead the students to formulate the problem – students themselves suggest the experiments that will allow them to solve this problem. The students should find out the flammability of plastics, their thermal and electric conductivity, their reactions with acids, bases or salt solutions. The results of the observation are recorded in tables, which improves on such abilities necessary for research as stating the hypotheses, realization of the experiments, collection and recording of data, processing the data, etc. The space for communication, argumentation and formulation of the explanations is possible thanks to another activity where the students solve tasks focused on the use of plastics, on the recyclation, on the processing and separating the waste. This activity uses the project method. Students learn, by solving various activities connected to the introduction to plastics and polymers, to find their way in the labels on plastics products and they find out what the various markings on plastics packaging mean. The teacher brings various kinds of plastics and plastic waste to the lesson, and the students examine it and notice the abbreviations. They assign names to the abbreviations and eventually learn to use them. During the examination of plastic waste, they also ponder of its future fate.

The teacher formulates the problems in the activities focused on the properties of plastics, and the students suggest experiments to solve the problem. The students' goal is to find out the flammability of plastics, their thermal and electric conductivity, their reactions with acids, bases or salt solutions. The results of the observation are recorded in tables, which improves on the following abilities necessary for research – stating the hypotheses, realization of the experiments, collection and recording of data, processing the data, etc. The students discuss in groups about their assumptions about the conductivity of plastics and compare them to the conductivity of other materials. At the end, they show their ability to apply the acquired knowledge in practice (for example, the electrical nonconductivity of plastics leads to the idea that they could be used as insulators). We are going to show you excerpts from the clasroom worksheet for the activity "Properties of plastics", "On the trail of waste" and "Separating the waste" (Ganajová, Šmejkal, Čtrnáctová, 2012).

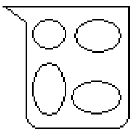
Determining density of plastic materials (PE, PP, PS, PVC) by comparing with water density

Propose a procedure by which you can verify and compare the density of the above plastic materials with that of water. You can look up water density in the chemical tables.

Findings:

1. In the picture, there is the result of the experiment to determine density of different plastic materials of PE, PP, PVC, PS. Write the names of the materials into the bubbles in such a way that it complies with the findings of the experiment.

Picture:



2. Complete the text with the following expressions:

„floats on water"; „sinks to the bottom of the beaker" „greater, smaller"
The density of water is ________ g/cm^3.
Polyethylene ____________, therefore its density is _________________ than that of water. Polystyrene ______________, therefore its density is ________________ than that of water. Polyvinyl chloride ____________________, therefore its density is _____________ than that of water. Polypropylene _____________________, therefore its density is ___________ than that of water.

Tracing waste

In the following tasks try to find out what happens to different kinds of waste in the environment and how long they decompose. There is a wood in your neighbourhood where you like walking in, cycling, you go to pick mushrooms or rest in some other ways. You discover on one of your walks someone has started an illegal dump:

When investigating the rubbish more closely, you found: juice box, cigarette butt, used tissue, invalid credit card, used chewing gum, banana skin, flat mobile phone battery, marmalade jar made of glass, perforated bicycle tyre, plastic mineral water bottle, apple core, old magazine, aluminium tin

You decide to watch how nature will cope with them itself. Here begins your investigation.

<u>Task 1</u>

You will come back to the dump in the following time intervals. Next to each of them write which of the things should have decomposed.

- One month later: …………………………………………………………..

- Three months later: ………………………………………………………..

- Two years later: ………………………………………………………….

- Five years later: ………………………………………………………….

- Ten years later: ………………………………………………………….

<u>Task 2</u>

You are 100 years old and in perfect health. Which objects will still be at the dump? Next to each object write its time of decomposition.

- .... ……… years

- .... ……… years

- .... ……… years

- .... ……… years

- .... ……… years

The materials we have prepared went through gradual pilot verifications at primary and secondary schools in Czech Republic and Slovakia. The method of questionnaire survey and statistical methods of processing said questionnaires were used to evaluate the pilot verification of the prepared activities.

Realization and results of the research

The pilot verification of the activities for the theme "Polymers around us" was done in Czech Republic on a sample of 50 primary school students, 64 grammar school students and 56 students of secondary chemistry vocational school, and in Slovakia on the sample of 100 primary school students and 50 grammar school students during the school years 2010–2011 and 2011-2012 (Čtrnáctová et al., 2011; Ganajová et al., 2011).

This means that we were verifying the processed activities on a sample of 320 students. The verification, which was tied to a questionnaire survey of the students and their teachers, showed that the activities are interesting for the students and develop their skills necessary to make the teaching more effective and to apply the knowledge in the real life.

The question "Do you think that the finished learning unit has a positive impact on pupils/students, especially on their perception of science?" had a positive response by 100% of students, as well as the question "If you agree, do you think it will have the positive impact in the long term, i.e. it will take several months or a year or more?"

The students' responses were positive even with other questions, like "I think these activities were very interesting" or "I wish we did these experiments again because it seems to be very useful".

The results show that 82% students think that these activities were very interesting and 64% students wish to do these experiments again because it seems to be very useful.

The teachers participating in the verification appreciated the non-traditional approach to the teaching of the theme that focuses not only on the theoretical knowledge, but also on the practical side of the theme. The interest of students was captured mostly by the activity where they researched the kinds and labels of plastics and the practical activities where they researched the properties of plastics. The result of the teaching was increased interest of many students about these materials, the realization of their importance for the society and the realization of the problems of waste disposal.

The teachers say that many students started to be very interested in separation of waste, which showed in their initiative to separate the waste in their homes and even at school. The students realized that the plastics form a huge part of the waste produced and if not separated, they end up either burned or in the landfills. The active inquiry and better awareness of recyclation improved the environmental mentality of many students. It was found that the chemical experiments and constant interlacing of theory and practice are hugely motivating for the students; that they improve their approach and increase their interest in scientific subjects.

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SCIENCE KNOWLEDGE OF STUDENTS IN THE TIME OF CURRICULAR REFORM

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Introduction and starting points of the research

Activities of the European Union (EU) provide incentives but also new demands on the educational reform in the EU member states. When the EU was established, the educational system was originally regarded as a distinct national area that would differ one country from another. Nowadays it is evident that this original pre-requisite has not been fulfilled, quite the contrary has arisen. At first, cross-comparing of the educational outcomes in the individual countries was initiated within the international research such as TIMSS or PISA, then this was followed by recommendations and by the EU programs that directly focused the national educational systems towards the reforms required by EU.

The curricular reform in the Czech Republic was implemented in the period of 2000-2010, already in accordance with the EU program and this reform defined new demands on the expected educational results, in particular in the area of competencies and the related skills.

A focus of our study was to identify and set a hierarchy of the required science skills of pupils/ students at different stages of elementary and secondary school and to determine the level of these skills in terms of intended, realised and acquired curriculum. The starting point for the proposed system of skills was IBSE (Inquiry Based Science Education).

IBSE is a teaching method based on pupils´/students' own inquiries that use a set of activising methods (Apedoe & Reeves, 2006; Čtrnáctová, H. et al. (2011); Linn et al., 2004). They are: the process of problem diagnostics, experimenting, recognition of alternatives, research planning, expressing and verifying of hypotheses, search of information, creation of models, discussion with the peers, and argumentation. It was found that just as you can create various kinds of inquiry cycles as a models of the way scientists do their research, you can also show the inquiry-based education in form of various models, which can be all considered variations of so-called "learning and teaching cycle" (Llewellyn, 2002). We have used the model of five-stage teaching cycle 5E with the structure of IBSE in Science subjects (see graph 01).

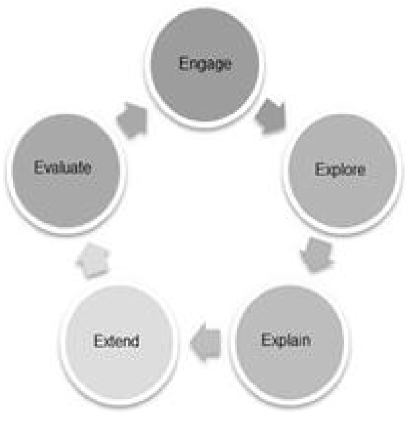

Fig. 01: Learning and teaching cycle 5E

Engagement – this phase requires to awaken the students' interest and curiosity about the theme; the teacher has opportunity to activate the learning, to evaluate the previous knowledge and to allow the students to use their previous experience with the theme.

Exploration – this is a good phase to engage the students i the enquiry – they will ask question and develop hypotheses about the work without direct instructions from the teacher. They start to collect the data and information, they suggest and realize observations and experiments.

Explanation – use of processes that lead to processing of the data and evidence of various groups as well as the class as whole; there is discussion and explanation of scientific terms connected to the research via exposition for the whole class.

Extension – the teacher helps to reinforce the acquired knowledge by extending the application of the evidence to new situations.

Evaluation – the teacher asks higher-order questions that will help the students with assessing, analysing and evaluating their work.

Research methodology

Following this teaching cycle, we have created a structure of knowledge necessary to its realization in the school practice. This was done in the scope of project Pupils´/students' Skills in Biology, Geography and Chemistry: the Research of Intended, Realized and Acquired Curriculum, whose main goal, based on multilevel analysis, is to suggest a connected system of pupil/student skills that should be acquired at the end of 1st and 2nd level of primary school, and at the end of secondary school, in geography, biology and chemistry. At this phase of project solution we chose testing and its statistical evaluation as the basic method of our research. We have created adequate taskas and arranged them into a test given to pupils/ students of the respective age category (Čížková, V. et al., 2009; Sherwood, 2007). At this point, we have first results of pupil testing at the end of 1st level of the primary school ready.

The testing was focused on five basic skills at all educational levels; they were the skills to: ask questions related to the science themes, to acquire information from various sources (text, tables, graphs, schemes, pictures, etc.), to organize and evaluate the results and to form conclusions. Seeing that 1st level of primary school only teaches generic Science subject, we created a unified test with the theme of building a sandpit, sand mining and changes in the environment caused by the mining. The tasks were created according to the 5E cycle. The test was given to 324 pupils of 5th grade of the primary school in 8 regions of Czech Republic.

Results of the research

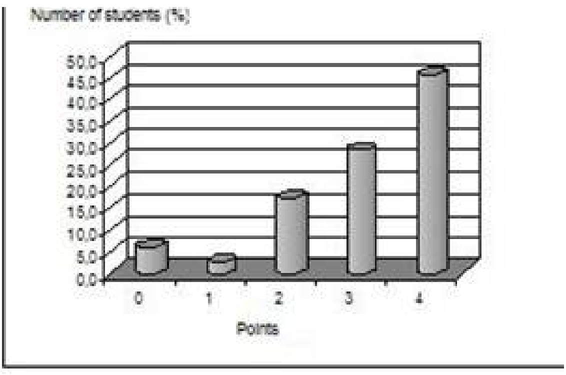

Fig. 02: Results of solving Task 1

Task 1 was a continous text. The pupils were introduced to the situation: they are the citizens of a city where a sandpit is to be built. The pupils' demand was to create two questions they would ask the city council about this construction. 46 % of pupils who created at two meaningful questions got the maximum amount of points; another 46 % of pupils created at least one meaningful question; on the other hand, 8% of pupils created no meaningful questions at all (see graph 02).

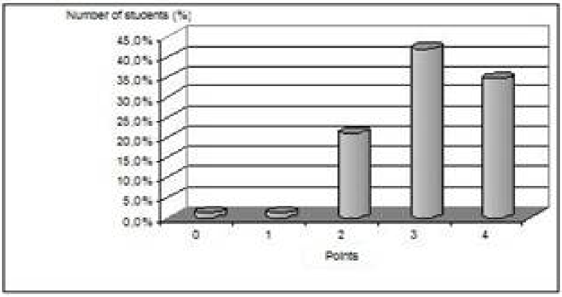

Fig. 03: Results of solving Task 2

Task 2 checks the skill of acquiring the necessary information from a scheme, map or graph. It contains a drawing of a forest where the sand would be mined. Some parts of the forest only contain a single type of tree, some contain more. The pupils should use the drawing to gain information about what parts of the forest would be affected by the mining and how, and use this to say whether the statements A-D are true or false. The success rate in choosing the right alternative was 60-90 %. 35 % of pupils, in total, were awarded the maximum amount of points. Even 3 points, a result 42 % of pupils achieved, is positive. This means that 77 % of pupils were awarded above one half of possible points. This results show that most pupils do have the skill to acquire information from a drawing or scheme – at least at a basic level. About one third of pupils has acquired the maximum level in this skill (see graph 03).

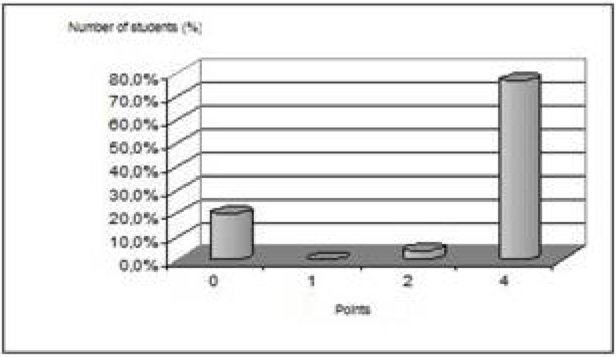

Fig. 04: Results of solving Task 3

Task 3 checks the skill to order and evaluate the information from a scheme, a map or a graph. Part of the task is a map that shows the mining area and four places where student's friends live. The pupil has to recognize areas with various levels of noise caused by the mining and order the places from quietest to noisiest. Pupils could get 4, 2, 1 or 0 points in this task, based on the number of properly placed places. Most of the pupils were able to order the places from quietest to noisiest or vice versa. The pupils with zero points usually put the places in the reverse order. Graph 04 shows the total results.

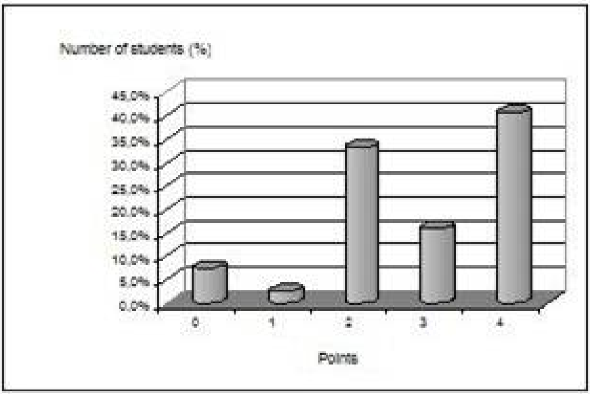

Fig. 05: Results of solving Task 4

Task 4 checks the pupils' skill to analyse data acquired from a text, a table or a graph. In this case, we check the skill to analyze data acquired from a table. The pupils have a table that shows data from before mining and during mining. They judge the amount of dust before and during, the change of amount of water in the wells and how many times the number of passing trucks increased. The data analysis has three degrees of difficulty. First piece of data could be simply read from the table, the second one could be found by comparing how many times is one value in table greater than another, and the last piece of data was a difference between two values in the table.

41 % of pupils got the maximum amount of points. 33 % of pupils got half of this amount. We can see a dip between these two point values. This means that if the pupils managed the operations with written values, they had no problem determining both of them. If they didn't, they only got two points for correctly reading the values from the table.

Task 5 is focused on checking the skill to form conclusions; the pupils, based on an interview between journalists and the city countil, are to answer whether the mayor answered a question truthfully and directly. The pupils also need to use the information they got while solving the previous problems in order to correctly assess the truthfulness of all mayor's answers.

The first part was quite difficult, the success rate was 75 %. Despite the fact that the question and the answer both contained the same word – "drying" – the pupils made more mistakes, most likely because of the amount of text. The second part had higher success rate, 79 %. Both the question and the answer are formed in fairly simple sentences. The third part was hardest for the pupils. This was most likely because the answer was not directly expressed and the pupils had to search for hidden meaning. The total success rate was 72 %. The fourth part was easiest for the pupils – although the answers are fairly long, they end with a clear message. The total success rate was 81.5 %.

Discussion and conclusion

The results of the tests show that most of pupils/students possess the skills required for IBSE, at least on a basic level. The most developed skill is the ordering of information, the least developed one is information analysis. So far, the results suggest that inquiry-based science education could be practically realized even now and that it doesn't require any special preparation of the pupils/students. To confirm this claim, it will be necessary to test a greater amount of pupils/students; the testing will continue and the results should be available by the end of this year.

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AN INTERVENTION PROJECT TO IMPROVE TEACHING AND LEARNING OF ORGANIC CHEMISTRY IN IRISH SCHOOLS

Anne O' Dwyer, Peter E. Childs

Context

Many researchers have identified Organic Chemistry as an area of conceptual difficulty (Johnstone 2006, Bhattacharyya and Bodner 2005, Rushton et al. 2008). Organic Chemistry is a conceptually difficult subject and requires the learner to be at the formal stage of cognitive development (Ingle and Shayer 1971). Studies carried out in the U.K. and in Ireland have shown that the majority of learners at Second-Level are still only operating at the concrete stage of cognitive development (Shayer et al. 2007, Childs and Sheehan 2010). These learners are faced with a number of difficulties and challenges in their quest to understand Organic Chemistry. There is much anecdotal evidence that these learners resort to rote-learning and memorisation rather than developing a true understanding of Organic Chemistry. The main areas of difficulty at Second-Level and Third-Level Organic Chemistry in Ireland were identified in the early stages of this research project (O' Dwyer and Childs 2011, O' Dwyer et al. 2011). It was found that many of the same topics are perceived as difficult by learners at both Second-Level and Third-Level. These findings were supported by previous Irish studies (Childs and Sheehan 2009).

Purpose

Organic Chemistry accounts for 20% of the Second-Level Chemistry syllabus in Ireland, and 25% of the examination(DES 1999, SEC 2011). It is important that pupils at Second-Level gain a positive attitude towards, interest in and understanding of Organic Chemistry. An understanding of Organic Chemistry is fundamental for students at Third-Level to progress to be effective contributors to the Pharmaceutical industries in Ireland. The purpose of the Organic Chemistry in Action! (OCIA!) intervention programme was to improve pupils' attitudes, interest and understanding of Organic Chemistry.

Methods

The OCIA! intervention programme was developed using the findings from those teaching and learning Organic Chemistry at Second-Level and Third-Level in Ireland. OICA! is a research-based resource designed to facilitate the teaching and learning of Second-Level and Introductory Third-Level Organic Chemistry. The intervention materials were designed with specific reference to the current Irish Second-Level Senior Cycle Chemistry syllabus (DES 1999). The materials can be used with introductory Third-Level Organic Chemistry courses.

The teaching materials were developed using ten key design criteria. A variety of teaching approaches were employed throughout the intervention programme. A number of factors were found to contribute to the difficulties in teaching and learning of Organic Chemistry. For this reason, a multi-faceted approach was taken to target these difficulties. The design criteria used are illustrated in Figure 01.

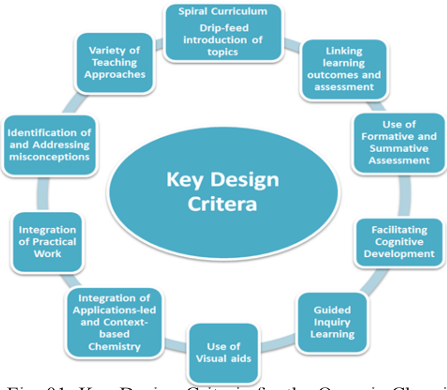

Fig. 01: Key Design Criteria for the Organic Chemistry in Action! intervention programme.

The intervention programme was trialled in six Second-Level schools in Ireland with 87 pupils. These six teachers involved were provided with a Teacher Guidebook, Pupil Workbooks (for each pupil) and a Teacher Resource Kit including all of the necessary resources to implement the OCIA! intervention programme. Two types of molecular modelling kits were provided: one for the teacher for use in demonstrations and another for every two pupils in the class. The Teacher Model Kits were commercial kits sourced from Molymod®. However, the Pupil Model Kits were custom-made for the project with the appropriate number and types of atoms, bond linkages and orbitals necessary for the activities included in the Pupil Workbooks. The teachers were also provided with a USB stick containing the PowerPoint presentations which were specifically designed to address the teachers' and learners' needs for each lesson in the programme. These provided a strong visual aid for the pupils' learning and help to facilitate understanding of difficult concepts. The PowerPoint presentations included video clips and links and animations of reactions and processes that the pupils would not otherwise be able to see in the classroom.The participating teachers attended a 4-hour Training Workshop in preparation for implementing the intervention programme.

Results

The OCIA! intervention programme was evaluated using three lenses: the participating teachers, participating pupils and through comparison with a Control Group. A mixed method of evaluation was used, with a combination of both quantitative and qualitative methods. The Control Group was composed of 117 pupils from nine different Second-Level schools. Information was gathered about the pupils' participation and performance in Science and Mathematics at Junior Cycle. It was found that the Control Group had a stronger background in Science and Mathematics than the Intervention Group. The pupils in the Control Group were taught Organic Chemistry using the traditional teaching approach.

An Organic Chemistry Test for Understanding was used to assess the understanding of the pupils in the Intervention Group and Control Group at the end of their study of Organic Chemistry. The same test was given to both cohorts of pupils. Each question on the test assessed the pupils' understanding of a different Organic Chemistry topic. The Intervention Group (median score = 49%, IQR= 41.50) performed better than the Control Group (median score= 44.75%, IQR= 35.00) in the Test for Understanding. The pupils' performance in each question in this test is illustrated in Figure 02. The pupils in the Intervention Group outperformed the pupils in the Control Group in all questions except one. The Control Group performed significantly better than the Intervention Group ($p=0.005$) in the question assessing Drawing. However, the Intervention Group performed significantly better than the Control Group on the questions assessing Isomerism ($p=0.034$), Classification ($p=0.008$) and Shape and Structure ($p=0.001$). These differences may be credited to the use of the Molecular Modelling Kits which were integrated into most lessons in the OCIA! programme. However, due to the multi-faceted nature of the OCIA! programme, it is difficult to identify which strategies contributed to the improved understanding of the Intervention Group.

The final question on the test (L.C. Examination Question) was a question taken from a previous state examination paper. As can be seen in Figure 02, the Intervention Group (median score= 7.0) outperformed the Control Group (median score= 6.0) in this question also. This suggests that the OCIA! programme was effective in preparing the pupils to answer an Organic Chemistry question in the Leaving Certificate (L.C.) Chemistry examination. More of the pupils in the Intervention Group (59.0%) than Control Group (52.1%) expressed confidence in attempting a question assessing Organic Chemistry in the Leaving Certificate examination.

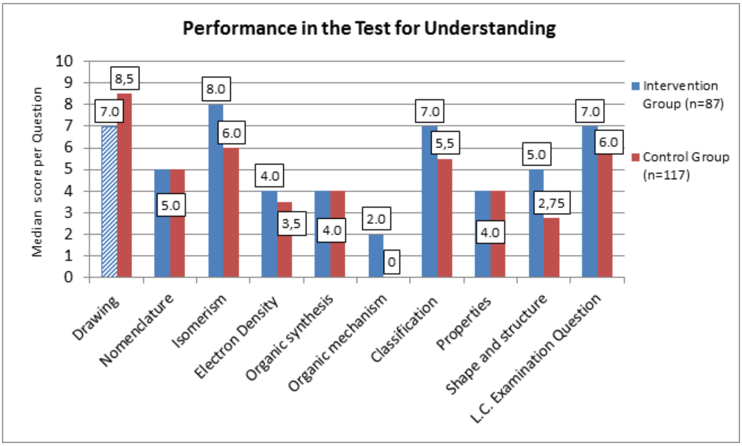

Fig. 02: Performance of the Intervention Group and Control Group in the Organic Chemistry Test for Understanding.

Note: L.C. = Leaving Certificate This is the name given to the terminal examination at the end of Senior Cycle Second-Level in Ireland.

As well as improving the pupils' understanding in Organic Chemistry, the OCIA! programme was also effective in improving the pupils' attitudes and interest in Organic Chemistry. The pupils who had participated in the OCIA! programme found Organic Chemistry significantly (p=0.012) more enjoyable (70.0%) than the pupils in the Control Group (53.1%). More of the Intervention Group (49.0%) that Control Group (37.6%) found Organic Chemistry easier to understand and more of the Intervention Group (66.0%) than Control Group (51.3%) also found Organic Chemistry interesting to learn.

Conclusions and Implications

All of the participating teachers expressed their intention to implement parts of the OCIA! programme in their teaching of Organic Chemistry in the future. The teachers also recognised the opportunities to use the resources and ideas in other areas of Chemistry and Science. Feedback from the participating teachers and pupils suggests that, while this intervention programme was enjoyable and facilitated the pupils' understanding, the time constraints due to syllabus and Leaving Certificate examination demands did not allow for the optimum level of inquiry-based learning and investigatory activities. Essentially, how Second-Level Chemistry is assessed will determine how it is taught. Until the assessment becomes less predictable and truly assesses understanding, it will be difficult to change how it is being taught. However, this project has shown the value and effectiveness of applying ideas from Chemical Education Research to the teaching of Organic Chemistry in Irish Second-Level schools.

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MODERN STRATEGIES OF SCHOOL APPRENTICESHIP STUDENTS OF NATURAL DIRECTIONS ASSISTED BY INTERNET LEARNING SYSTEM WITHIN THE FRAMEWORK OF THE EUROPEAN UNION PROJECT

Piotr Jagodzinski, Robert Wolski

Introduction

Department of Didactic Chemistry is realizing an innovative projects: „Modern multilateral strategies to prepare students for the profession of teacher assisted by Internet learning system. Nature in school practice" and the "Good school - better practice - great teacher. Preparation of schools and practices guardians for effective cooperation with students of chemistry " [1, 2]. In the framework of the projects, we combine the method of remote training with students apprenticeship of Faculties of chemistry and geography. Both projects are implementing with priorities: high-quality education system, improving the quality of training and an effective system of training and improvement of teachers. The projects are in the implementation phase, which will last until the end of 2014, and the effect of their realisation should be optimized and innovative training program content and methodology of chemistry and nature in the professional preparation of future teachers of these subjects.

Diagnosis of the apprenticeship system implementation

In the framework of conducted pedagogical research we diagnosed a system training for nature students specializing in teaching at the Adam Mickiewicz University in Poznan. Diagnostic survey was conducted in a group 247 students preparing to become teachers in the years 2008 - 2010, who made the practice content and methodology. Among these students 109 was bi-directional educated (Chemistry and Environment, Geography and the Environment) and 138 students were enrolled in uni college of chemistry, who also chose a block of teaching subjects. Parallel survey was conducted among 64 teachers of chemistry and science in junior high schools and high schools in Poznan. Here are the results obtained for each particular problem. It was found that the school laboratory equipment in teaching materials is not sufficient in the opinion of 67% of teachers (N) and 82% of students (S). Up to 64% of teachers said they are not well prepared to accept and provide substantive and methodological care for students. Also, more than half of that it is 51% of the students felt that teachers are not well prepared to conduct practice in terms of mentoring and methodical. Most students, proposed a 89% increase in the number of hours of practical training. This opinion is shared 57% by teachers, adding that a small number of hours of practical training translates to inadequate preparation for work in school. As many as 82% of students and 47% of teachers noted that the cooperation between students and tutors is insufficient. Most activities are carried out in university arranged conditions, which does not correspond to real teaching situations. This problem was noticed by 79% of students and 74% teachers. Respondents stated that during the practice they havet enough time to get to know a teacher in many ways, that is, inter alia, in terms of educational work and the rules of the school. This issue was pointed by 59% if teachers and 93% of students. An important issue is the realization of experiments in chemistry and science lessons. As many as 45% of teachers and 62% of students said that the teaching of these subjects are mostly without natural experiments, which are also essential in the nature education. The problem of poorly functioning system of cooperation between schools and univerities indicated 79% of teachers and 51% of students, while a lack of motivation of teachers to act as guardians of school practices identified 73% of the teachers. These results encouraged us to make proposals on financing practices in the European Union project to modernize the practices program and develop standards of practice to prepare students for work as a teacher of science. Therefore, we also asked students and teachers about the merits of the implementation of remote education system for the realisation of teaching practice as an innovative element to facilitate cooperation with schools and university students. Commented positively 87% students and 63% of surveyed teachers on how to apply the system of remote education in the implementation of practices as a factor in the rehabilitation quality of education.

Purpose of research

According to the project the goal of students practises in content and methodology of science is the ability to independently conduct chemistry or nature class by the students and familiarizing with the totality of a teacher work, as well as with rwealization teaching and education tasks in the school. We assume that through the implementation of practices, graduates will be adequately prepared to conduct lessons in first degree and postgraduate courses. Within the project are realized two types of content and methodological practices, ie, the interim practice and continuously practice.

Through the implementation of design Project we plan to obtain increased quality of students' practical skills to work as a teacher of science. The planned increase in quality should be achievable through proper preparation of schools practices and teachers implementing an innovative formula of practices, to provide future teachers the competence package in accordance with European standards, deepening and expanding cooperation between universities and schools, increasing the motivation of teachers to conduct practices and improving their skills in this field, the development of web-based information and experience exchange between the university, teachers and trainees. Increase the quality of students practical skills should also be achieved by enhancing the quality of the students preparation to conduct a methodical teaching of chemistry through the implementation and improvement of microteaching methods both in the classroom on campus and in class at school. It is also important to develop ground of effective method of methodical and formal preparing for the students to conduct lessons in the practice and to develop a methodology for analysis and assessment of lessons practices, by tutors and students - trainees and the effective self-control and self-assessment of their own work.

Assumptions of projects

The implementation of the practices were supported by a modern model of education. This model assumes overlaping different methods and forms of education. This new educational model requires appropriate implementation conditions closely connected with the use of information technology tools. Implementing of practice by using e-learning allows you to add new methods to conventional training methods, and also allows you to modify these methods.

Realization of the practices established using the method of blended learning. The practices organization based on this method involves allowing communication and collaboration between trainees and school practices tutors. Access to educational materials is via the Internet, so that it can be used anytime, anywhere. The use of blended learning in the implementation of practice is very valuable because it combines various methods of teaching and learning. This is done by the meshing of Internet resources and practices [3, 4, 5].

In implementation of the practices was used the method of remote learning, because you can use elements of telecommunication technology to teach in special situations. For example, trainees have the need for frequent consultation with practices carers while preparing to carry out new lessons. In this way, via distance learning are also conducted trainees training, discussing issues related to the profession [6, 7]. On e-learning platform are conducted for trainees presentations, demonstrations, simulations and remote lectures online. Through its flexibility and orientation this materialsare helping in individualization of the learning process. A great value for trainees is the ease of making changes and updating the content of the training materials by the authors of these materials [8, 9]. During the implementation of pedagogical practices benefit from the method is primarily the possibility of rational use of time by the trainee. Trainee is free to organize work time, additional time to acquire necessary knowledge for the proper conduct of the practice. Therefore, the classes of e-learning methods enrich the classes conducted by conventional methods. So they can may be more effective. In the process of school practices, where the participants acquire professional qualifications of teachers, there is also access to help files, such as instructional videos, multimedia instructions of chemical experiments, examples of lesson plans, movie recordings registered with different teaching situations possible to observe in the classroom [10, 11].

Each student do committee and methodical work experience in two stages - interim and continuous practice. In the first stage they undergo interim practice during the academic year. Interim practices consist of visiting by students of chemistry and science classes conducted by experienced teachers, substantive and methodological analysis of inspected lessom; conducting lessons independently by students on the selected theme, getting familiar with the functioning of a student in the school administration, student participation in the school teaching councils, acquainting with the way of planning, conducting and documenting classes, using techniques of self-control and self-assessment of their own work through horizontal and vertical analyze of learning outcomes. How are interim practice fulfilled? After a series of chemistry and nature laboratory classes undertaken by the students conducted is a two-week interim practice consists in observing the lesson. Students will divide into groups of several people personal. Each student will visit 3 lessons a week for a total of 6 lessons. Then the students return to college for a two-week series of classes, during which they conduct trial nature and chemistry lessons to prepared by them lessons plans. Classes are realized by microteaching, consisting in video recording of certain passages of lessons conducted by students, including their specific teaching skills. Then the students return to school for 2 weeks, during which they visit and conduct chemistry and science lessons. Conducted lessons are filmed and then analyzed in terms of content and methodology to other classes at the university. Teachers make video recording of all classes held in school for students - trainees. These video recordings are placed on the distance learning platform. This allows each trainee to watch themselfs and other colleagues, with their consent, in practical application. In this way they can make the analysis of other instances which is illuminating. I n the second semester classes of didactics of chemistry and science students are (divided accordingly as in the I semester) re-implementing the interim practice in schools according to the scheme: 4 inspected lessons and 2 lessons carried out on an 2 x 2 weeks.

During the implementation of practices, the ability to conduct a lesson by the students is assessed by the teacher-school practice tutor and by the faculty of the Department of Didactics of Chemistry AMU. They inspect selected chemistry lessons and nature conducted by students then togheter with trainees carry out substantive and methodological analysis of conducted lessons.

Students - trainees are required to conduct daily practices journal, which record all visited and conducted lessons by them. At the end of practice the studentnote his observations from the course of practice,and academic tutor makes an entry on the course of the work of a student in school and on his professional aptitude.

In the second step is carried out continuous practice, during which students attend for a month in the school life. This involves conducting 10 classes for students of chemistry or the nature and visiting 62 other lessons. The course of practice is documented by the trainee in the daily practice journal. After that, the trainees participate in staff meetings, participate in extracurricular activities, participate in meetings with the parents and so on. At the end of the continuous practice in school tutor makes an entry about the suitability of the student to work as a teacher in the daily practices journal.

Instructional materials available on the distancelearning platform

The system of remote training allows you to place instructional materials available through the Internet. Therefore, the authors of the project prepared innovative films of natural experiments. They have an important meaning in process of teaching preparing students to conduct classes and serve as an instruction. They can be used as a means increasing the attractiveness of conducted lessons and facilitate understanding of the newly introduced difficult issues in class. During the students preparations of draft of conducted chemistry and nature lessons is necessary selection of appropriate teaching methods and appropriate didactic, optimally supporting the process of lessons learning. Trainee can in this case use films as multimedia instructions before preparing to run lessons. Videos are available on remote education platform, so that trainees will be able in preparation for leading lessons, use them. This will allow detailed planning of the course of the lesson, and it is no easy matter, especially since a large part of the lesson, fill experiments. These materials allow trainee to make the right decision during the preparation of a merita, methodological and formal for lessons [12, 13].

Results

Trainees are involved in research on the effectiveness of newly developed methods of implementation of practical training using the internet by answering the questions in the surveys and tests. The study will last until the end of 2014, students who completed the planned practice with positive results should demonstrate the skills of planning, conducting and documenting classes, observation of classes and its documentation, analysis of teacher and students discuss the common practice by practice tutors and students, analyze their own work and its effects and the effects of students' work, systematic work on distance learning platforms. Most students who completed the survey, said at this stage of research, the method of e-learning increases the effectiveness of training. Also have indicated that this method facilitates access to training materials, and intensified contact with the school practices guardian, because the learning process was designed to be the sum of the best features of each of the methods with simultaneous elimination of most of their disadvantages. This result may change in the further course of study.

Summary

Innovative pedagogical practices to prepare students to become science teachers are carried out within the European Union project Modern multilateral strategies to prepare students for the profession of teacher assisted by Internet learning system." and the "Good school - better practice - great teacher. Preparation of schools and practices guardians for effective cooperation with students of chemistry All the results, developed standards for realization of practices and research on improving and a new strategy of professional training will be known in 2014 that is when the project will be completed. We have the first results of research on the effectiveness of used blended learning method in during the practice implementation. You may say that planned training program will give better results than those practices carried out in accordance with existing standards and practices program in force before the start of the project.

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RESEARCHES INTO THE CAUSES OF CHOOSING THE EXTENDED MATRICULATION EXAMINATION IN CHEMISTRY AMONG SECONDARY SCHOOL PUPILS OF BIOLOGICAL AND CHEMICAL PROFILE

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Introduction

In school year 2012/2013 will be introduced a new core curriculum to teach chemistry in secondary schools. On a basic level content will cover issues related to the chemistry of everyday life and they will be implemented in all the first years of secondary school. Students who complete their chemical education at this stage will not connect their interests and future with life sciences. In the second class the students will attend nature subject. According to the changes of the new core curriculum assumes the implementation of the chemical subject in dimension 1 hours per week in first class and 1 hour of a nature per week in second class. Whereas, students who are interested in the natural sciences in second class rather than In chemistry object, will learn the advanced chemistry program. Advanced chemistry will include a total of 240 hours in the second and third grade. This applies to classes of biological and chemical profile. Similar changes will concern subjects: biology, geography, physics, computer science. Therefore, the students of biological and chemical profile classes will not have a chance to deepen their knowledge with the subject physics or geography. In the future this may affect the choice made by the students taking the matriculation examination at the advanced level. Assumptions of the reform require to pass in matriculation examination at least two subjects at an advanced level [1].

Purpose of research

The aim was to determine the motives which guided the students of biological and chemical profile classes selecting the subject of chemistry at the advanced level, preparing for the matriculation examination. We were interested in the following problems:
- How many students say they are willing to pass chemistry at the advanced level of the matriculation examination in the classes of bio-chemical profile?
- What learning outcomes attained candidates passing the matriculation examination of chemistry?
- What factors influenced the choice or no choice of chemistry at matriculation examination?
- What result did students expect from chemistry at matriculation examination?

Methodology of research

For the test we prepared two questionnaires. One survey was intended for students passing chemistry matriculation exam at a advanced level. A second survey was intended for other students who have not chosen chemistry AT matriculation examination or appear to pass it only at a basic level.

The survey consisted of four parts. In the first part students have to determined why they had decided to choose chemistry at the advanced level of the matriculation examination. In the second part of survey students had to indicate three fields of study that they take into consideration in their further education. The third part of the survey related only to candidates passing matriculation examination at the advanced level and needed to complete the following text: “I am convinced that during the extended chemistry matriculation examination I manage to achieve a score of at least ......%, but due to my plans for the further study I want to obtain the optimal result for me ......%. “The fourth part of the survey required to write obtained grades by students of the chemistry subject after completion of second grade material of secondary school. The study was conducted among students in matriculation classes implementing expanded chemistry program in three high schools of Poznan [2].

Results

The research included 104 third grade students in secondary schools. A desire to take the matriculation examination in chemistry at the advanced level expressed 59 students which is 57% of tested. Remaining number of 45 students representing 43% agreed that would not take the matriculation examination in chemistry. The decision of taking by students' matriculation exam in chemistry at the advanced level was dictated by the fact that chemistry is a subject that is required during the recruitment of students chosen field of study. This aspect has indicated 90% of the students. As many as 34% of candidates taking matriculation examination in chemistry at advanced level states that well passed exam gives a larger choice of courses and further education. Then 30% of exam candidates said they fully consciously chose this subject. In research 25% of the students pointed out the fact that chemistry is the subject intelligible to them, and 54% said that the chemistry does not required in many cases, learning by heart , making it easier to learn and understand the material. For 51% of surveyed students teaching chemistry have appeared to be very interesting. Almost half of the surveyed students it is 49% want to make good use of the effort to learn chemistry. 46% of surveyed students said they are interested in chemistry and want to achieve a good result for the matriculation examination in chemistry. These indications are confirmed by the grades in chemistry, which have obtained these students after finishing learning chemistry in second grade.

Tab. 01: Expectations of high school graduates - prospective results from matriculation examination of chemistry

Grade after completion of II class	Predicted results by the students [%]	Optimal results expected by the students, [%]
Very good	54	87
Good	51	84
Satisfactory	59	82
Poor	44	65
Average	54	80

Pupils are confident that at matriculation examination they are able to achieve an average score of at least 54% of the points, although because of the plans for further study would like to get an average of 80% points. Youth selected studies in which chemistry is also one of the subjects of tuition. These are medical guidelines - choice of 53% students, pharmacy - the choice of 29% students, biotechnology - the choice of 24% students, chemistry - the choice of 15% students. This is confirmed by the students choosing classes with extended training in biology and chemistry.

Different, are formed the results of the survey in a group of students who have not chosen the chemistry at extended matriculation examination. 45 students filled in a questionnaire. As many as 76% of students said that chemistry is not required for recruitment to their chosen field of study. At the same time 51% of respondents argued select a different subject than chemistry when admissions process makes it possible. Also, 47% of respondents said they chose the biology and chemistry profile class because of the interest in biology, treating chemistry and science as an obligation of this profile. For 42% of respondents to achieve a good result from matriculation examination in chemistry seemed impossible. Similarly, claimed 40% of respondents considering chemistry as a difficult and incomprehensible subject. This confirms the opinion of 38% students, which highlights the fact that they receive poor grades in chemistry. A survey can also determine that 24% of respondents were not interested in chemistry in general. The confirmation of these are satisfactory and poor grades in chemistry that students received after they had completed their studies in second grade. These students often choose fields of study such as: physiotherapy 18%, obstetrics 13%, education 13%, tourism and recreation 11%.

Conclusions and summary

Based on the survey can be stated that students are not guided by grade received in subject when deciding on the next stage of their education. It is worth noting that school grade obtained from the subject of chemistry has little influence on the choice of this subject in extended matriculation exam, both as a factor in favor of choice of the subject, and against choice of this subject. Perhaps the role of grades in chemistry subject is overestimated by the teachers in the context of the choice of subject for the matriculation exam. On the other hand, crucial meaning has interest in the subject, the assessment of own intellectual capacity for science , as well as plans for the choice of study courses. It is the students' pragmatic approach to issues related to the direction of their own development and the university offers. These factors largely determine the decisions of high school graduates. You might wonder whether this effect is not too big and if often students do not overestimate own capabilities. In the opinion of teachers, however, evaluation gives reliable information on progress and opportunities for pupils in the subject.

Students who have declared a desire to pass the matriculation exam in chemistry at the advanced level, consider chemistry as a matter of an interesting, enjoyable and understandable, but argue that it is not an easy subject. Many students of biological and chemical profile classes associate their future with chemistry, which greatly motivates them to learn the subject.

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METHODOLOGY OF FILMS PREPARATION AND EDUCATIONAL RESEARCH WITH DEAF-MUTE AND HARD OF HEARING STUDENTS IN THE FIELD OF CHEMISTRY

Piotr Jagodziński, Robert Wolski

Introduction

Direct contact of the learner with the chemistry leading to the development of a number of personality traits such as: memory, imagination, perception, different forms of thinking,, inclusive. the scientific At the same time are formed personal predisposition, such as: independence, curiosity, perseverance, initiative and creative interests (Lang H. G., Propp, G.,1982). Acting in the natural environment acquires different skills, both intellectual and motor. Chemistry touches this particular area. Active student contact with chemical reactions and physical phenomena leads to the need for their description and explanation. In consequence it is shaping students' characteristics and psychological dispositions consisting in search for causes (Woods M., Blumenkopf T. A., 1996). The most important form of realization of the test method in chemistry is a laboratory experiment. In the process of problem solving chemical experiment acts as motivation, discovery and viewing (Jagodziński P., Wolski R., 2009). For deaf-mute and hard of hearing students' development of these characteristics is impaired due to nonfunctional or poorly functioning hearing receptors. In these conditions is further complicated the problem of teaching, because deaf people do not know anything about the sounds, and above all do not hear the speech with its intellectual and emotional richness (Jenny B., 1990; Lang H. G., Stinson M. S., Basile M., Kavanagh F., Liu, Y., 1998). Available teaching materials for teaching science, and especially multimedia means, including educational videos for students with described disabilities are not accepted their functions. The rate of information transfer is too fast, the number of graphic characters is too small, no sign language interpreter, too complicated language phrases and names. Deaf-mute and hard of hearing students informed teachers who work with them about these issues. They have indicated that, for these reasons, these measures are little use for them and do not help to understand the difficult issues chemical. On the other hand this information were signaled to us by teachers of these students. This encouraged us to take specific measures, because we deal with, inter alia, development and production of new teaching aids for teaching chemistry. Because there are few teaching aids for teaching chemistry deaf and hard of hearing students, and the problem is interesting, we decided to take on the task of preparing appropriate materials. The Department of Didactics of Chemistry, Faculty of Chemistry, AMU has developed and implemented a collection of educational videos to learn chemistry. Videos relate to chemistry experiments at the secondary school and high school and are intended for students with hearing and speech dysfunctions. Then we examined the factors that contributes positively to perceptual abilities of students. We studied effect of extended video sequences, the introduction of a sign language interpreter, adding subtitles and logos, slowing down the timbre of voice comments and commentator. Based on these procedures we can see that the weight of information transfer in the films was shifted toward the imaging layer. These factors may have an impact on increasing the efficiency of information transmission by means of teaching which is the educational video.

The methodology of films creating

Appropriate methodology is required for the preparation of films for this group of students, in which specially was placed the image of a sign language interpreter. This requires a separate registration of recording process of experiments and a separate image of an interpreter. For the films we used custom software to obtain special effects and digital processing.

Preparation of tools to implement films

First, we prepared set of film scripts, including a list of particular scenes. Already at this stage considered all methodological procedures that have an influence on increasing the effectiveness of perception of the transmitted information. In imaging layer of scripts we included a detailed picture of the corresponding logos, signs, drawings and computer animation. We also planned a correspondingly larger number of characters that are useful for deaf-mute students, for example, replacement of sound effects with suitable signs – speech balloon. In the audio layer of scripts, especially in the comment teacher layer we used appropriate treatment. Comment text must convey information in as straightforward as possible, so with the use simple phrases, expressions and words. This is due to the fact that sign language is poor in the signs and therefore requires simple terms. That is particularly difficult in the case of terms and chemicals expressions. In the layer audio of scenarios, especially in the layer comment the teacher uses appropriate treatment. Comment text must convey information in as straightforward as possible, so with the use simple phrases, expressions and words. This is due to the fact that sign language is poor in the signs and therefore requires simple terms. That is particularly difficult in the case of terms and expressions chemicals. For the purposes of these films were created additional, new characters signs for chemical terms. With prepared screenplays we began to produce films. Therefore, the first stage of our work was to organize a suitable selection of the proper lighting and background. Used to produce films Incandescent light with matte filters at maximum leveled out reflection of light bulbs in the convex surfaces of laboratory glassware. We used a digital camera to record video in the DV system. Digital cameras usually have the ability to set the white balance, making it much easier to work when using incandescent lighting. Digital recording allows easier transfer of material to the computer and its further processing. As the pace of comment has to be slowed a demonstrator in the films imaging layer must adequately slower perform each laboratory activities. Separately recorded sequences with silhouette of sign language interpreter on the background of greenbox, which will later be incorporated into the imaging layer of the film. Image of lector transmitting information in sign language was located in the lower right corner of the frame. For better visibility signs sign language lector is dressed in black and short sleeves. It is a necessary procedure providing that signs snap send by fingers and hands are clearly visible.

Fig. 01 , 02, 03 Realization of film sequence with sing language interpreter

To transfer and edit the footage was used Adobe Premiere CS4 program. While to incorporation into the image of a sign language interpreter in the films we used Adobe AfterEffects CS4 (http://www.adobe.com). While sequences with animation models of chemical compounds were prepared in 3D Blender program designed to modeling of various objects (http://www.blender.org).

Special procedure in the preparation of films was the realization of a comment read by the teacher. The pace of this comment was slowed by about 30% compared to the standard prepared comment, to synchronize with the rate of transmission of sign characters by sign language interpreter.

This is how were created the final versions of educational films with chemical experiences for secondary school and high school in learning of deaf-mute and hard of hearing students.

Fig. 04 Window of Adobe AfterEffects to create special effects in films

Fig. 05 Window of Adobe Premiere to mount film sequences

Fig. 06, 07, 08 Selected frames of educational films for the deaf-mute and hard of hearing students

Results

Investigations on the effectiveness of educational films of chemical experiments for of deaf-mute and hard of hearing students in secondary school and high school, and research into the function of sign language in movies were conducted. Was studied also the influence of factors on the degree of understanding of the content of the films you saw above. We determined the gain and loss and the effectiveness of educational messages for all groups of students participating in educational experiment. The best results among the tested groups of deaf-mute and hard of hearing students in secondary school reached the experimental group, students who worked with video, in which the course of the experiments was translated by a sign language interpreter. In secondary school students group the increase it was 46% and 15% of loss. For high school students knowledge gain was 49% and 12% of loss. Good results for those groups reached especially two categories taxonomic C and D taxonomy of educational objectives Niemierki ABCD, it is in solving problems (Bloom, Engelhart, Furst, Hill, Kratwohl 1956; Czupiał, Niemierko, 1977; Jyż-Kuroś i inni 2008). The elimination of a sign language interpreter explaining the course of the experiments resulted in a significant decrease of knowledge in the corresponding control groups - secondary school students gain 17%, 39% loss of knowledge and high school students 21% and 34%. It resulted about 29% decrease of effectiveness of educational films, measured in groups of secondary school students, and similarly in high school. Replacing of a sign language interpreter by text appearing at the bottom of the screen did not match the expected results. As a result, there was a 18% decrease in the effectiveness of educational films. It was expected that the replacing of a sign language interpreter with text that appears at the bottom give this nucleus of the results with less effort while making films, because the realization of subtitled films is less time consuming and requires simpler tools but it turned out differently (Jagodziński, Wolski: http://pubs.acs.org/doi/full/10.1021/ed101052w).

The problem in case of graphic characters in the films is presented a little bit different. For example, deleting the names of inscriptions relating to laboratory equipment, laboratory activities, and the names of chemical compounds caused a decrease in the efficiency of films only about 7%.

Summary

The introduction of special versions of films for deaf-mute and hard of hearing students allows them to achieve better learning outcomes than when working with conventional films. This gives students the opportunity to intellectual development, at least in the teaching of chemistry, as the authors of the publications examined. For sure this will give the ground for further education to deaf-mute and hard of hearing students in the fields, where one of the core subjects are chemistry.

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IMPLEMENTATION OF SCIENCE WORKSHOPS - THE NEW CURRICULUM PROPOSITION FOR THE STUDENTS OF UPPER PRIMARY AND LOWER SECONDARY EDUCATIONAL STAGE – A TEACHERS' VIEW

Bożena Karawajczyk, Marek Kwiatkowski

Introduction

This paper presents some preliminary results of the project "Science workshops in Elbląg region. Pilot programme for implementation of curriculum course in primary and secondary schools". The partners of the project are: Elbląskie Stowarzyszenie Wspierania Inicjatyw Kulturalno – Oświatowych Euro-Link and the University of Gdansk. The main goal of the project is to broaden the interest of students of the age 11 – 16 in science, as well as to develop their practical skills and competences. For this purpose, a new course, Science Workshops, has been proposed for the students of upper primary and lower secondary schools.

From 2011, the course has been implemented in selected schools in Elbląg region. Ninety six students' groups take part in this project. The classes are conducted by experienced science teachers (upper primary) and biology, chemistry and physics teachers (lower secondary). The dedicated programmes and textbooks have been developed for both educational stages. The idea of programmes stemmed from the concept that the practical activity of students is most important to the development of practical competences. The diverse types of this activity include problem solving by experiments, observations and measurements with the use of the appropriate laboratory equipment. The course is meant to stimulate scientific curiosity and cognitive activity of students, which will hopefully induce the future interest of young people in studying science and engineering. The content of the course is interdisciplinary and covers curricula of Science (upper primary) as well as Biology, Chemistry, and Physics (lower secondary). The textbooks are aimed on continuous experimental activity of the students. In fact, they are rather exercise-books, wherein students can write down the observations and conclusions. Students participate also in diverse outdoor activities and excursions.

All participants of the project have the access to the Internet portal, where the students can upload their results, discuss with teachers and others students, and verify their achievements. Teachers can use this portal to share their experience, ideas, experimental procedures, etc. Students' results are evaluated by teachers by scoring points. The students can score only positive points (there are no negative points), so even weaker performers are encouraged to participate in the activities too. The Science Workshops are realized in form of weekly meetings, every meeting lasting for 90 minutes. Not more than twenty persons take part in the meeting and students work in small groups (3 – 4 persons). The meeting starts from the introduction outlining the problem, then students try to formulate hypotheses, run the experiments (verify the hypotheses, solve the problem), and finally they present their results to the other students.

Teachers are expected to create the friendly environment, conducive to gaining new knowledge by the students themselves. The general role of the teacher is to pose the problem and then to allow the students to seek for the solution. The teachers coordinate students' activity, provide the support, but they should not give out the ready solutions. This new role is rather challenging, since the teachers are used to work in the different formula. For example, during the regular Science, Biology, Chemistry, and Physics classes not more than 10 – 15 minutes (20% of the time) is devoted for students activities, while during the Workshop meeting students work by themselves on average for 90% of the time.

Before the implementation of Science Workshops to schools, the teachers have been trained in two aspects: the merit of programme (teachers have gained new knowledge required to run the course) and the pedagogical approach (the teachers have been introduced to the project methodology and organisation of meetings; they have watched videos presenting similar meetings conducted in United Kingdom).

The Questionnaire Study

The survey was directed to 24 teachers participating in the project. The questionnaire asked about opinions of the teachers what is their role in the Science Workshops course. None of the respondents took part in the similar type of classes before, though about 33% declared that they occasionally conducted experiments after classes for interested students.

The teachers were asked why they decided to join the project. For 58% of them, the main reason was the willingness to do something new, different from everyday routine. The rest of them declared that the financial reward was also important. Only one person decided to join the project exclusively for financial reward. These results indicate that the teachers were genuinely interested and engaged in the new type of school activity.

The survey revealed that the teachers generally prepared themselves to the classes, supplementing their knowledge from the Internet (100%), as well as from the academic and school textbooks (89%). They asked for help from the other teachers only occasionally (21%).

The teachers admitted that they were not always successful as moderators or animators of the students' activity. As much as 89% behaved rather as instructor, directing the action of students and leading them to the appropriate solutions and conclusions. This seems to be the effect of the limited experience in such type of classes. Teachers involuntarily try to use methodology known to them from their past work in class. They point out that students are not prepared to such activity themselves too – they are more use to the situation where somebody leads their thinking and acting. Therefore the students find it difficult to formulate hypothesis, to verify them, to draw conclusion and to work in groups. Frequently, they ask the teachers for help because they are afraid to make a mistake. This, in turn, makes teachers to take initiative and control the students' actions.

Asked about the attitude of students to the new course, the teachers pointed out that students learned how to work in groups (65%) and how to run simple observations and experiments (89%). Many teachers noticed the increase in knowledge and interest of the students in science (53%). They also declared that Science Workshops affected their methodology for Science, Biology, Chemistry and/or Physics classes run by them – they started to use the similar teaching style and included more experiments during the classes (89%).

Conclusions

Preliminary results of the project indicate that in the opinion of teachers Science Workshops may be interesting alternative or supplement to the existing science, biology, chemistry and physics curricula. Although the project has lasted only one year yet, some desired changes in teachers' attitudes towards the development of practical skills and competencies are already visible. Currently, the project is in a transient phase, wherein the teachers learn how to change their role in the class from the traditional leader and lecturer to the moderator and/or animator of students' activity.

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PRINCIPLES OF GREEN CHEMISTRY AND THEIR USING IN ORGANIC SYNTHESIS

Jiří Havlíček, Jan Čermák, Karel Myška, Małgorzata Nodzyńska, Karel Kolář

Intoduction

Green chemistry is a new trend in chemistry, which have regard for ecology and economy aspect of the chemical reactions. It was suggested the 12 principles of Green chemistry [1]:

1. Prevention – it´s better to prevent waste than to treat or clean up waste afterwards.
2. Atom Economy – design synthetic methods to maximize the incorporation of all materials used in the process into the final product.
3. Less Hazardous Chemical Syntheses – design synthetic methods to use and generate substances that minimize toxicity to human health and the environment.
4. Design Safer Chemicals – Design chemical products to affect their desired function while minimizing their toxicity.
5. Safer Solvents and Auxiliaries – Minimize the use of auxiliary substances wherever possible make them innocuous when used.
6. Design for Energy Efficiency – minimize the energy requirements of chemical processes and conduct synthetic methods at ambient temperature and pressure if possible.
7. Use of Renewable Feedstocks – use renewable raw material or feedstock rather whenever practicable.
8. Reduce Derivatives – minimize or avoid unnecessary derivatization if possible, which requires additional reagents and generate waste.
9. Catalysis – catalytic reagents are superior to stoichiometric reagents.
10. Design for Degradation – design chemical products so they break down into innocuous products that do not persist in the environment.
11. Real-time Analysis for Pollution Prevention – Develop analytical methodologies needed to allow for real-time , in process monitoring and control prior to the formation of hazardous substances.
12. Inherently Safer Chemistry for Accident Prevention – choose substances and the form of a substance used in a chemical process to minimize the potential for chemical accidents, including releases, explosions and fires.

From this we chose as follows for school chemical experiments. Microwave assisted solvent – free synthesis of organic compounds was use for the chemistry teaching. Reaction of the aromatic carboxylic acids with aliphatic and aromatic amines was selected as school laboratory experiment [2, 3].

$$R-COOH \quad + \quad R'-NH_2 \rightleftharpoons R-COO^{-}R'-NH_3^{+}$$

$$R-COO^{-}R'-NH_3^{+} \rightleftharpoons R-CO-NH-R' \quad + \quad H_2O$$

Results and discussion

The mixture of carboxylic acid and amine in the porcelain crucible were heated in the commercially microwave oven.

The reactions under this conditions, according to Green chemistry principles respect:

1. Any hazardous substances use in the experiments
- acyl halogenide was substitued by acid,

2. Reduce of the auxiliary substances for example solvents

- reaction was realized as solvent- free,

3. Save of the energy for heating of the reaction mixture

- energy consumption for heating is small, time of the heating is very short ,

4. Time of reaction is very short

- reaction time is short, high temperature of reaction mixture, because ammonium salt is the intermediate,

5. Very good yield of reactions is achieve

- reaction proceed with good yield,

6. No adjacent products arise

- formation only one product - amide.

These reactions, as school chemical experimets, show the contemporary trend in organic synthesis – ecologic and economic aspects of reactions.

Conclusions

Solvent-free microwave assisted synthesis of amides is in agreement with the some principles of Green chemistry.

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MICROWAVES IN THE SCHOOL ORGANIC CHEMISTRY EXPERIMENT

Jiří Havlíček,Kateřina Zemanová, Karel Myška, Karel Kolář

Introduction

Organic reactions under microwave irradiation are a new alternative in school experiments area (1-3). We show a some reasons for realization microwave assisted solvent-free reactions.

1. The technique is very useful for the acceleration of organic reactions.
2. The microwave irradiation has a positive influence on the reaction yield.
3. The reactions can be realized in commercially microwave oven.
4. Microwave assisted reactions we can use school organic chemistry courses.

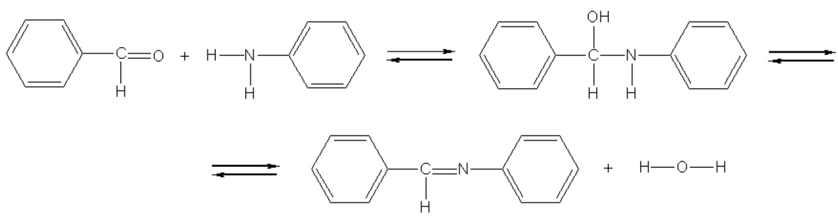
Experiments were tested for the using in the organic chemistry teaching. The main criterions for selection of experiments are simplicity of the realization, transparence of reactions and their reproducibility We selected a number of the organic reaction types.

1. Acylation reactions of amines and alcohols.
2. Condensation reactions aldehydes and ketones with amines, hydrazines and hydroxylamine.
3. Nucleophilic and electrophilic substitution (reaction of the aromatic sulfonic acids with natrium hydroxide, reaction aromatic amines with sulfuric acid).
4. Synthesis of heterocyclic compounds (synthesis of heterocyclic amines).

We have a certain experience with synthesis of the amides (3-4). The reaction of the benzoic acid with aliphatic amines without solvent in the commercial microwave oven is successful. Yield of the reaction is good, time of reaction is short. The reaction show also very good reproducibility. Now we tested of two new experiments – reaction of aldehydes with amines and reaction of amines with sulfuric acid.

Experimental

Reaction benzaldehyde with aniline is the first example of the solvent – free microwave assisted organic synthesis.



The mixture of 0,42g benzaldehyde and 0,37g aniline in the watch glass overlaped porcelain crucible, was heated in the microwave oven (700 W, 2450 MHz, reaction time – t= 1min.-Fig. 01., t=5 min.). After finishing of the reaction, the mixture was analyzed by TLC chromatography (silica gel, hexane : ethyl acetate/ 8 : 2, UV detection, aniline – RF=0,28, benzaldehyde – RF=0,54, benzylideneaniline – RF=0,68).

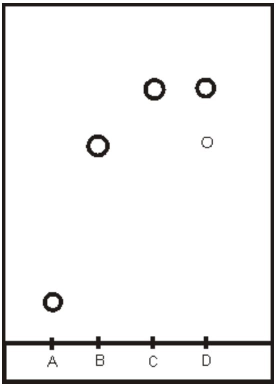
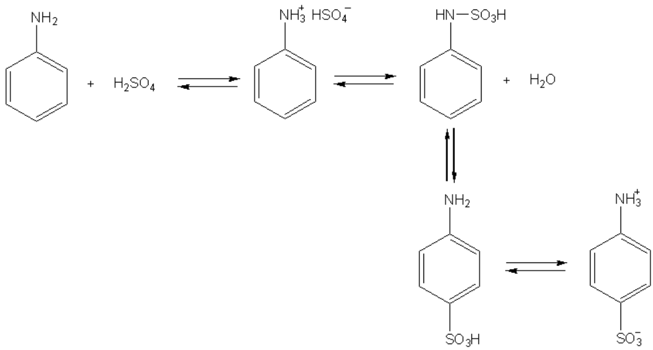


Fig. 01. TLC analysis of reaction mixture (t=1 min.)

Another example is reaction aniline with sulfuric acid.



The mixture of 0,10g aniline and 0,20g sulfuric acid in the watch glass overlaped porcelain crucible, was heated in the microwave oven (700 W, 2450 MHz, reaction time – t= 5 min.-Fig. 02., t=10 min.). After finishing of the reaction, the mixture was analyzed by TLC chromatography (silica gel, propanole : ammonia/ 2 : 1, UV detection, aniline – RF=0,91, sulfanilic acid – RF=0,57.

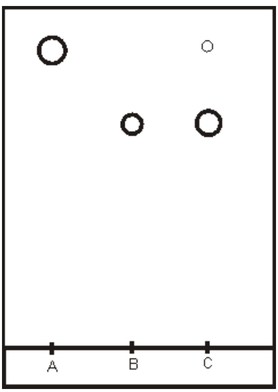


Fig. 02. TLC analysis of reaction mixture (t=5 min.)

Results and discussion

The experiments are very simple with good reproducibility, time of reaction is short. Principles of reaction are transparent. Under there conditions one main product arise. Some starting substances and products are polar compounds. High polar products and intermediates (water, anilinium hydrogensulfate, sulfanilic acid) are for microwave assisted reactions very important. Water or anilinium hydrogensulfate have positive role in this reaction. Sulfanilic acid occurred in the form inner salt. Long time of reaction did not suitable, the chinonimine dyes can be form. Under this conditions can be the reactions use in the school experiments.

Conslusions

This trend – solvent-free microwave assisted organic synthesis, is very significant in the chemistry education, because it is in agreement with Green chemistry principles. Two experiments – reaction benzaldehyde with aniline and reaction aniline with sulfuric acid where tested for using in the chemistry education. The results show, the experiments are useful for teaching of chemistry.

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IMPLEMENTING STEM-TEACHIING IN EUROPEAN COUNTRIES: THE ROLE OF THE STAKEHOLDERS

Martin Lindner, Louise Bindel

The context and purpose of the framework

The EU-project ESTABLISH (European Science and Technology in Action Building Links with Industry, Schools and Home) funded through the 7th framework program wants to make clear the role of the various stakeholders in implementing new ways of STEM (Science, Technology, Engineering, Mathematics) teaching. Among these the companies (industry as well as small and middle enterprises / SME), academic institutions on third level education, and school administration are seen to be involved as stakeholders. However, neither their influence nor their effectiveness had been researched so far. This paper presents the results of our research, conducted in studies throughout Germany and ten European countries. The results are linked to the sociological and political concept of governance, which was introduced to the political system after the breakdown of the iron fence 1989/90 (Türke 2008).

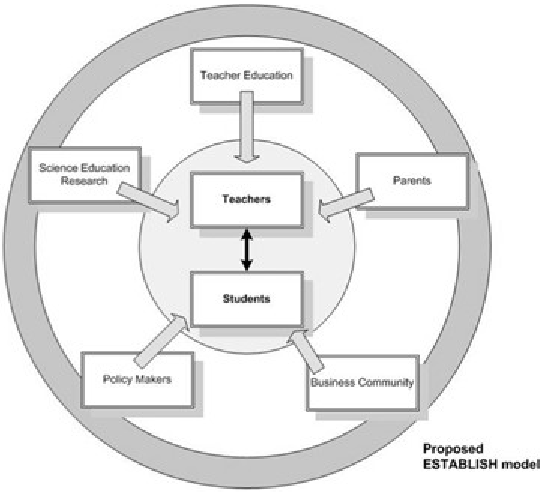

Fig. 01: The combination of the stakeholders according to the ESTABLISH approach. Every stakeholder interferes with the interaction of teachers and students on the same level, there is no hierarchy

Methods

About 20 Persons of companies, school administration and science centres were asked in a semi-structured interview to get information about recent innovations in STEM education. The persons focussed in the interview on one innovative element, e.g. new textbooks, new curricula or new ways to implement new methods. They described important elements of this innovation and the way it was brought into praxis. We asked explicitly for fostering and for hindering factors. - The collaboration between schools and companies was researched in two projects. One is a long lasting cooperation of an important industrial company in Finland (Nokia), the other is a regional network including schools, SME and a university for applied studies in Northern Germany. This research was also conducted with interviews, but additionally with observations, which were recorded in a manual.

Results

Our results show a widespread awareness on STEM education and a broad willingness to foster new approaches towards a more IBSE orientated science teaching. The methods to implement IBSE are new curricula, teacher professional development courses in a new way of collaborative settings, new experimental workshops for teachers to implement this teaching to the classroom or building up networks for teacher professional development. Six countries are described in case studies.

Denmark

The project focussed by our researched was “Science communities”, an initiative for science fares, a more IBSE orientated science teaching and activities like egg-races. The program was joined by 19 of 39 communities in Denmark. Each community provided one person to be in charge of the program and its implementation. The results show a great autonomy of either the communities, the program coordinators and the schools. In terms of curriculum, of financial aspects and of program topics schools were able to chose from a variety of offers. The program coordinating persons, gathering twice a year in conferences, seem to be experienced teachers, teacher educators or administrative staff.

Germany

In Germany we made interviews in three of the 16 states, one in the North and two in the eastern part. We saw an increasing autonomy of the schools concerning their curriculum decisions, their professional development of the teachers and their support. Two states are very much influenced by the SINUS-Program, which was also a model for the well known Rocard-report, which influenced the last seven years of European science education programs (Rocard et al. 2007). These Federal states put their efforts on cooperative settings of teachers, working together in small groups on special topics to solve actual questions of classroom work in science and math. As the assessment is not too much centralized, some freedom is given to the teachers to test new methods and to experiment with them.

Ireland

Our Irish interview partners reported about sustainable changes in mathematics and science teaching in the last years. They were implemented through small groups of teachers dealing on questions of teaching and implementation of new methods. All of this seemed to be very much up to date, but a crucial contradiction damages nearly all of the innovative approaches: the nation-wide final exam. This assessment decides about the life-long career of all students. As everyone wants to pass with best marks, every lesson is designed to cover the test requirements – and not the IBSE orientated methods. From our perspective a change is necessary to change the type of assessment to make IBSE more accepted.

Israel

In Israel new teaching and learning methods in the STEM subjects were introduced broadly in the last years. As the school system is highly centralized, school authorities organized the implementation. Several regional training groups for teachers were brought together, distributed over the whole country. The work is guided by science teaching experts at the Weizman institute. Together with the introduction of more IBSE oriented lessons the central tests had been changed, addressing the new requirements. We have the impression that this combination of being advised by a research institute and having not only the professional development but also the assessment in one hand, helps most in introducing IBSE methods.

Turkey

The recent political development in Turkey shows a development of a more anti-modern direction. It seems to show a tendency of centralization, creating an atmosphere of innovations in „closed shops“, in commissions which are not interested in involving persons from outside, from school practice or from universities researching on science education. It is likely that religious influence on school might hinder innovations. School and teachers´ autonomy could be decreased in this situation. The approach of IBSE, which needs some kind of autonomy, could not be developed in such an environment.

Czech Republic

Our interview partner in the Czech government is an external advisor, who has worked in several countries not only in southeast Europe. He diagnoses a strong orientation on hierarchy in these countries. This might be a relict of the years under soviet pressure, but might also be conserved because of the language isolation of countries like Czech republic. IBSE is seen critically, as the orientation on content is much more elaborated than in other European nations. A remarkable observation is made by the fact that obviously the academic staff has a high recommendation and is seen as experts with a special status.

Cyprus

The Cyprus government launched a complete modernisation of the school system. In this context not only the curricula are renewed but also the schedule, which is changed from 45 minutes to 80 minutes lesson. The implementation of new science curricula is done in a process in two steps. In the first period a few groups of teachers were asked to discuss new approaches to Science teaching, involving elements of IBSE. The results of these groups are discussed by the educational experts in internet fora. In the second step governmental organs will formulate the new curricula. The whole process is supported and monitored by an external advisor

Results from analysing the collaboration between companies and schools

One of the major results of this research is given by the fact, that students involved in programs with technical firms feel positively selected and see this as an honour. This is an external motivation for a better performance in Science and Mathematics classes. And, together with this, they report they feel friendship which the other students in this group. This group dynamic result is not only seen in STEM projects, but also in school sports, theatre or school orchestra activities, but it could also be used to foster STEM orientation.

The overview on our research on collaboration between schools and companies, as well as third-level education institutions, is wrapped up by the following characteristic facts:

- Collaboration is based on personal relations
- Any collaboration needs reliability
- The duration of a partnership is crucial: longer collaborations are more stabile
- Principals should actively support STEM partnership
- Partnership is give and take on both sides
- Consider the win-win-effects
- Collaboration fosters self esteem of students (and teachers)
- Cultures of schools and companies are different (e.g. personal management)
- Take the differences between school and companies into consider
- Expect disappointment on both sides
- External support is helpful (e.g. collaboration under the umbrella of EU-programs)

Conclusions and implications

The results of the interviews with administrative people show a regional difference from north to south, according to results from sociological studies based on OECD data (Windzio et al. 2006). These authors formulate six types of governance from analyzing OECD data on educational aspects. These types are regionally distributed, only in few cases spread across Europe. Germany, Ireland as well as Turkey can be linked to the „State based governance“, but the recent development show a different development in Germany. Denmark stands for the Scandinavian government type. The Czech Republic is linked to the Anglo-Saxon government type. However, a few new developments were found, based on recent political developments in southern European countries, some of them influenced by external advisors.

The collaboration between schools and companies varies in a large scale. Crucial points are the teachers´ workload and a lack of agreements on the objectives of the cooperation. A very simple relation could be found between the duration of the cooperation and the satisfaction on it on both sides.

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ON THE COMPUTER SUPPORTED MODEL BASED LEARNING IN CHEMISTRY – EXAMPLE OF ACID-BASE TITRATION SIMULATORS

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Introduction

The natural science instruction closely relates to using models. They work as tools for increasing clearness, making the learning content easily understood, providing information, objects and phenomena which are not visible by human senses.

The approach to instruction which applies models is in Anglophone areas called Model Based Learning and is understood as a constructive process aiming at learners´ activities - to re-construct, interpret, experiment, predict, direct, create, evaluate (Frischherz & Schönborn, 2004) with the purpose to create a mental model of studied phenomena (Gobert & Buckley, 2000).

These days, strongly influenced by dynamic ICT development, the learning models are frequently provided in the electronic form. The computer models work on the basis of the mathematical or formal-logical model, which work as means of visualization or simulation of modeled system behaviour (Bílek, Nodzyńska, Paśko & Kmeťová, 2007, Ornek, 2008). Computer models differ in the way of processing and degree of interactivity. Frischherz and Schönborn (2004) use two types of computer models – animations and simulations.

Animations are characterized by low degree of interactivity and low degree of freedom for the user who can watch only object on the screen, or change modes of presentation or manage the sequence of images. The mathematical or formal-logical model, the animation is based on, is hidden to the user and cannot influence it in any way.

Simulations are also based on the implicit model, with no approach from the user, but their interface does not enable to influence some parameters and observe related changes in the model behaviour. Lliboutry (1987) differs simulations from animations as being not only the mean of presentation but the method of learning replacing the study of real phenomenon.

Frischherz, Schönborn and Schulin (2003) propose six types of e-learning activities for working with electronic learning (study) materials: assimilation, reproduction, application, generating, communicating and reflecting pieces of knowledge. “All provided activities require quality prepared learning objects - animations and simulations.“ (Bílek, Nodzyńska, Paśko & Kmeťová, 2007). Frischherz and Schönborn (2004) mention eight quality criteria (see Results of expert evaluation – pilot survey) for animations and simulations as learning objects which provide required added value to the instruction.

Frischherz and Schönborn (2004) also propose the procedure of creating didactically efficient simulation which includes following steps: 1) scientific analysis of the problem and creating the conceptual model, 2) reduction of the conceptual model in relation to the learning objectives, 3) adjusting to the learner’s cognitive level and creating the didactic model, 4) computer processing and creating a design model. The computer processing of simulation requires two different layers (Le Maréchal & Robinault, 2006). The first layer is on the algorithm level which is processed by the CPU, it is usually hidden to the user and the question is whether it is necessary to inform the user about it, or to what extent. The second layer provides the displays on the monitor which refer to calculations in the first layer. Various semiotic registers are used for displays in this layer – mother tongue with professional terminology, symbols (e.g. formula), tables, diagrams, graphs, animations etc. One concept may be expressed in various ways, and each approach may provide specific information. The sense of the concept enables understanding and putting into accord the whole expression file (Tiberghien, Buty & Le Maréchal, 2003). “To acquire a new concept means to be able to work with it within one register and at the same time to switch from one register to another." (Pekdag & Le Maréchal, 2003). But Le Maréchal (2006) attracts attention to the problem that using of any register calls for implementing student's specific knowledge and skills to work with it. The used displays do not have to have the same content for both the students and the teacher who has more professional knowledge in the field (Sanchez, 2008).

Our study focuses on learning computer animations and simulations of open-access acid-base titrations which are available on the Internet. The learning computer animations are understood as didactic means providing great visual potential which in our opinion lies in the feature that applying various parallel illustrations animations can more easily create student's imaginations on relations between the macroscopic, microscopic and theoretical aspect from the point of level of information the student works with, and enable to connect the practical (running the titration), graphic (drawing the titration curve) and numeric (calculation of the concentration of the examined solution) aspect from the point of required outputs which prove the learning content was acquired by the learners. The objective of this paper is to analyze these applications and evaluate them from the point of their further application in the chemistry instruction on the general higher secondary school level.

Methods

The research activities are running in two sequencing phases. First, the didactic analysis of the research sample of 35 open-access learning applications was made (see http://titrace.wz.cz/simulatory/simulatory_cely.html), which are available on the Internet, and now the expert evaluation of selected ones is running.

The special methodology was designed for the expert evaluation of selected applications which is based on evaluation of 1) clearness (i.e. what and what way information is provided by the application), 2) methods of managing the learning activities (i.e. how the application activates the user for activities and how the activity is managed) and 3) interactivity (i.e. what type of interactivity the application provides). Several criteria were listed for each of these three fields of evaluation relating to the learning objectives of the acid-base titrations on the general higher secondary school level.

The learning computer animations and simulations are evaluated in relation to the explicitly defined set of learning objectives (Mazák, 1989) and at the same time to the level of processing relating to the quality criteria of computer animations and simulations proposed by Frischherz and Schönborn (2004). The evaluative form of collected data was designed, being based on questioning and scaling. Two rounds of the Delphi method will be applied for evaluation. Chemistry teachers on the lower and higher secondary school level, experts in chemistry didactics, chemists-analysts and IT professionals with chemistry education worked in the expert role.

Results of didactic analysis

The results of didactic analysis showed that the analyzed applications relating to the topic of acid-base titrations usually presented three partial topics – running the titration, course of the titration curve, calculation of the concentration of the analyzed solution.

Single items of the learning content were presented by various means. Let us focus on two most important ones within the topic. The first one is the titration apparatus which was presented in seven ways – schema, image, photograph, animation, video-sequence, interactive 2D model, interactive 3D model. The second item was the running chemistry reaction which was in simulations presented as the chemical equation, animation on the molecular level, animation of changing the volume and colour of solution in the titration flask, drawing the titration curve and table of collected values.

Computer simulations are understood as means suitable for presentation on various levels of information and aspects of chemistry learning content. The didactic analysis showed that the interconnection of various levels was usually missing in the analysed applications. Nearly two thirds of them presented the one-level information only. From the point of connecting various aspects one fourth of applications presented only one aspect – the graphic one, most applications connected two aspects, mainly practical-graphic and practical-numeric one.

The analyzed applications differed in the level of clearness, managing (directing) student's learning activities and interactivity, which resulted in various types of e-learning activities provided by the applications, e.g. assimilating (adjustment), reproducing, applying and generating information.

Proceeding from the analyses results the researched applications can be structured in three types which substantially differ in three fields – clearness, managing (directing) student's cognitive activity and the interactivity, but on the other side they prove the same or similar algorithm of going through the programme:

1. Simulators of running the experiment.
2. Generators of titration curves according to the user's choice.
3. Presentation of the concrete titration.

Each category is supposed to have different potential to be applied within the chemistry instruction, i.e. in different methods, organization forms and phases of instruction. To verify this expectation is one of the objectives in the second phase of our research activities.

Results of expert evaluation – pilot survey

Three learning applications for expert evaluation were selected to represent the above mentioned types. Application 1 represents running experiments with various solutions and serves as the trainer of calculations of the set concentration (see http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/stoichiometry/a_b_phtitr.html). Application 2 draws titration curves according to the data provided by the user (see http://faculty.concordia.ca/bird/java/Titration/Titration_demo.html). Application 3 presents how the titration of solution of hydrochloride acid by the standard solution of sodium-hydroxide is made (see http://users.skynet.be/eddy/titratie.swf).

The objective of the evaluation is to validate whether the application supports the process of instruction where it is expected, the correctness, usability in teaching practice and the quality of processing in selected applications.

The evaluation tool was based on questioning and scaling. First, the application was compared to the set of learning objectives in the topic of acid-base titration. Second, the design of the application was evaluated in ten fields (professionalism, adequacy to learning objectives, adequacy to learner's cognitive level, clearness, motivation items, activating and managing student's learning activities, feedback, interactivity, graphic and technology processing. Third, evaluators recommended in what phase, for what content what learning application should be used. From the provided ones they selected the appropriate level of education, user, form of instruction, phase of the lesson and method of instruction. Fourth, the quality of learning applications was detected against eight quality criteria defined by Frischherz and Schönborn (2004). They are Scientific standards, Content selection and reduction, Learning activities, Type of media, Didactic context, Visualization Usability and Aesthetic quality. Each criterion relates to statements which the evaluators express their agreement or disagreement to Fifth, evaluators expressed the importance rate of the single criteria to the general quality of the learning application.

Nine evaluators participated in the pilot analyses (three lower secondary school teachers, five higher secondary school teachers, one university teacher) showing following findings.

Data collected in the first phase of evaluation, when applications are compared to the set of learning objectives, showed wide extent of non-uniformity in evaluation. The evaluators agreed in one conclusion only, i.e. the applications support reaching the following learning objectives:

Application 1 Learner is able to describe the procedure of the acid-base titration.

Application 2 Learner is able to illustrate the pH change within the running titration by the titration curve. Learner is able to define the point of equivalence on the titration curve and read the consumption of the standard solution.

Application 3 Learner is able to describe the procedure of acid-base titration. Learner is able to illustrate the pH change within the running titration by the titration curve. Learner is able to define the point of equivalence on the titration curve and read the consumption of the standard solution. Learner is able to calculate the concentration of the researched solution from the measured values.

In the second phase, where the quality of processing was evaluated, the evaluators´ highest agreement was detected in Application 3, on the other hand with Application 2 evaluators agreed in one item only (Professionalism) which received higher evaluation in all three applications. Application 3 was highly evaluated (Excellent – Very good) in all items (instead of Interactivity which received Good). These results correspond to those in the fourth phase which focused on the quality of applications according to eight criteria by Frischherz and Schönborn. The interesting is that in these two phases evaluators most frequently selected the choice “Cannot say“ in providing the feedback and the adequacy to the learner’s cognitive level.

Evaluators´ recommendations of the third phase focusing on how to use the application are summarized in table 01:

Tab. 01: Evaluators´ recommendations how to use the application

	Application 1	Application 2	Application 3
Level of education	higher secondary of chemistry, grammar school, university of chemistry, university teachers´ training	higher secondary of chemistry, grammar school, university teachers´ training	lower secondary, higher secondary (non chemistry), higher secondary of chemistry, grammar school, university teachers´ training
User	learner	teacher learner	teacher learner
Form of instruction	group	frontal	frontal
Phase of the lesson	fixation	fixation	exposition fixation
Teaching methods	pupils´ experiment	pupils´ experiment	verbal-visual demonstration experiment

Evaluators also agreed in the fact that not an application could be used in diagnostic phase of instruction.

The fifth phase of evaluation focusing on evaluation of importance single criteria by Frischherz and Schönborn on the quality of the learning application showed the evaluators agreed the Didactic context, Scientific standards and Content selection and reduction were considered the most important ones. They all were evaluated very positively in the fourth phase. On the other hand, the least important criteria were Type of media and Aesthetic quality. The highest agreement of evaluators appeared in the Aesthetic quality criterion.

Conclusion

The research study focuses on the learning computer-supported open-access simulations on the Internet. Resulting from the didactic analysis of 35 learning simulations we described three characteristic types of learning applications which can be used for the chemistry instruction to some extent. Then we introduced one application representing each type which underwent the expert evaluation. The pilot survey showed that in evaluation of Application 1 (focusing on running experiments with various solutions and practises calculating the concentration) and Application 3 (dealing with one single situation) is higher agreement than in evaluation of Application 2 (drawing titration curves according to the user's data). This phenomenon might be explained from the evaluators´ experience point of view. While the presentation programmes (type) and practising programmes (type 1) are considered traditional in the chemistry instruction, the use of generators of titration curves (type 2) e.g. as the tool of autonomous research students´ activity has not been so common. The importance of the IBSE (Inquiry-Based Science Education) approach in the science education has been mentioned in professional journals and publications for several years. To verify whether the Application 2 type is the appropriate alternative didactic means for teaching the topic of acid-base reactions based on students´ autonomous research activity will be the object of following researches.

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THE INFLUENCE OF THE KNOWLEDGE OF ATOMIC STRUCTURE ON THE INTERNET SEARCH OF THE INFORMATION ABOUT MICROWORLD.

Anna Michniewska, Paweł Cieśla

For most of us Internet is a great source of information. Very often we search on the Internet for information and we don't think if this information is credible and reliable. It happens very often that theories that are on the Internet are incomplete do not conform to the actual scientific theories or even are wrong. The best example of this is searching for model of atom on the Internet. Most of the sources show the model of atom in the way that Rutherford or Bohr represented it 80 years ago. (Cieśla & Paśko, 2009) Which models of atom can students find on the Internet?

Most of the websites contain the wrong information about the model of atom (Nodzyńska, 2005c,d; 2012a,b). We can divide websites in five groups depending on the level of their correctness: (Cieśla & Studnicka, 2008)

I. Their models represent the correct model of atomic structure, one which is the closest to the actual scientific theories. They show the electron cloud whose density drops as the distance from nucleus increases.

II. In this group there are models which show the electrons as balls which move on the tracks of the same surface and such representation suggests that atom is flat and not spatial.

III. There are models which may suggest that structure of atom is three-dimensional as well as the model depicts electrons moving on specific tracks – orbits.

IV. This group includes models which have disproportional measures of atomic nucleus in relation to the size of the very atom.

V. This group includes models of atoms which are utterly different from the actual model of atom.

On one hand it is very difficult to find the models of atomic structure which are in the first group but on the other hand it is pretty easy to find those belonging to the II group and the III group. We must remember that these models are put on the Internet not such by scientists but people who claim to have some knowledge on this subject and they do not.

The aim of the research was to show how much students know about the atomic structure and check if the students will use their knowledge while searching for atomic structure on the Internet. Students were from two low- secondary schools in Cracow where the teachers taught differently this material. Another aim of the research was to see how the way the teachers teach students influences the very knowledge of students.

Our hypotheses are following:

1. The way of teaching influences the students' knowledge.

2. The negative transfer is triggered by obtaining the wrong information.

3. Students' knowledge influences the search of model of atomic structure on the Internet.

The survey was anonymous and the students were asked to match the description and drawing of the model of atomic structure with a website. The students were asked to sign the sheet of paper with their number and name; the folder as the title of the website. Students were asked to describe and draw the model of atom and search on the Internet the actual model of atom as well as cite the website where they found the model of atom. In both schools the teachers depicted the atomic model which was composed of a nucleus and electrons moving around the nucleus forming a sort of electron cloud, but in one school, let's call it the school number 1, the teacher introduced a concept of electron shell to explain the formation of bonds. The teacher from another school, let's call it the school number 2, didn't introduce the concept of the electron shells nor the concept of well-defined tracks on which the electrons move. From now on we will refer to the school n. 1 and the school n. 2.

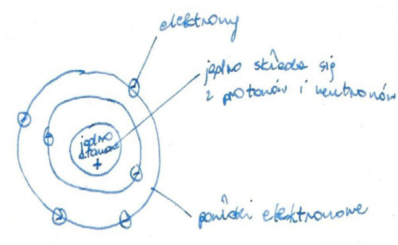

Fig. 1: One of student's answers from school n. 1

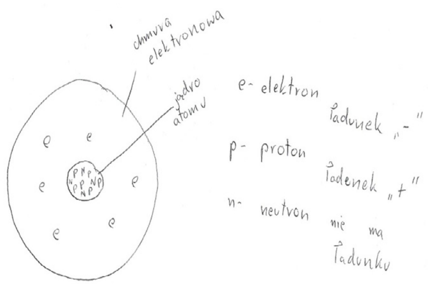

Fig. 2: One of student's answers from school n. 1

Either in the school n. 1 or in the school n. 2 most often the students wrote and drew an atom which was composed of a nucleus (fig. 3). The difference between these schools was that the students from the school n. 1 claimed that the electrons are set on the shells while the students from the school n.2 claimed that the electrons form an electron cloud.

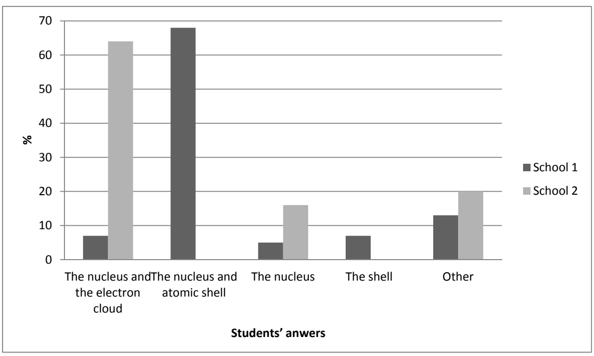

Fig. 3: Pupils' descriptions of the structure of atom.

Most of the students, no matter which school it was chose the model (fig.4) belonging to the third group (which looks like a planetary model of atomic structure). What was surprising, such models of atomic structure chose also those students who had never been familiar with the concept of electron shell and therefore such type of model should have been unknown to them.

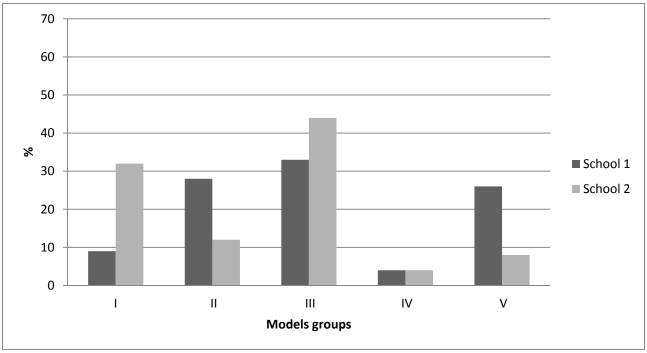

Fig. 4: Groups of models of atom chosen by pupils as correct, found in the Internet.

The analysis of the description of model of atomic structure and the model found on the Internet shows that among the students which described the atom as one composed of nucleus and electron cloud the school number 1 and the school number 2 the students most often chose the models which belonged to different groups. In the case of school number 1, where students described the atom most often as one composed of nucleus and electron shells, the students chose most often atomic structure from the group II and III.

When it comes to the school n. 2, the situation looks different. There was no student who described the atomic model as nucleus with electrons moving in the shells around the nucleus. We can notice that a great deal of atomic models found by the students reflect their answers. 24% out of all models found by the students are the current models of atomic structure. It is alarming though that 28% out of the found models represent the atom belonging to the third group which seemed to be unknown to them.

To conclude, on the basis of the results of the research we can say that the hypotheses are correct. The research proved that the way of teaching influences the knowledge acquired by the

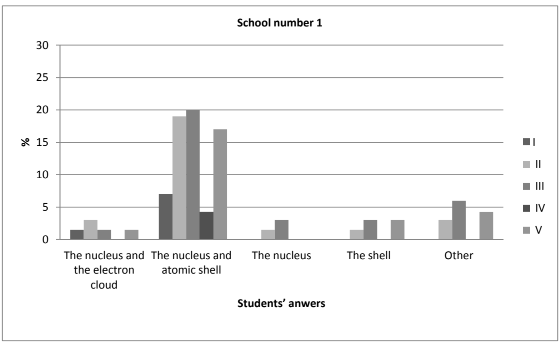

Fig. 5:

students. In the school where the teacher introduced the out-dated term of electron shell and then the elecron cloud we noticed the negative transfer. The students from the school n. 1 had a lot of difficulties in describing the atomic structure correctly. It confirms the hypothesis that when you introduce the wrong information and then correct information then the negative transfer emerges (Paśko, 2007; Nodzyńska 2004a,b; 2005a,b; Nodzyńska & Paśko 2004, 2006).

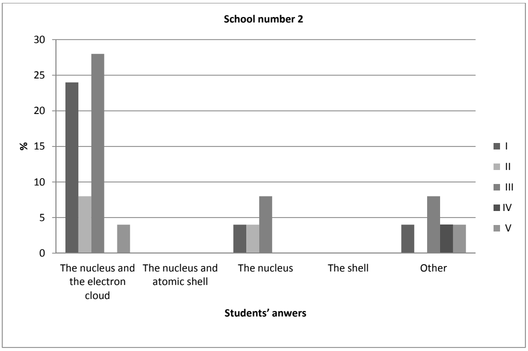

Fig. 6:

The following research show that the knowledge to some extent influences the search of information on The Internet. Yet, very often the same Internet sources had an impact on the atomic models searched by the students. Some of the students chose the models which basically they did not know but because they found many such representations of them on the Internet they considered them to be correct. A few times the students did not reflect on the correctness of the information found on the Internet. The teachers and parents should be repeating students that Internet is not the source of all information. They should show the students the credible and reliable websites because not all sources which are accessible on the Internet correspond to the scientific research. We need as well to introduce a uniform and most importantly a correct way of teaching about the microworld so to avoid the misconceptions in pupils' minds and the negative transfer.

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PRIMARY STUDENTS´ MISCONCEPTIONS ABOUT SUBSTANCES: WHERE DO THEY COME FROM?

Júlia Miklovičová

Misconceptions in general

In the last few years, the research of misconceptions held by students of all ages, became one of the possible ways, how to make teaching and learning process more effective. The question was, how can these misconceptions, which are formed long before the beginning of school attendance be overcome and how to help students to understand the complexity of the world surrounding them to create correct conceptions about their environment and to use these knowledge in behalf of themselves alone and of whole society. According to the available literary resources [3] it is not possible to identify these conceptions as absolutely valueless only because they are incorrect from the scientific point of view (Larochelle a Desautels). Point is, that these conceptions are in most cases very strongly „anchored“ in students´ mind scientific structures, and they have stable position in their knowledge structures. These concepts together (in spite of not being scientifically correct) create theoretical and logical basis for complex understanding of the world for a concrete individual.

Where do misconceptions come from?

Identification and categorization of various scientific misconceptions should be very important part of educational strategy of teachers as well as curricular experts. When misconceptions of students are sufficiently examined, it is possible to work with them and enable students to create scientifically correct picture of the concrete phenomenon and things in students´ environment and also help students to „survive“ in the contemporary world full of different kinds of information.

The same importance as to identifying misconceptions can be assigned to sources of students misconceptions themselves. These knowledge enable us not only to work with misconceptions, but also to prevent from their formation.

According to many literary resources concerned with this subject matter it is possible to say, that misconceptions can be divided into two main groups according to the source:
1. non-school science misconceptions: misconceptions of this type start to develop early before children start to attend school, but their development continues also during the compulsory schooling and later. These misconceptions are connected mostly with daily life and experiences of pupils, apart from school experiences. All under mentioned sources should be included into this category:
- family [11], peers, media [12], literature for children and youths and other available sources of information including ICT, own experiences, using science terminology in everyday language [12], Boo (1998)[8].
2. school science misconceptions: misconceptions of this type are very closely related to compulsory school attendance of students. These misconceptions usually goes from the situations and experiences, which student can not acquire by other means. The sources of misconceptions, which come from school education can be: teachers [1; 9; 11; 7], textbooks [4; 8], ways of teaching [2; 5; 10].

School as a source of misconceptions? By no means?!

One of the roles of school should be also „burning the bridges“ of previous misconceptions, which pupils bring to the education process and which rooted mostly in familiar background of a pupil. According to the available studies it is evident, that also school itself very often create appropriate conditions for the formation of students misconceptions. School provides them a „matrix“ for formation of an experience which is essential for creating a misconception. Students then apply created experience to all similar situations, mostly those connected with school science. In this case, student is not confronted with uncertainties, so he keeps his conceptions and he works with them since he meets them for the first time.

The influence of the school in the process of the creation of science conceptions in students´ mind was proved by Thomson and Logue [11] who found out, that students in early school ages are able to provide more logical argumentations based on their intuitive knowledge than older students, who were confused with logical differences between intuitive and school knowledge.

Coming out from researches and studies investigating this topic it is quite amazing, that teacher was identified as one of the sources of students misconceptions. Teacher is very often the only scientist, who student can confront his concepts with and this teacher could be the one, who fails. This failure can not be necessarily reflected in the scientifically incorrect interpretation of different phenomena. It can have its roots also in insufficient or inadequate interpretations. Student is provided with incorrect experience and misleading opinion, which he accepts without reservations.

Results of realized researches also show, that in some cases teachers themselves do not understand science correctly and their knowledge contain some common misconceptions about basic scientific phenomena e.g. particulate nature of [7] or chemical reaction rates [6]. Other results of similar studies indicate, that teachers have also problem with distinguishing of symbols, models and pictures from real scientific interpretation of abstract concept or concrete phenomenon. [13].

In the connection it is possible to mention also problems in the future teachers education at universities. It was found, that future science teachers do not have correctly acquired basic scientific concepts. [1].

Another problematic element in school science can be the way, how scientific knowledge is acquired at school. School do not provide student with sufficient experience and proof. [12]; also insufficient teaching methodology and inadequate school aids used during the classes were denoted as a problem [2]. Students are not expected to work creatively and solving stated scientific problems. They are mostly expected to follow exact procedures and use algebraic algorithms [10], observe the phenomena with the result which is known before the experiment is proceeded. The science in this case is becoming a strictly controlled experimental activity, which has nothing to do with real life [5].

During the teaching process teachers very often prefer stated textbooks as the only resource of information with which student can work. However, some misleading information, that should lead to the formation of misconception can be also find in textbooks. The formation of these concepts is supported with incorrect work with texts or tables occurring in textbooks. Possible source of students misconceptions can be also inadequately selected or incorrectly interpreted pictures [4], which primary task should be to facilitate students´ learning or simple text.

Identification of possible sources of chosen misconceptions of primary school students about substances and their changes

This part of the article will be targeted mostly on the identification of possible sources of misconceptions of 143 students of 5 primary schools in Slovak republic. The age of students, who participated in this research was from 6 – 15 years (the research took place in 2007). Students´ concepts were examined through phenomenographic interview, in which the concept POE (predict – observe - explain) was used. We chose two stimulus situations were we used two series of experiments: 1. folded copper sheet put into the flame of a burner; 2. interactions between substances – salt, water, baking soda, vinegar. For better identification of possible sources of misconceptions about substances held by primary school students, also content analysis of science textbooks was made (we worked with textbooks, that were used by students at the time the interviews were in progress).

Overview of misconceptions and the identification of possible resources can be found in the Table 01 and Table 02 below:

Tab. 01: Non-school misconceptions of primary school students about substances and their changes

detected misconceptions	**possible source of misconceptions**
Particles, from which the substance is made have the same properties as the substance they come from	In most cases identified misconceptions have its origin in non school experiences of respondents connected mostly with sensual perception.
Substances can get lost during interactions	
Substances can be changed into another substances during interactions	
Particles do not move until they are moved mechanically by external source	
There are stronger an weaker substances. Weaker substances gives their attributes to stronger ones.	
Air is not composed of particles	
Liquids and gases are continual substances	
Solid substances are composed of particles, which looks like crystals, drops, points, powder, balls, squares...etc.	
Two substances can merge to one without chemical reaction	
The essence of substances stays unchanged after chemical reaction	
Ash doesn't have weight	
Evaporation is any escape of gas from liquid, and it doesn't have to be connected with the change of state	There were also identified some concepts, which are used in daily life and their meaning in these situations should be quite different from their meaning in science
Melting, fusion and dissolutions are used as synonyms	
Evaporation = formation of gas during chemical reaction.	
Water consists of two balls of oxygen and one ball of hydrogen (5th grade)	Available literary resources for children. Student himself declared, that he used encyclopaedia to gain this information.
Bubbles in mineral water are minerals	In this case it can be the effect of media (commercials) in which the concept of mineral is connected with water, but it can be also simply perceptual characteristic (this is mineral water what means, there should be minerals somewhere)

Tab. 02: School-science misconceptions of primary school students about substances and their changes

detected misconceptions	possible source of misconceptions
Atoms are visible when we are looking through microscope	In this case we identified the incorrect attitude of a teacher as well as textbooks, which are used by students. Students work with microscope at biology lessons for the first time. They have an opportunity to see what normally cannot be seen. Students can thing, these "microbes" are the smallest parts of a matter, or that they are something similar. It is also possible, that students did not understand the difference between model, picture and reality.
Atoms and molecules are situated in all substances together	This is almost from word to word what textbook says. Teacher should use adequate methodology to prevent the formation of the conception
Chemical bonds are dashes between atoms	Textbook and incorrect interpretation of teacher should be the source of this misconception. Pictures, which are mostly of symbolic character can be found in science textbooks that draw chemical bonds as dashes.
Chemical bonds always stay the same after substance changes anyhow (also in solution – NaCl as a lattice with balls of hydrogen and oxygen and chemical bonds as dashes between them)	In the textbook of physics there could be found a picture of NaCl as a lattice with green and red balls which are in a lattice. Text and picture without adequate teacher's explanation can lead to the formation of a misconception
Elementary particles of substances can change their size	Models are not understood correctly. Particles in this models are presented by balls of different size
Concepts: atoms, molecules and ions are used as synonyms.	Text in textbook is not so clear („Every substance consists of atoms and molecules"). The theorem needs to be completed by teacher's adequate explanation.
Attributes of the substance, which is considered to be stronger and which come into chemical reaction remain the same	In schools, acids are presented as the substances, which can dissolve (or break down) substances faster than water. Acids are dangerous and water is not. The attributes of acids are mostly demonstrated using H_2SO_4 or HCl.
Acids (vinegar) have strange attributes, they are able to decompose other substances	
Solution = solid substance dissolved in liquid	Teacher often choose one of the dissolution experiments (salt and water) to explain the nature of solution. Other experiments or examples are often ignored because of the lack of time at the lessons or difficulty of the demonstration.
chemical reactions = mix of substances	Chemical reaction is mostly presented as mixing of two substances which change their properties during the change. Symbolic transcript of chemical equation only confirm the misconception, because students very often do not fully understand the meaning of chemical formulas.

Results

In general we can say, that school science influenced mostly older students (6^{th} – 9^{th} grade), to whom science was presented by more concrete scientific facts, with the use of scientific terminology. Science, as it is presented in curricular documents and textbooks for younger students, is based mostly on everyday experiences and so they do not „force“ student to revalue actual conceptions. Older students are trying to explain presented phenomenon by using scientific terminology, however the conceptions are in some cases at the level of younger students. It was evident, that students (mostly 6^{th} – 9^{th} grade) are trying to answer the question according to the supposed expectations.

Misconceptions, that were detected during „copper sheet and fire“ experiment were mostly connected with daily life of students and with their experiences with burning in general. It was evident, that pupils were not confronted with similar experiment at school. On the other hand, while observing second experiment, students tended to use scientific terminology (dissolving, chemical reaction, atoms, molecules, etc.) and in general, they tried to explain this phenomenon more scientifically than before. Anyway, these scientific interpretations fail, when they have to come through something, they do not know from school (vinegar and water or vinegar and salt). In unknown situations students turns to their original misconceptions and experiences from daily life.

It is fact, that misconceptions from daily life are present also in school science. However, it is interesting, that misconceptions, which have their roots in school are not transferred to daily science so often. One of the possible reasons is, that school science is too concrete and special and so it is fixated to other concrete and special (scientific) experiences, with which students work at school.

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DETERIORATION OF THE LEVEL OF EDUCATION: RETRIBUTION FOR THE SCIENTIFICO-TECHNICAL PROGRESS

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When stating that a human factor is to be blamed for the recent frequent catastrophes and accidents, what is usually meant is an insufficiently prepared specialist or a professional with a deficient level of education.

Hence a logical question arises about quality and value of education, necessity of the perfection of the system of education, competition of the leading countries and unions, leading world universities, industrial companies for the specialist (scientist, manager), and finally for the dominant position and hegemony in the fast-developing world.

Education is considered to be the widest sphere of human activity in the modern society (industrial sphere is thought to occupy the first place). The modern system of education engaged more than 1 billion of students and 50 millions of educators at the beginning of a new millennium. Consequently, education, especially high education, can be viewed as an important factor of the social and economic progress. It is vital to understand that a human being is a primary and the most valuable asset to the modern society, capable of searching and mastering new knowledge and making non-standard decisions (Golubev). At present stage, one can perceive the limitation and danger of further human development via pure economic growth and enlargement of the technological power. It is an extensive way for the human progress, and this subject became exhausted long ago. The overall awareness is centered on the fact, that future development of the whole society and every country is, first and foremost, determined by the level of culture, knowledge of the human beings, rather than technological progress (Golubev).

Knowledge more often becomes a commodity in the modern society and as any commodity it requires presentable appearance and corresponding means of dissemination. Social development clearly indicates, that knowledge incarnate the source of income, innovation and means of its practical application. Since knowledge occupies a key position in the economic development, the role of education in the structure of social life is crucial. The acquisition of new knowledge, information, skills and abilities, approved orientation on their renewal and development become fundamental characteristics of the employees in the post-industrial economy. It is worth remembering that information and theoretical knowledge represent strategic resources of the country, and together with the level of educational development, they determine country's sovereignty and national security in many respects. Transition from industrial to informational society threatens to aggravate one of the most significant problems of the present – how to overcome underdevelopment in many countries. Informational hiatus lies over industrial hiatus creating double technological hiatus (Solovov: 1999).

Dispersion of education is as important as its fundamentality. Schools and higher educational establishments can choose their own educational programs. As a result, there appears competition between schools, programs, forms and methods of education. This approach cannot always be justified. There is also a tendency to internationalization of education, which makes schools responsible for acceptance or rejections of certain educational technologies.

Much has been said and written about the necessity to increase the level of education (internet sources (Oshchapovsky: 2010; Education at the close of the XX century: 1992; A role of higher education in modern civilization; http://ru.wikipedia.org/wiki.)), since its modernization represents an objective condition of the continuous scientific-technical progress of the society. A significant proof of this phenomenon is the fact that besides traditional education, there also appear new pedagogic technologies and tactics: phenomenological approach, interactional approaches, heuristic learning, programmed learning, context learning, active learning, didactic heuristics, learning based on different computer technologies etc. (Pedagogical technologies), as well as new organizational approaches and schemes (Bologna process).

It is widely recognized that the level of education characterizes the ability of an individual to perform a certain task and, generally, be engaged in any kind of activity. It is worth mentioning that education is a purposeful process of upbringing and training to the benefit of human being, society and state (http://ru.wikipedia.org/wiki); a process and result of mastering of the systematized knowledge, skills and abilities, which are necessary for practical activity (Ukrainian soviet encyclopaedia).

One can often hear about the worldwide crisis of education today.

According to our point of view, the experience of the countries and communities, which reached the highest level of education at a certain period of time, is very useful for analyzing and understanding this problem. Ancient Greece serves the classic example of the high level of education, since Ancient Greek Schooling produced a multitude of philosophers, statesmen, public figures, military leaders. Current generations still learn from their creative results and achievements. For example, the level of education in Athens in V c. BC was so high, that there was no illiterate man among the free citizens (Winnichuk: 1983). Although there were no formally organized schools, the achievements of the Ancient Greek mentors, pedagogues, teachers and philosophers serve a perfect example for the whole humanity in creation of various kinds of education: from pre-school to high education. The Ancient Greeks made the foundations of the modern pedagogy, which are currently effective.

The main principles of education in Athens were the principle of "*kalokagathia*", used by the classical Greek writers to describe an ideal of personal conduct, harmonious in mind and body, and the principle of "agonistic behavior", related to contest of both individuals and groups of individuals in various spheres of life, different situations in order to achieve the highest appraisal (Winnichuk: 1983). The well-known Olympiads also advocated those principles. The whole programs of study were based on them. However, different states (polices) had their own peculiarities, stipulated by various social needs. For example, the Athenians tried to maintain the balance between the intellectual and physical preparation of the ideal citizen (Winnichuk: 1983) . Thus, Athenians produced perfect examples of democracy, philosophy and sciences to the world. And, on the contrary, Spartans insisted on physical education, hence, follows the logical question: what kind of trace did Sparta leave in the world history?

In the modern world, full of scientific and technological advances, machines and technology took the whole burden of production and the necessity of physical preparation decreased giving way to mental preparation. Undoubtedly, one should have been looking forward to exponential burst of intellectual advances of the human beings, similar to those, which took place in the last third of the XIX – beginning of the XX centuries.

However, there is a significant crisis in the sphere of education at the end of the XX century and there are many indications about this phenomenon in the scientific literature.

One should point at the negative role of technology (informational, computer, device technology etc.), which on the one hand increased the possibilities of the human being, but on the other – decreased the requirements for human mental preparation, since technology assumed a role, which was primarily intended for the individual: role of the transmitter, prompter, advisor, interpreter, performer, accumulator of the knowledge and general information. And, since human muscles usually get weak and atrophied due to idleness, similarly the weakening of the intellectual activity leads to mental backwardness and gradual degradation of the individuality. After all, why should one study how to count if there is a computer or calculator for this purpose? Why should we learn how to think if the computer can choose an optimal variant and solve the problem? There is also no need in making analysis, if there are computer programs that will analyze and produce their own prognosis etc.

The ideas of Adam Smith, concerning the division of complicated tasks to simpler ones, division of labor to less complicated activity, which can be entrusted to less qualified specialist, thus compromising on expenses, took a negative stance in the scientific activity and education (Pavlov, Malysheva: 2000). For example, why should anyone learn how to titrate, weigh, extract in chemistry, if it is possible to take a sample of the material and make an input into the computer chromatograph (spectrometer etc.)? The device will provide the necessary result! Why should a teacher show a student real chemical experiment, if it is possible to show a multimedia video clip? It is enough for a person to have several simple skills instead of education and the reagents can be saved. However, there is no "sense" of substance, respect for a substance, there are no skills in handling the reagents and materials, and, finally, there are no skills of how to conduct a safe work at the laboratory or production site.

That is why such an abundant enthusiasms with technology does not promote the increase of knowledge and leads to the situations when even a not enough qualified employee can do a certain type of work with the help of prompters, advisors and assistants (including computer and internet).

Hence follows a logical conclusion of the student: why would anyone need a high quality education and why would anyone apply serious efforts to get it?

In this case, it is worth remembering the classical statement of B.F. Skinner "Education is something that will stay in your memory, when you forget everything you'd been taught." But, on the other hand, why does a student need memory, if there is a computer memory, Internet, mobile phone in order to get through with someone and obtain a ready answer? Why does a student need to study, strain his brains, read, think, analyze, compare? There are always other, more attractive ways to spend one's time.

The weakening of student's motivation to obtain deep, serious and high quality education takes place here. Some pedagogical methods also push to that kind of conclusion, presenting the process of knowledge obtaining as some sort of a game. But if someone is tired with a toy, it is simply thrown out… and forgotten! But the opinion about education, as something not very much serious and necessary always stays. And then, it is very difficult to instill interest to the process of knowledge obtaining, as a very important, heavy and necessary work, which requires serious attention, concentration, considerable mental efforts etc. And, the famous saying, "easy come, easy go" is very appropriate here.

In our view, the process of knowledge obtaining must be difficult and strenuous. If a dog does not run and does not jump, it will not find, and will not get a good food, it will only crawl and pick up strangers scraps, usually low in calories.

There follows logical conclusion of the problem: why are *teacher's* efforts needed? Why should the teacher be bothered to spend the time to get through to the student, if the latter can access ready information in the Internet?

Therefore, in our view, such new types of educational technologies as interactive, heuristic etc. will be of little help. Another approach is needed to provide the suitable level of education.

It is necessary to take into account other circumstances, which are not given due attention, namely: what will happen, if this fast and free access to information, knowledge is denied? What if someone blocks information sites and violates normal work of software either with the help of viruses or some other method, provides intentional misinformation to prevent the normal functioning of separate important individuals, organizations, maybe even countries?

To our mind, this all resulted in a certain crisis in the system of education. It might have even been done intentionally: the systems of education are in constant competition, informational space is full of such ideas as "be special", i.e. be different from anybody else although by means of a hole in the ear or pierced nose. And no one recommends, "be bright, knowledgeable and qualified" …

The question is, whether we will solve this crisis of education within the framework of existent technologies or by means of new ideas necessary for the organization of the educational process and post-educational systems of activity. To answer this question, the system of values in education, tasks, aims methods and perspectives should be revised.

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BIOACTIVE SUBSTANCES IN SUNSCREENS AND ENVIRONMENTAL POLLUTION. COMPUTER AIDED CLASSES

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Abstract

Students of "Chemistry of bioactive agents and cosmetics" course should have some experience in predicting bioactivity of chemicals applied in cosmetics, not only from experimental data but also from their molecular structure. The computational approach is one of the newest and fastest techniques developed in chemistry of bioactive substances.

Proposed computer-aided classes includes:

- the prediction of human skin permeability coefficients on the basis of physico-chemical parameters calculated according to the structure of chosen group of organic sunscreen ingredients
- the calculation of bioaccumulation factors of organic sunscreen ingredients in tissues of living organisms.

Proposed classes allow students to get acquainted with basic methods of calculation of pharmacokinetic parameters by use of freely available software and data bases only.

Introduction

Excessive exposure to the sun's UV radiation causes a number of human health problems, including sunburn, skin cancer or premature aging of the skin ("Skin and the Sun", 2002; Hoeijmakers, 2009). The UV spectrum is conveniently divided into three groups based on wavelength: UVC (100-290 nm). UVB (290-320 nm) and UVA (320-400 nm). UV filters are lotions, sprays, gels or other topical products that absorb or reflect some of sun ultraviolet radiation and protect human body against the detrimental effects of sunlight. Sunscreen works by combining organic an inorganic active ingredients. Both afford protection mainly against UVB rays in 280 to 320 nm range. Some sunscreens offer additional protection from UVA rays in the 320 to 400 nm range (Gasparro, Mitchnick, Nash, 1998; Robles Velasco, 2008; Serpone, Dondi, Albini, 2007).

Inorganic ingredients: titanium dioxide and zinc oxide have traditionally been used in sunscreens because of their ability to reflect and scatter UV light. In recent years, sunscreen producers have started using the nanosized forms of these compounds, which makes sunscreens more transparent, less viscous and lets them blend into skin more easily. Toxicological risk with use of nanoparticles in sunscreens was investigated (Newnam, Stotland, Ellis, 2009). Although inorganic sunscreens are gaining in popularity, organic sunscreens are still used in greater amounts. Organic sunscreens are often classified as derivatives of antranilates, benzophenones, camphors, cinnamates, dibenzoylmethanes, p-aminobenzoates and salicylates.

These aromatic compounds absorb a specific portion of UV spectrum that is generally re-emitted at a less energetic longer wavelength. The organic sunscreens are almost always used in combination because no single organic sunscreen agent, at levels currently allowed by Government Regulations, can provide a high sun protection factor (SPF). Moreover, individual organic sunscreens have a relatively narrow absorption spectrum that can be broadened by combination.

A sun protection factor (SPF) is a measure of how effective sunscreen on exposure to the UVB rays is.

SPF is given by:

$$SPF = \frac{MED_{\text{protected skin}}}{MED_{\text{unprotected skin}}}$$

where MED is the smallest dose (in J/m^2) of UV radiation that produces a delayed sunburn on skin. In equation “protected skin” means skin covered with 2 mg/cm2 of sunscreen and “unprotected skin” means uncovered skin. SPF can be also calculated as the ratio of time required for person’s protected skin to redden after being exposed to sunlight compared to the time required for the same person’s unprotected skin to redden:

$$SPF = \frac{t_{\text{protected skin}}}{t_{\text{unprotected skin}}}$$

Monochromatic protection factor (MPF) is the other parameter which is the measure of the amount of UV radiation blocked by sunscreen. SPF is the single value while MPF varies depending on wavelength. SPF is determined by in vivo methods (from sunburn experiments on human volunteers) while MPF is derived from lab measurements of UV transmissions. MPF is given by:

$$MPF = \frac{1}{\text{Transmitance}_{(\text{wavelength})}}$$

SPF can be computed by combining the MPF spectrum with the effective action spectrum (EA) for sunburn.

The SPF gives only partial information about the action of UV radiation on skin because invisible damage and skin aging are also caused by ultraviolet type A (UVA), which does not cause reddening or pain. Additional information for customers give BOOT star rating system. BOOTs star rating system is the method used to describe the ratio of UVA to UVB protection offered by sunscreen cream or spray (Table 01) (Robles Velasco, 2008).

Tab. 01: Boot’s Star Rating system and its relation with sunscreen claim for UVA protection.

Star category	Sunscreen claim related to UVA protection
No stars	No claim (too low for UVA claim)
*	Minimum
**	Moderate
***	Good
****	Superior
*****	Ultra

Skin permeation

Skin is composed of three layers: epidermis, dermis and subcutaneous tissues. The stratum corneum, the outermost thick layer (15-20nm) of epidermis is the main barrier that controls permeation of topically applied substances. The permeability is a fundamental problem in delivery of the cosmetics to and through the skin.

There is little evidence suggesting any active processes involved in skin permeation of sunscreen ingredients, therefore we suppose that, the underlying transport processes are controlled by simple passive diffusion. In this case permeability depends mainly on the lipophilicity of the molecule. The relative lipophilicity is usually expressed by its octanol/water partitioning (logP), which is assumed to be related to the membrane partitioning. There are many programs available today for calculating logP. In our computer-aided student classes the software from vcclab platform (www.vcclab.org) was used.

Lipophilicity described by the partition coefficient (logP) is the main determinant in analyte skin penetration. Molecules size must be also considered, because the dimensions of compound has essential influence on diffusion coefficient value. Molecular weight is commonly used as a measure of molecular size, but not the ideal one. One should also take into account the molecular volume depending on the shape of molecule. On the other hand, the molecular volume often depends on conformation of the molecule, which is difficult to establish, since not much is known about its conformal behavior during membrane transport.

The quantitative structure-activity relationships (QSAR) used for prediction of organic sunscreen permeability coefficient (Kp) are given below:

log Kp = 2,19 + 0,781 log P 0,0115 MW (Fitzpatrick, Corish, Hayes 2004)

log Kp = 2,771 + 0,769 log P 0,00734 MV (Barrat 1995)

Molecular volumes and 3D structures of investigated compounds were determined by use of Chemspider and Jmol free software (www.chemspider.com; www.jmol.org).

The results are presented in table 02.

Bioaccumulation

Chemical substances used in UV-filters exhibit low water and high lipid solubility, leading to their high potential for bioaccumulation. These carbon-based chemicals accumulate in tissues of living organisms, where they can produce undesirable effects on human health or environment at certain exposure levels.

The level of chemical bioaccumulation is usually expressed in terms of the bioconcentration factor (BCF) defined as the ratio of the substance concentration in organism (CB) and the environment (eg. water) (CW)

$$BCF = \frac{C_B}{C_W}$$

Bioconcentration factor (BCF) value is the result of four processes (ADME):
– A (adsorption) refers to the transport across a biological membrane into internal parts of organism;
– D (distribution) process, which occurs after absorption and concern the circulation the substance throughout the body;
– M (metabolism) it is generally detoxication mechanism, but in some cases intermediates or final product show more toxicity than parent compound;
– E (excretion) elimination of substance (or metabolites) from organism to waste

In general the experimental measurements of bioconcentration are time consuming and expensive. For this reason paid attention to estimation of bioconcentration by use of QSAR methods.

When measured bioconcentration factor are not available, the BCF, based on QSAR relationships, can be used to indicate the ability of compound bioaccumulation. For this purpose many various QSAR correlations are proposed.

In this paper, calculation of log BCF was conducted by use of equations given below:

- linear correlations give a fair approximation of BCF for nonionic, non-metabolized substances with logP in the range of 1 to 6 eg.:

log BCF = log P - 1,32 (Mackay 1982)

- linear relationships break down with more hydrophobic substances. For estimation of bioconcentration substances with log P> 6 more complicated correlations can be used: bi- or polynomial equation:
- bilinear model proposed by Binstein, Devillers and Karcher (1993):

$\log BCF = -0{,}164 \log P^2 + 2{,}059 \log P - 2{,}592$

- polynomial BCF model proposed by Connel and Hawker (1998):

$\log BCF = 6{,}9(\log P)^4 - 1.85 \bullet 10\text{-}1(\log P)^3 + 1{,}55(\log P)^2 - 4{,}18 \log P + 4{,}79$

The curve described by polynomial equation resembles a parabola with maximum log BCF value at log P = 6,7 and decreasing log BCF values for chemicals with log P> 6,7. However, the section of this curve between log P values of 3 and 6 is approximately linear and closely related to linear previously obtained for this range of log P values.

The results are presented in table 02.

Conclusion

The expected results of the applied teaching method were as follow:

- to acquaint students with a new methods of compounds bioactivity estimation by use of specialized software;
- to reveal of internet possibilities as a tool for solving biochemical problems;
- to give students the opportunity of gaining to experience with new methods of conducting scientific experiments with the use of computer

The advantage of this type of project is their scientific and creative aspect in comparison with classes in which students only memorize factual information. The main role of the teacher is to guide students through modern biochemical software and stimulate them to achieve further goals using new abilities.

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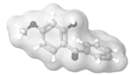
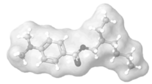
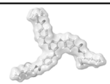
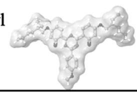
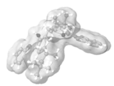
Tab. 02: The examples of the calculation results of sunscreen ingredients permeation and bioaccumulation parameters.

	3D image	log P	MV	log Kp		log BCF		
						linear	non-linear	
							quadratic	polynominal
Benzophenone-3		3,290	189,981	-2,246	-1,635	1,970	2,407	2,035
2-ethylhexyl dimethyl		5,040	281,241	-1,444	-0,960	3,720	3,619	3,863
Ethylheksyltriazone		13,260	728,677	-1,301	2,077		-4,125	3,889
Diethylheksylbutamidotriazole		11,820	664,775	-1,769	1,439		-1,167	1,112
Bis-ethylheksyloxyphenol methoxyphenyl triazine		7,900	552,789	-3,241	-0,753		3,439	4,167
2,2'-Methylenebis[6-(2H-benzotriazol-2-yl)-4-(2,4,4-trimethyl-2-pentanyl)phenol] (Biscotrizole)		11,430	567,730	-0,841	1,852		-0,483	1,027

INTERNATIONAL ACTIONS ON CHEMICAL THREATS REDUCTION

Czesław Puchała

Introduction

Chemistry has played a significant role in the dynamic civilization development around the world in 20th century and in the last years of 21st century. In civilization development chemistry, its industrial processes and manufactured products will still have a huge share. Unfortunately, civilization progress has caused unfavourable changes in natural environment. Against common opinion, chemical industry is not the only culprit in environment destruction – according to the statistics, it takes the third place. In the space of the last half-century, there have been many tragic chemical disasters which causes were described in different sources. At this point, it is worth to mention just briefly some of the disasters. In 1974, because of a breakdown in chemical plants in Flixborough, huge amounts of hot cyclohexane leaked from cracked pipeline. Two years later in Seveso, as a result of reactor explosion with trichlorophenol, there was area contamination with dioxins. In 1984 in Bhopal, there was a release of about 40 tons of methyl isocynate to the atmosphere. Whereas in the year 2000, large amounts of cyanide from mining-production complex in Baia Mare got through to Tisa and Danube. The last chemical disaster took place in 2010 in Hungary. Red mud was released after dam break in Ajka alumina plant. Chemical disasters resulted in fatalities (Bhopal), diseases (Seveso) or enormous waste in natural environment (Ajka disaster in Hungary). It was obvious that proper steps should be taken in order to minimize chemical threats.

Examples of actions to reduce chemical threats

Two solutions come up in order to prevent further natural environment degradation. First one is to resign from civilizational progress, which from obvious reasons, seems to be unreal. However the second solution is to take steps towards set-back of unfavourable changes in the environment. At first these actions consisted in pollution dispersion by building high chimneys which were emitting carbon dioxide and dust. The next step of pro environmental actions consisted in pollution reduction thanks to sewage treatment, desulphurization and exhaust fumes dedusting (techniques like end-of-pipe). Considering the influence of industry on environment, attention is concentrated on pollution coming from industrial processes and the fate of products itself, after they are used, is often forgotten. The latest approach includes the whole life cycle of a product "from the cradle to the grave", namely from raw material to utilization and product management after it is used. New technologies are implemented to minimalize unfavourable production influence on environment. In literature they are described as sustainable technologies, clean technologies or green technologies (Taniewski, 2004). A. Johansson points out a development of soft technology which uses renewable raw materials and provides biodegradation products (Johansson, 1997).

Since 80's a number of international initiatives were made to increase chemical safety (examples were described in (Burczyk, 2006). The International Programme on Chemical Safety (IPCS) was formed in 1980. Its aim is to support international cooperation to develop scientific basis for risk assessment for people and environment connected with application of chemicals. In 1984, on the initiative of Canadian Chemical Producers Association (CCPA), programme called Responsible Care was founded. The purpose of the programme was to oblige chemical companies to reduce the influence on natural environment, improve work safety and protect health. In 1989 the programme was accepted in Europe by the European Chemical Industry Council (CEFIC). Polish chemistry industry started to implement the programme in 1992.

Green chemistry plays a significant role in actions in favour of chemical threats reduction. The concept of green chemistry was born in 1991 and Paul Anastas is found as its initiator. The idea of green chemistry, usage possibilities and its educational role will be presented in further part of the article.

REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation entered into force in 2007. Its task is to register, evaluate and authorize (confirm) chemical products.

The idea of green chemistry

Green chemistry has been functioning for 20 years. It is long enough to summarize its achievements and describe perspectives of development. In the first place it is worth to mention some terminology issues and reasons for green chemistry foundation. Following synonyms are also used: chemistry friendly for the environment, clean chemistry, pro environmental chemistry or pro ecological chemistry. By definition "green chemistry is the design, development and implementation of chemical processes or products to reduce or eliminate the use and generation of substances hazardous to human health and the environment" (Ritter, 2001). Green chemistry should not be identified with sustainable chemistry. Philosophy of green chemistry is based on 12 rules which were formulated by Anastas and Warner (Anastas and Warner, 1998). While analyzing assumptions of green chemistry, a question arises: are there any criteria which allow to accept the chemistry as "green"? There are effectiveness measures of green chemistry and as example we can be enumerate: environmental factor (E-Factor), environmental quotient (EQ), atomic effectiveness (AE) or life cycle assessment (LCA). Green chemistry should be treated as one of action forms which aim to reduce environment threats. At the same time green chemistry signs in the scope of sustainable development. Achievements of green chemistry are put into practice: new methods of synthesis with the usage of original and selective catalysts, synthesis without participation of organic solvents, application of new reactive media, new technologies of reaction management and usage of renewable raw materials (Burczyk, 2006).

Educational role of green chemistry concept

There has been a negative image of chemistry and its products in the society. It seems vital to change this point of view and introduce issues connected with possible threats but in right proportions. Popularization of green chemistry concept should serve a purpose. The knowledge about this subject should be included in chemical and ecological education. The subject matter of green chemistry can be found in the university curriculum. Its implementation goes double-track: it can be included in chemistry subjects curriculum (for example in general chemistry, organic chemistry or technology) or it can be treated as a separate subject. In case of separate subject, there are lectures, conservatories and laboratory classes. But green chemistry can also be present as a subject on non-chemistry specialization as it is at Jan Długosz University in Częstochowa where on specialization Environmental Protection conversational lectures devoted to green chemistry are held.

Already mentioned life cycle assessment (LCA) allows to describe environmental nuisance of a product. It contains the whole product life cycle, starting from raw materials excavation through transport, production and recycling. Life assessment LCA can be the subject of school educational projects and benefits coming from its usage were described in a paper (Szewczyk and Nawrocki, 2007). The authors of the project proposed different subjects which can be realized within LCA strategy (for example "From hard coal to electric energy", "From iron ore to everyday products", "Why does poluthene rule our life?"). Mass media, which unfortunately contribute to present false image of chemistry, can play an important role in popularization of the issue among society.

Research results

The aim of the research was to estimate students' knowledge regarding the issue of green chemistry. A survey was chosen as a research technique and a questionnaire was a research tool. 41 chemistry students and 51 environmental protection students gave answers to questions included. The first question referred to students associations with chemistry and its products. More than 82% of environmental protection students and more than 73% of chemistry students have ambiguous associations because chemistry and its products are necessary in life but they can also be harmful. By answering the second question, the students were to point out the place which, according to statistics, chemistry takes in a destruction of natural environment. The most pointed out second place which is not true. More than 58% of chemistry students and more than 37% of environmental protection students cannot imagine life without chemical products (question no. 3). All chemistry students and more than 86% environmental protection students encountered the term “green chemistry” (question no. 4). More than a half of chemistry and environmental protection students knew when the term “green chemistry” occurred (question no. 5). By answering question no. 6, the students were to give synonyms for green chemistry. The most chose chemistry friendly for the environment (82,9% chemistry students and 94,1% environmental protection students) and clean chemistry (accordingly 63,4% and 56,9%). The concept of green chemistry was known to almost 88% of chemistry students and to more than 80% of environmental protection students (question no. 7). Almost 53% of environmental protection students and almost 49% of chemistry students think that green chemistry can contribute to environment protection (question no. 8). The next question related to green chemistry usage in biotechnology. Almost 88% of chemistry students and more than 76% of environmental protection students think that green chemistry can be used in biotechnology. The last question concerned popularization of green chemistry concept. The students have chosen following ways: mass media (85,4% chemistry students and 76,5% environmental protection students), dissemination of green chemistry knowledge among workers of chemical industry (accordingly 80,5% and 56,9%) and as a subject on chemistry studies (65,9% and 51%).

Conclusions

A lot of international initiatives were made in order to reduce chemical threats. Green chemistry is among them. As the conducted research shows, the issue of green chemistry is known to chemistry students but in a lower extent to environmental protection students. Popularization of green chemistry concept can be contributive to change the negative chemistry image in the society.

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MIND MAPS IN CHEMISTRY EDUCATION: POTENTIAL AND LIMITATIONS

Martin Rusek, Ondřej Solnička

Introduction

Penetration of information and communication technology (ICT) into society had recently brought an urgent need to rethink former educational approaches. Not only there is more information than ever before, but also their value changes as they are findable more easily.

The former educational goal – to remember – has changed considerably. It is more important to know about trusty sources of information and to use the information properly than to remember and transfer it in the exact wording.

The value of information is not the only change. Progress has been made in description of human learning process too. The theory of meaningful learning (Ausubel, 1968) has been further developed leading to a change from instructivism to constructivism (see Tonucci, 1991; Tracey, 2009). Further changes have been accelerated by the development of psychodidactics (see Škoda & Doulík, 2011).

These findings had led towards mind map development by Tony Buzan. Mind maps are a method of representing and classifying information in accordance with brain human processes knowledge (Buzan, 1989). Despite this field has recently been developing (Carnot et al., 2003; Fisher et al., 1990; K. E. Chang, Sung, & Chen, 2002; K.E. Chang, Sung, & Chen, 2001; Martin, 1994; Novak, 1990; Weideman & Kritzinger, 2003), quickly changing potentials of ICT in mind maps creating leave room for further work. In addition, although the concept of mind mapping is well described, there have not been many papers published for chemistry education. This gap is partly filled by this paper.

1. Model TPACK

For a distinct description of contemporary position of education, the PCK (Pedagogical Content knowledge) model (Shulman, 1986) advanced into TPACK (Technical and Pedagogical Content Knowledge) (Mishra & Koehler, 2006; Thompson & Mishra, 2007) will be used. It is obvious that with growing quantity of information the Content dimension spreads. Forceful development in the field of science naturally brings a lot of new information into particular science school subjects. Fortunately, development in biometric science along with general need of educated society has been bringing progress to the Pedagogical dimension as well. When performed using digital technology, the intersection of all three TPACK model sets is fulfilled, hence educational process may be optimized.

2. Mapping

In the literature, two terms are usually used to describe the maps: mind map and conceptual map. Ming maps use one main concept as a starting point or a "central word" and further up to 10 other sometimes called "child words" are placed around enabling further spread (see Buzan, 1989). Conceptual maps are "two-dimensional representations of cognitive structures showing the hierarchies and the interconnections of concepts involved in a discipline or a subdiscipline" (Martin, 1994). These maps usually consist of network of nodes.

The only difference between the two types is only one central word (mind maps) and more central words (conceptual maps) (Weideman & Kritzinger, 2003). Another insight suggests concept maps are a visualization of pure concepts whilst mind maps stress not only concepts but also relations among them.

2.1. Advantages of mind maps

Authors of this paper along with others (Allen et al., 1993; Carnot et al., 2003; Weideman & Kritzinger, 2003) list these advantages of mind or conceptual mapping in education:

- help users distinguish between essential and nice-to-know outcomes,
- set ways of thinking are challenged (preparation for modern methods),
- help identify concepts which are key to more than one discipline,
- provide a basis for discussion,
- support a holistic style of learning (shows complexity of science),
- increase the efficiency of information retrieval,
- enhance text comprehension,
- increase students' understanding of topics,
- bring order to complex tasks.

Another significant advantage of mapping lies in complexity of intelligences (Gardner, 1999) and senses students use when creating a map. For example: compiling a map allows a graphically-gifted student (who may not be successful in chemistry) experience success, whilst student with disposition of logical-mathematical intelligence will excel in sorting "child words" around the central one. Important factor is that both of these students not only do what they are good at, but they also learn from their peers thus develop other intelligences.

2.2. Disadvantages of mind maps

In the literature (Chang et al., 2001, 2002) these disadvantages are listed:

- It is inconvenient for a teacher to provide appropriate feedback to students during concept mapping.
- The construction of a concept map is complex and difficult for students, especially for novice students.
- Concept maps constructed using paper and pencil are difficult to revise.
- The 'paper-and-pencil' concept mapping is not an efficient tool for evaluation.
- Frustrates novice students.
- 50% of the junior high school students felt that using concept mapping as a learning tool was difficult.

Authors of this paper also see a disadvantage in students keeping the maps as they usually do not use their notebooks but extra papers and loose them. Also, less creative students spend less time creating a map and disturb more creative students who are engaged in their work.

2.3. Creating mind maps

It is necessary to help students develop their mind-mapping ability thereby not to expose them to frustration etc. Practice also illustrates that training cuts difficulties caused by handwriting, use of space etc.

Basically there are two types of approach towards mapping: "construct-on-scaffold" and construct-by-self (Chang et al., 2002). The 'construct-on-scaffold' method is derived from the „completion strategy" (Paas, 1992; Van Merrienboer, 1990) or the „fill in the structure"(Naveh-Benjamin, Lin, & McKeachie, 1995). The construct-by-self strategy grants students more autonomy once they are familiar with the mapping process enough. They also help teachers avoid possible overload on students (Paas, 1992).

Using scaffolding has more use in certain fields: „The experimental results indicated that the 'construct-on-scaffold' system had more positive effects on students' biology learning than those of the 'construct-by-self' and 'paper-and-pencil' methods." (Chang et al., 2002). The fact that learning through a scaffold produced the best learning effects may result from the reduced workload of the scaffold aid. It is evident that in certain school subjects such subject matter requires students' understanding of classification. Mapping is an effective method to be used.

Chemistry, Biology but also even History, Literature etc. are such subjects.

The students using the 'construct-on scaffold' version outperformed the students using the 'construct-by-self' version, yet the 'construct-by-self' version evoked the highest percentage of students who wanted to use concept mapping in their future study tool(Chang et al., 2001). It seems that this map form is a good start for students.

2.4. Mind maps editors

Students can draw the maps either by hand or use an application. Obviously, some students enjoy themselves more when drawing the map of a paper adding sketches etc., whereas some students' by-hand compiled maps are just confusing babel of bubbles. There is no one and only way to create mind maps. Nevertheless a research revealed that group using a computer created more complex maps than the group that used paper/pencil (Royer & Royer, 2004). Advantage of computer-created maps is also in their keepability, shareability and also editability. From this reason, attention was paid to mind-mapping software.

Possibilities of these editors have changed considerably since Martin's (1994) editors review. The most significant feature was brought with possibilities of web 2.0 and modern sharing, exporting, shared editing etc.

From a list of 25 online and offline applicable and tested editors three were examined deeper:
- Spiderscribe (http://www.spiderscribe.net/),
- MindMeister (http://www.mindmeister.com),
- Bubbl.us (https://bubbl.us/).

These were chosen on the basis of their popularity among users in the world and on the authors' consideration. The most important factor was usability of an editor and accessibility in schools. To use these, Flash is required. All of the chosen were designed to work on computers, laptops or tablets. Despite of some differences, the usage of all is very intuitive. Main differences consists in the number of maps a free account can contain, number of used "child words" etc. Very important tool is changing fonts and colours in order to make the map lucid. All three editors proved to be a sufficient tool not only for a Chemistry classroom.

Conclusion

With more and more information people are overwhelmed with, the content of school subjects swells too. Sorting information and understanding relations among them is still more demanding. Fortunately modern science and also pedagogy brought Tony Buzan to developing mind mapping as a method of sorting concepts similarly to the way human brain works with it. Proven effective, this method has spread and has been further developing. Nowadays with the development of ICT, creating mind maps is easier than ever before.

Chemistry classrooms may benefit from using mind maps in many ways and not only in classic setting. Mind mapping is an efficient way how to store information during any lesson, after brainstorming at the beginning of IBSE or project-based learning etc.

Although the authors of this paper recommended only three mind map editors, in their future work they are going to describe the rest of analysed editors as the future of mind mapping is approaching. Therefore Chemistry teachers need to be prepared for that too.

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SUPPORT FOR USE OF PROBEWARE IN SCIENCE FOR TEACHERS AND PUPILS

Petr Šmejkal, Eva Stratilová Urválková

Introduction

The interest of students in science and technical branches has in many countries decreasing tendency (Osborne et al, 2008). For example, in the Czech Republic, the science knowledge dramatically decreased between years 2006 to 2009 and the deterioration was the second worst among the countries involved in research (Palečková et al, 2010). There is a variety of reasons, however, one of them is that the science subjects, especially physics, chemistry and mathematics, are considered to be very complex and academic. To enhance the situation, it is important to introduce more visual concepts (presentations, illustrations, experiments, interpretations etc.) into science education as well as to make a better link between the education and common and professional life. These two approaches come together in microcomputer based laboratory (MBL). MBL, today mostly called probeware, is one of various ways how to support science education. Its advantages in science education are immediate feedback during measurement, usually low consumption of chemicals and other equipment and, especially, a way of experimental work which reflects real work in current science laboratory. The variability of measurements can be fruitfully employed in inquiry based methods. Barnea et al. (2010) refer that using probeware together with inquiry increased the number of students in science course for advanced students. The disadvantage of probeware is still lack of suitable educational materials, lack of experience and pedagogical knowledge and possible technical problems that can discourage teachers. Hence, there is an effort to create appropriate teachers' and students' materials regarding probeware so that teachers can have the theoretical support when implementing new educational tool into science education. Such materials were/will be prepared in a framework of projects Přírodní vědy a matematika na středních školách v Praze (Science and Math at secondary schools in Prague, Faculty of Science, Charles University in Prague) and COMBLAB (2012). At the same time, laboratory courses for teachers and pupils were held and evaluated. This contribution presents results from last five courses for secondary school students. Contributors tried to find out students attitudes to probeware and arranged courses.

Methods

An orientation questionnaire research was used to evaluate attitudes, opinions and expectations of students related to probeware. The questionnaire was filled by the students after a laboratory course oriented to general chemistry phenomena during which probeware was used as a main didactic resource. The laboratory course was focused on pH measurements (including calibration), conductivity measurements related to water analysis (conductivity of water, conductometric titration), and spectroscopy measurements (qualitative and quantitative analysis). The questionnaire contained 12 questions, few of them (3) were targeted to personal information as age, sex and class, the rest (9) was focused on opinions and attitudes to instruments (probeware) as advantages and disadvantages of the instruments (3), acquired knowledge (3) and organization of the course (3). All the questions were open, so that wider variability of the answers could be acquired. Consequently, the answers were analyzed and sorted into groups of the same or similar meaning and converted into charts describing percentage ratio of the answer group. Experimental systems Pasco and Vernier with appropriate sensors (pH, conductivity, spectrophotometer), USB converter (USB link or Go! Link) and computer with control software (DataStudio by Pasco and/or Logger Lite by Vernier) were used for the lab course.

Sample

The study group consisted of totally 99 secondary school (gymnazium) students (66 females and 33 males). These students were divided into two groups. The first group - "regular class" - consisted of 59 students (41 females and 18 males, age was 15 17 years) without any preferences to science subjects. The second group – "science class" – included students of science seminar held at school for students with preference to science subjects. In this group, there were 40 students, 25 females and 15 males, 17-18 years old. None of the students has worked with the probeware before. The students´ subject preferences were verified by answers to one question of the questionnaire related to the favorite subjects of the students. The results confirmed that students of the "science class" mostly preferred science subjects (biology, chemistry, mathematics) while students of the "regular class" preferred languages (English, Spanish, French,…), social sciences and Czech language.

Results and discussion

In general, the answers of males and females did not differ very much which confirm our previous results (Šmejkal et al, 2011) that gender is not a key factor in using probeware in science subject education. Hence, the expectations, attitudes and opinions as well as handling with probeware are similar for both, boys and girls.

The answers to the first ("What was a goal of the lab exercise?") and the second question ("What are the advantages of employment of instrumental techniques in chemistry education?") reflected students attitudes and expectations. Regarding the first question, the most frequent answers referred to measurement of some quantity (about 50 %), to learning to work with instruments (more than 40 %) and to improvement of chemistry knowledge (more than 40 %); purpose and didactic aspects of using of probeware in chemistry education were also mentioned. Hence, the answers indicate that students mostly consider and expect educational as well as practical benefits of the lab course. In the case of second question, more than 35 % students (see Fig. 01) appreciated precision of the probeware.

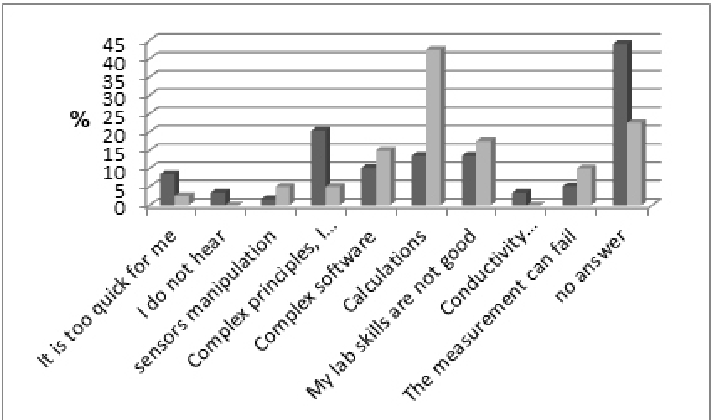

Fig. 01: Students´ answers to question "What are the advantages of employment the instrumental techniques in chemistry education?" – dark grey – "regular class", light grey – "science class"

This answer reflects students' positive attitude and uncritical confidence to modern technologies. Students often rely on the results provided by instruments (and computers) and do not consider the factors which can influence the results (human factor – e.g. lab skills, quality of sensors, weather conditions, software problems, etc.). It can lead to incorrect implications and, hence, it is really important to stress the attention to correct interpretation of measured data, theoretical background and interpretation of factors which can influence the measurement and its results. About 25 % of students also mentioned that the measurement is quick and there is a simple and user friendly handling with the probeware and control software. It indicates that students working with appropriate and suitable probeware system can focus on the nature of followed phenomena, better than to the control of system. That is important for implementation of suitable probeware system in science subject education. Some students also mentioned didactic effect of the probeware. More than 10 % mentioned that they can acquire new knowledge, and more than 10 % of students presented employment of instruments in common "real life" laboratory and in common life. As presented in Fig. 01, the answers of both groups ("regular class" – dark grey vs. "science class" – light grey), and, to some extent their ratios, were similar, nevertheless, the "seminar class" students mentioned more advantages, e.g. extended features of probeware for chemistry education and that the experiments made using probeware can be more visual than traditional experiments (always more than 10 %). That implies that students of "seminar class" can distinguish, expect and, probably, apply more possibilities provided by the probeware than the students of "regular class". In the case of possible disadvantages (question "What are the disadvantages of employment of instrumental technique in chemistry education?"), more than 20 % of students mentioned that there are no disadvantages or did not write any answer (about 12 %). That supports statement that handling the probeware is simple and measurement is user-friendly. On the other hand, the measurement showed to be complex for more than 25 % of students. Deeper analysis of the answers showed, that the "complexity" is more related to management of the measurement overall, not to handling the devices and measurement technique. During the course, students have to coordinate a lot of actions in a limited time: sensor handling, controlling the measurement by software, application and/or gathering lab skills, understanding the theoretical background and interpretation of the results. That can be stressful and evoke the feeling of complexity. This fact should be taken into consideration in organization of laboratory course and related worksheet preparation. Hence, teacher should let "some space" for students to manage not only the measurement and data interpretation, but also to acquire some new lab skills, understand the background etc. Some fraction of students (ca 7 %) also mentioned high price as disadvantage. It is not surprising, nevertheless, the fraction is relatively small and price does not seem to be a principal factor for students, which would hinder employment of probeware in science subjects education. Although, in the most cases, we did not observed any significant difference between the "regular class" and the "science class" in answers to the question related to disadvantages of instrumental devices, the "regular class" students mentioned more than the "science class" students that they can break the device or the sensors (see Fig. 02), while "science class" students wrote that "The measurement can fail". In this answer, a higher self-assurance in usage of probeware of "science class" students was reflected, which was also confirmed by a test of acquired knowledge (3 questions), in which, the students of "science class" showed better results.

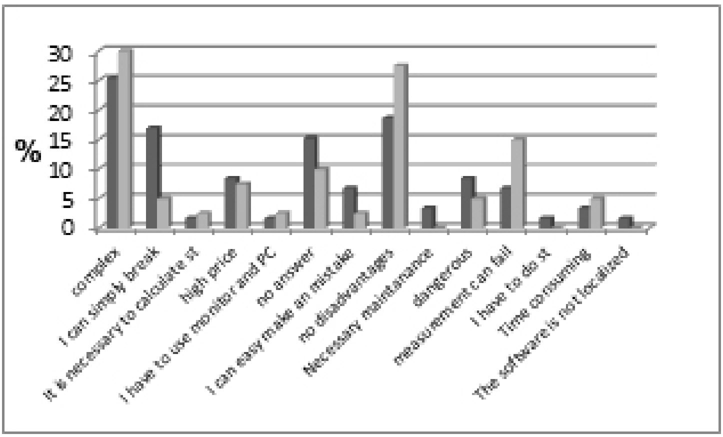

Fig. 02: Students´answers to question "What are the disadvantages of employment the instrumental techniques in chemistry education?" – dark grey – "regular class", light grey – "science class"

The results also showed that students of “science class” were more familiar with the content and scientific background of the lab course and with a background of technical function of probeware and they could better deduce their strong and weak points. On the other hand, the acquired knowledge was not perfect in the case of “science class”, because only about 15 % of students of this group answered correctly the questions related to the course and 55 % answered correctly only one or two questions. 30 % of students of the “science class” did not answered or answered incorrectly all the questions. Nevertheless, in comparison to the answers of “regular class” (6 % correct answers, 28 % not exact answers and 66 % wrong or none answers), preference in science subjects in the “science class” was shown. Not very good results in acquired knowledge, as well as in the group of the “science class”, support the previously stated idea that the content of the lab course is rich and students have to manage not only to understand the phenomena and/or theme studied, but also a lot of other operations including lab skills, understanding of theoretical background, measurements specifics etc. It is also important to connect the findings together to understand the studied phenomena and, unfortunately, the Czech students are not in general able to do that. Hence, it is difficult for students to remember and connect together all the important knowledge acquired during the lab course and, consequently, they fail in a test. That stress attention to good preparation and organization of course, including related things as worksheets, warming up activities, questions etc. with regard to previous related knowledge of students in order to minimize all the mental as well as physical activities not related to the studied phenomena. The students were also asked to express problems that they faced during the measurement (“What were the problems during the measurement? – see Fig. 03”).

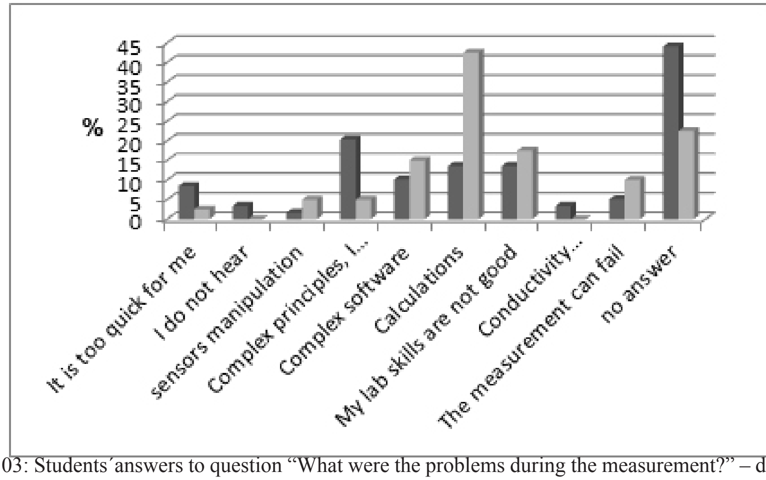

Fig. 03: Students´answers to question “What were the problems during the measurement?” – dark grey – “regular class”, light grey – “science class”

More than 40 % of “regular class” students and more than 20 % of “science class” students did not provide us with any information. The higher percentage of blank fields regarding this question for “regular class” students can be explained by a lower motivation and lower involvement in the measurement due to their preferences. These students were not able to fully identify their weak and strong points; therefore the spectrum of answers was not as wide as in the case of “science students”. About 40 % of students of the “science class” reported problems with calculation, which was more than in the case of the “regular class” students (about 12 %). On the other hand, about 20 % of the “regular class” students mentioned as a problem “complex principles” of measurement in comparison to around 5 % of “science seminar class”. The differences in percentage can be explained in the following way: the students of “regular class” have probably poorer theoretical background than the students of “science class”, hence, the problems are more complex for them (including, to some extent, “calculation” problem) and they mention more "complex principles" to cover their obstacles appeared during measurement. The "science class" students mention more particular obstacles like calculations and sensor manipulation that are identified by them. On the basis of lectors' observations, calculation is a problem for majority of students, but only few students were able to identify it. A significant part of students of both groups (about 20 %) also reported that their lab skills are not good. That was also confirmed according to observation of lectors, moreover, it can be estimated that insufficient lab skills were observed in both student groups. In this observation, decreasing tendency in number of laboratory courses and activities held at Czech schools manifested itself. It can be concluded that there has to be paid some attention to lab skills training before involving probeware in Czech school laboratories. The answers from previous questions were also reflected in the question "What would you improve during the laboratory course?" More than 35 % of "science seminar" students and 25 % of "regular class" students asked for easier and slower lab course, which showed that they had problems with managing the work. In a feedback, majority of provided courses were evaluated by the lectors as too overestimated compared to students' skills. Although lectors responded to actual situation and tried to adjust the tasks during the course, the course overall seemed too complex for students. This misunderstanding and inappropriate course level was mostly caused by incoming teacher's unreal or excessive demands. They presented their students to lectors as experienced students, but lectors revealed the truth until they started the course. On the other hand, in the questionnaire, more than 20 % of "science class" and 10 % of "regular class" students wrote that they do not want to change anything. Quite high percentage, 35 % of "regular class" students and more than 20 % of "science class" students did not answer anything. For "regular class" students, it can refer to low motivation for science at all. Some students (10 % in both groups) would prefer more workspace, so that more members of the group could personally handle the devices.

Conclusions

The results of the orientation questionnaire inquiry showed positive attitude of majority of students of the both followed group ("regular class" and "scientific class") to probeware measurements. Some students are also able to identify the practical as well as didactical benefits of probeware. On the other hand, the results of testing of acquired knowledge accompanied with the answers to the particular questions of the questionnaire showed that during the course, students have to coordinate a lot of actions in a limited time: sensor handling, controlling the measurement through software, application and/or gathering laboratory skills, understanding the theoretical background and interpretation of the results. Hence, the content of the probeware lab course should not be overestimated and students´lab skills, previous knowledge, theoretical background and other factors influencing the course have to be taken into account for preparation of the lab course with probeware.

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STEREOSCOPY IN CHEMISTRY EDUCATION – NEW EDUCATIONAL MATERIAL AND ATTITUDES AND OPINIONS OF TEACHERS AND PUPILS

Petr Šmejkal, Jan Břížďala

Introduction

Stereoscopic projection is a method of three-dimensional (3D) imaging on a two dimensional (2D) plane. Human vision uses several cues to perceive relative depth in scene in front of him. One of the most important is stereopsis, a binocular cue, i.e. such, where use of both, the left and right eye, is necessary (Laubr, 2006). Binocular vision of a scene creates two different images of the scene, one by left and one by right eye, depending on different angles given by position of eyes on a head. Consequently, brain composes the images together and forms a 3D image with depth information. Stereoscopy uses the corresponding strategy to induce a 3D vision and presents two offset images separately to the left and right eye of a spectator. These two-dimensional images are then combined in brain to give the perception of 3D depth (Wikipedia, Stereoscopy). There is a variety of stereoscopic techniques, among them, anaglyph, passive and active stereoscopies are frequently used (Laubr, 2006). In the case of anaglyph, each eye's image uses filters of different (usually chromatically opposite) colors, i.e. red and cyan. Anaglyph 3D images contain two differently filtered colored images, one for each eye. When viewed through the "color coded" "anaglyph glasses", each of the two images reaches one eye (because the second image is filtered by corresponding filter of glasses), revealing an integrated stereoscopic image (Wikipedia, Anaglyph 3D). Passive stereoscopic visualization is provided through two images which are projected superimposed onto the same screen through polarizing filters or presented on a display with polarized filters. The viewer has eyeglasses which also contain a pair of opposite polarizing filters. As each filter only passes light which is similarly polarized and blocks the opposite polarized light, each eye only sees one of the images, and the „depth" effect is achieved (Wikipedia, Stereoscopy). Active stereoscopic technique uses shutter glasses which are synchronized with a projector. The projector very fast switches the images (originally acquired under different angles corresponding to conditions of the binocular vision) for left and right eye and, every frame, the shutter glasses block the light to pass through to the eye which should not see the image. Hence, every eye can see just the image specified for it and consequently, the illusion of depth is formed (Wikipedia, Stereoscopy).

Of course, the stereoscopic projection has a potential to be employed in education, especially in technical and scientific subjects (civil engineering, construction, 3D structures in chemistry and physics etc.), where the additional information about depth can be important or principal for understanding of taught theme. Also, in the cases where "more believable" effect of the projection is needed to be evoked (explosions, various apparatuses, safety information, stories, …), the stereoscopic projection can be usefully employed. The advantages and benefits of employment of stereoscopy in education are mentioned by variety of authors (Dejl et al, 2010; Kooi et al, 2010; Burewicz et al, 2002; Trindade et al, 2002), of course, in chemistry, it can be used for proper 3D visualization of chemistry structures (Trindade et al, 2002; Burewicz et al, 2002; Terriberry et al, 2002; Stockert et al, 1994; Glick et al, 1992; Goddard et al, 2007; Rozzelle et al, 1985; Abraham et al, 2010). On the other hand, some authors pointed out that stereoscopy is (in education) beneficial only in some cases and if it is well and meaningfully implemented (Litwiller et al, 2011). Hence, there is a lot of work in technical, methodical and meaningful implementation of stereoscopy into secondary school education. Unfortunately, some factors hinder the penetration of stereoscopy into secondary school education. In past decades, the price was a limiting factor, nevertheless, last year, the prices of corresponding technique decreased to a reasonable level. Thus, nowadays, the limiting factors for employment of stereoscopy in education are lack of suitable educational materials, lack of pedagogical knowledge and lack of technical experience among teachers. In addition to that, there is a question whether teachers and pupils can distinguish potential and benefits of stereoscopic projection in education and support employment of the stereoscopy in education. Also, there is a question whether, vice versa, the stereoscopy can support the education process. Concerning the mentioned factors, this contribution is focused on making new stereoscopic content – short videos of selected chemical experiments and creation of a new database of the stereoscopic videos of the chemical experiments and, consequently, evaluation of the prepared videos and the database among primary and secondary school teachers and pupils. We also evaluated the opinions and attitudes to stereoscopy in chemistry education at primary and secondary schools by their teachers and pupils.

Methods, sample and equipment

The attitudes of teachers to stereoscopy in school education and quality of prepared database of stereoscopic videos of chemistry experiments was followed using web-based questionnaire containing totally 19 questions (7 – „yes/no“ type, 1 - free comment, 11 - 5 point bipolar scale). 337 secondary school teachers were asked for cooperation by e-mail with database characteristics. 33 teachers (i.e. about 10 %) responded and filled in the questionnaire.

The attitudes of pupils and their evaluation of few prepared stereoscopic videos was tested using short questionnaire, which was filled in by pupils after the projection of few stereoscopic videos. Our sample contained 92 pupils of primary school and 19 pupils of secondary school, the questionnaire consisted of 5 questions (1 - multiple choice, 2 – „yes/no“ type, 2 – 5 point bipolar scale).

We also attempted to roughly evaluate the effect of acquired knowledge during stereoscopic projection. 92 students of primary school were divided into two groups (47 and 45 pupils). The first group followed the stereoscopic presentation (video „Smoking” – Břížďala et al, Kouření – stereoskopický snímek), the second group attended a lab course with lab activities focused on experiments related to smoking (Evidence of substances in cigarette smoke – Šulcová et al, 2011; Evidence of thiocyanates in salivas – Hájková et al, 2008; and Cigarette pyrolysis). I addition to that, 19 pupils of secondary school attended educational course held with “classical approach” (presentations). After the courses, the pupils of all the groups were tested using a written test with 9 questions (multiple choice).

For video recording, camcorder Panasonic HDC-SDT750 with 3D adapter or two camcorders Sony HDR-XR105E synchronized using V3 A/VR cable via LANC connectors were used. The post-production of recorded videos (editing and finalization) was done using Adobe Premiere Elements 10 or Adobe After Effects CS4 software with plug-in DepthQ Combine installed on a computer with CPU Intel Core i5 (four cores), 2 GB RAM, 2 HDDs 1 TB, 8x USB, graphic card NVIDIA Quadro FX 580 and stereoscopic monitor Samsung SyncMaster 2233RZ as a display. The video recording and post-production was done on the basis of experience described in references: 3D Journal (Točte snadno vlastní filmy), FysWeb (Návod na tvorbu 3D fotografií a videa), Břížďala et al, 2010 and Břížďala et al, 2011.

Stereoscopic presentation in a class was provided by the system consisting of notebook Acer Aspire 5747DG, projector Acer H5360, 15 pieces of 3D glasses NVIDIA, emitter NVIDIA GeForce 3D Vision and stereoscopic players - Stereoscopic Player by 3dtv.at and Stereoscopic Player by NVIDIA. For presentation of stereoscopic videos through web (in web page based questionnaire), YouTube.com player providing anaglyph, based on HTML 5 and side-by-side projection was used.

Results and discussion

New database has been prepared and published on websites www.studiumchemie.cz and www.chem-web.info/cz/chemie-pro-ss. The database comprises more than 25 stereoscopic videos (general chemistry, inorganic chemistry, organic chemistry, biochemistry, forensic chemistry), with total length of about 1 hour.

The results of monitoring of attitudes of teachers and quality of prepared database of stereoscopic videos of chemistry experiments is summarized in charts bellow in figures 01 (attitudes to stereoscopy in education) and 2 (evaluation of the database of videos of chemistry experiments). The results of orientation questionnaire inquiry showed that majority of teachers (more than 80 % strongly agree or agree) as well as pupils (more than 80 % agree or strongly agree) support employment of stereoscopy in school education. The positive attitudes of teachers were also confirmed by answers to other questions, i.e. more than 80 % of teachers (almost 60 % strongly agree) would use stereoscopy in education if they have appropriate equipment and more than 90 % of teachers also believe that the stereoscopy in education would be appreciated by pupils.

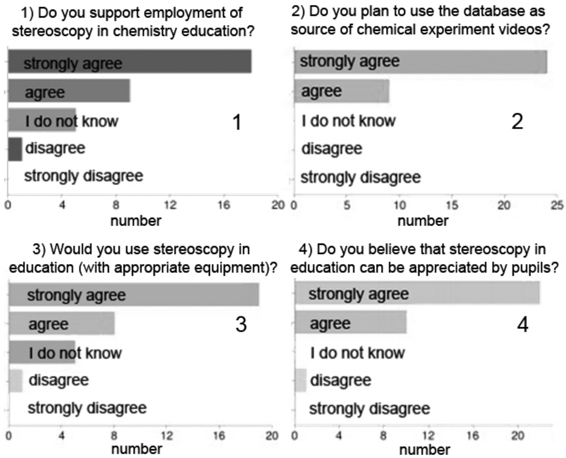

Fig. 01: The charts evaluating attitudes of teachers to stereoscopy in education; the questions are written above corresponding chart

Teachers also valued positively the created videos and marked them by an average degree (chart 6, fig. 02) slightly under 2 on 5 point scale (1 is the best). The stereoscopic (3D effect) was awarded by an average mark of 2, the database graphic and experiment presentation by average mark of 1.6, video quality by average mark of 1.9 and comprehensibility and clarity of the database were marked by 1.4. All the teachers plan to use the database as source of chemical experiment videos (also in 2D format). The pupils marked the stereoscopic videos and effect similarly by an average mark of 2.2 (see table 01).

Tab. 01: Stereoscopic projection – rating of sample stereoscopic video from database by pupils

1	2	3	4	5
18	43	26	4	1

The results indicate that the experiments of the database are acceptable for teachers as well as students and of sufficient quality for employment in primary or secondary school education.

Surprising results were found in answers of pupils to the question "What kind of lesson do you prefer - lab course, stereoscopic projection or "classical presentation"?" Seven pupils only reported the stereoscopy lesson, 19 "classical" presentation and 64 lab activities. Although it can be deduced that the "classical" presentation is more popular than stereoscopy, the deeper look has to be done. After interviews with few pupils, it was found, that majority of them prefers lab courses over all kinds of presentation (stereoscopy and "classical" presentations), nevertheless, majority of them also prefers stereoscopic presentation over "classical presentation". If they have to choose only one possibility from the three mentioned options, the lab course is the best option for them. Consequently, the stereoscopy projection is not voted among the three options, nevertheless, if there are only two options, "classical" and stereoscopic presentation, stereoscopic presentation would be, probably, selected in more cases.

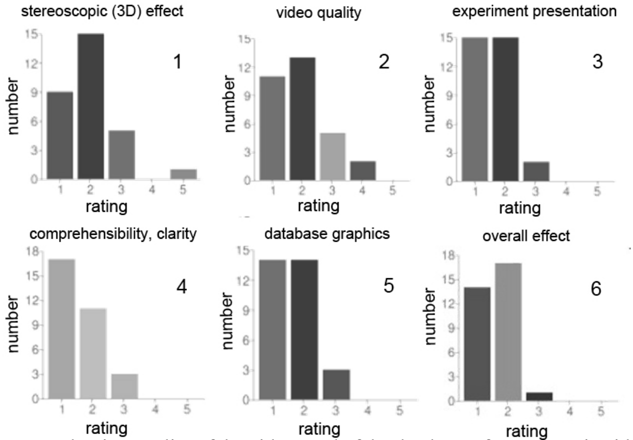

Fig. 02: The charts evaluating quality of the videos and of the database of stereoscopic videos of chemistry experiments (the corresponding questions are mentioned above the corresponding chart.

Rough evaluation of the effect of acquired knowledge during stereoscopic projection made on the results of test filled in by three reference groups (group 1 – stereoscopic video, group 2 – lab course, group 3 – pupils of secondary school, "classical" presentation) also showed surprising results (see fig. 03) which indicate that short-term retention of knowledge in the case of employment of stereoscopy is, at least, comparable to the retention of knowledge acquired during the laboratory course. Although the results are very preliminary, it seems that stereoscopic projection can be a prospective way of presentation in education at primary and secondary schools, and it is supported by teachers as well as pupils with not negligible effect.

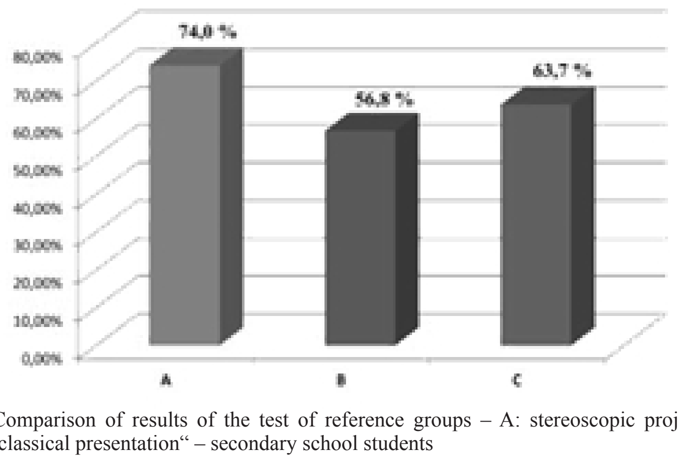

Fig. 03: Comparison of results of the test of reference groups – A: stereoscopic projection; B: lab activities; C: „classical presentation" – secondary school students

Conclusions

A new database of stereoscopic videos of chemistry experiments has been prepared and published - it consists of more than 25 chemical experiments of total length about 1 hour.

- The database evaluation showed that database fulfilled teachers´ expectations (mostly rated between 1-2); the quality of prepared videos evaluation showed similar rating between 1-2 (on

bipolar 5 point scale, 1 is best).
- The majority of teachers as well as pupils consider stereoscopy as educationally prospective and attractive method to employ in chemistry education.
- Although the pupils prefer the lab presentation and activities, the evaluation showed that stereoscopic projection can have, at least, a similar effect with respect to acquired knowledge.

Acknowledgement

The financial support by CZ.2.17/3.1.00/32121 (Přírodní vědy a matematika na středních školách v Praze) project awarded by ESF and Centralized development project C26 (Rok chemie – chemie všem. Popularizační a motivační program pro žáky a učitele středních škol a laickou veřejnost) awarded by MEYS CR, are gratefully acknowledged.

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CHEMISTRY FOR NON-CHEMISTS

Iwona Stawoska, Agnieszka Kania

Teaching non-chemists chemistry requires particular didactic preparation. In the learning process there appear some specific problems, such as **very diversified knowledge level** in the group as a whole, which is a consequence of a different level of skills gained at the secondary school, as well as **lack of motivation** in case of some students as a result of previous school experiences. Additionally, realization of particular topics requires sometimes sketchy implementation of new scientific methods and concepts, e.g. absorption spectra.

In the last years there are an increasing number of non-chemical studies, among others environmental studies, ecology, nursering, wellness, cosmetology, etc. All of them have chemistry as one from the basic subjects.

We can suspect that not all of the students who have chosen one of the pointed types of studies learned chemistry in the profiled classes at the secondary school. In other worlds, not all of them gained chemistry knowledge at the level higher than elementary. On the basis of our experience in teaching we found that many students have serious difficulties for example with an easy calculation of concentration of solutions or with writing the equations of chemical reactions. However, some of the topics are possible to learn at home on the basis of already got information at the secondary school. On the other hand, there are a group of topics which are difficult to understand by students themselves. Among pointed topics are for example these which are connected with absorption and emission of light, enzymatic catalysis or reactions mechanisms.

In the presented paper we would like to present an example scenario of exercises which concentrates on the basic concepts relative to coordination compounds, such as definition of complex, coordination number, geometry of the compounds, nomenclature, equilibrium of the chemical reaction and thermodynamic constant. During classes students conduct experiments aiming to synthesis of a particular complex and investigating its chemical properties.

The general aim of the classes is to prepare non-chemistry students for a laboratory work. Students learn to perform basic laboratory activities (e. g. weighting, pipetting, crystallization, filtering and washing the crystals) and necessary calculations, as well as write chemical reaction equations. Students improve the skills of data analysis, mathematical calculations and public presentations. They learn and practice the nomenclature of the coordination compounds, consolidate such concepts as equilibrium of the chemical reaction and the efficiency of the synthesis reaction. Students get familiar with the concept of absorption spectra and their role in understanding of chemical reactions.

Here, we present our didactic ideas leading to stronger motivation of non-chemists and their greater involvement. The proposed classes are directed to students of biology, biology and geology, environmental protection as well as cosmetology or wellness and include 4 hours of seminar and 3 hours of laboratory work per week.

The course/schedule of the classes is as follows:

1. Previous seminar – an **assessment test**, on the grounds of which **some student were chosen to be 'experts'. Implementation of some basic information regarding the structures and naming of the coordination compounds, isomeric forms and their reactivity, type of ligands and characterization of coordination bounds, elementary information regarding absorption spectroscopy** (Bielański, 2002; Kettle, 1999) .

2. Tasks are presented to the students (Ćwiczenia laboratoryjne z chemii nieorganicznej, 1989). They are asked to make calculations that let them solve the problems.

Ex. 1.

Calculate the efficiency of synthesis of $CuSO_4 \cdot 5H_2O$ based on the performed experiment.

Procedure: Weigh 2 g $CuSO_4 \cdot 5H_2O$, dissolve the compound in 7 ml 25% aqueous ammonia on the water bath (attention! Work under the fume hood!) In the next step, cool the solution and add gradually 7 ml ethanol, gently stirring the solution. Leave the mixture for about 30 minutes. Filter the crystals on the Büchner funnel. Wash the obtained preparation with small amounts of ethanol, dry on the filter paper and weigh.

Comments: Students learn to perform basic laboratory activities (e. g. weighting, pipetting, crystallization, filtering and washing the crystals) as well as necessary calculations. For some of the students this exercise is the first opportunity of working with chemical glass. For that reason a short introduction is required in order to present the used glass and explain its appliance.

Ex. 2.

Write the equation of the chemical reaction and the nomenclature of the coordination compounds participating in the reaction.

Comments: Students learn and practice the nomenclature of the coordination compounds, consolidate such concepts as e.g. equilibrium of the chemical reaction.

Ex. 3.

Write the equations of chemical reactions taking place during the experiment described below. Explain the results.

*Experiment: Pour 2 cm^3 0.5 M CuSO4to each of three test tubes. Then add to the test-tubes water and ethylenediamine in the amounts given in the **figure 1**. Shake the solutions and compare the results. Measure the absorption spectra of each of the solution. If the absorbance is higher than 1, dilute solutions.*

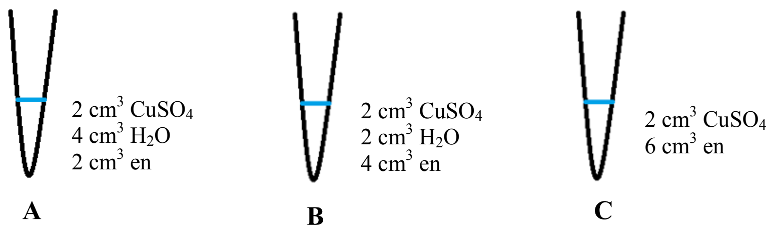

Figure 1. The amounts of substrates taking part in the conducted reactions.

Comments: Students observed changes during the experiment. They try to understand and explain what has happened in the test tubes. They attempt to write the equations of the chemical reactions taking place during the experiment. To better understand the changes, the absorption spectra of the reaction mixtures are measured, **figure 2.**

This requires a special introduction concerning absorption spectroscopy, the UV-Vis absorption spectrum, its parameters (position of the band, its intensity and half width) and a concentration dependence what was pointed above and can be realized during part of the seminar. The importance of this investigating method is briefly discussed.

Didactic solutions

During previous seminar a diagnostic test takes place, on the grounds of which some students are chosen to be 'experts'. During discussed classes students organize themselves in three-person groups; each group includes one expert and works on its own task. Students work the problem out

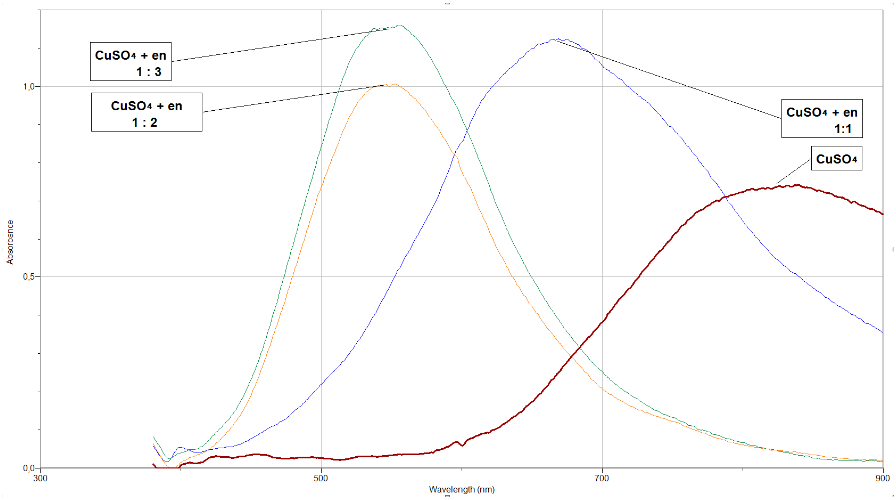

Figure 2. The absorption spectra of the Cu(II) complexes in the aqueous solutions and various contents of en, namely: $CuSO_4$:en 1:0; $CuSO_4$:en 1:1; $CuSO_4$:en 1:2; $CuSO_4$:en 1:3. Solutions were 10 times diluted regarding the concentration shown in the procedure above.

together – an expert helps others to understand the problem and other students can ask questions. They all make the calculations together. A non-expert student from each of the subgroups presents the results of calculation to the whole group at the blackboard.

Conclusions

The assessment test allows the teacher to select the students who can perform chemical calculations in the best way. This method gives other students the opportunity of solving the problem on a one-to-two basis that establishes as a **less formal relationship**. Thanks to this, they learn better because they are **not afraid to ask questions**. Experts learn as well, as **teaching is the best way of learning**. In case of any doubts, all students can ask the teacher for explanations, as he/she all the time watches over them. In this way **all the students are engaged** and motivated to work. This method has already succeeded in secondary school and it is supposed to be very promising at the universities, as well (Drzewiecka-Matuszek, T. Dyląg,. Skalna, I. Stawoska, I. Maciejowska, 2003).

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NEUROBIOLOGICAL AND DIDACTIC ASPECTS OF THE PROCESS OF EDUCATION AS A KEY TO DIDACTIC SUCCESS

Paulina Zimak, Małgorzata Nodzyńska

Introduction

While starting the teaching-learning process both a teacher and a pupil want to and ponder over how to come to a didactic success. The success achieved in the course of an educational process depends on many factors. Educationalists point to external factors – methods of educating, proper selection of didactic materials, teachers responsible for the educational process. They also mention internal factors – intellectual qualifications of pupils participating in this process, that is psychophysical predispositions, interest in particular subjects, the level of intellectual arousal, and initial knowledge of a subject (Wołek et al., 2007).

When it comes to the analysis on the physiological level, it is the nervous system that is the system responsible for all regulations and integrity of organism's functions. It consists of the central nervous system (abbreviated as CNS) and the peripheral nervous system (abbreviated as PNS). Nerve cells (neurons) of the central nervous system have the capacity to generate, analyse, and integrate impulses. The cerebral cortex built the with grey matter is the place of the most complicated analysis and integration processes. The cerebral cortex covers the hemispheres of the human brain (Sawicki, 2005). About 95% of the human cerebral cortex is made of the so-called neocortex (Latin neocortex) – phylogenetically most recent part of the cerebral cortex – and covers the white matter. The remaining 5% consists of the archicortex (Latin archicortex and the paleocortex (Latin paleocortex), which are to be found inside the hemispheres of the human brain (Sawicki, 2005).

The nervous system begins to develop in the third week of embryonic life (embryogenesis). It is made of the nervous tissue whose cells develop in the process of neurogenesis. In the previous century the world of science unanimously held that neurogenesis does not take place in the brain of an adult human. This theory was invalidated in 1990 (Requarth et al., 2011). It was proven that in hippocampus, in adult humans new neurons and glial cells may develop from stem cells in the process of proliferation and diversification (Sawicki, 2005; Requarth et al., 2011). Hippocampus (Latin hippocampus, etymologically – of a shape resembling a seahorse – Fig. 3) is phylogenetically old part of the cerebral cortex with a three-layer structure. It constitutes a part of the limbic system (synonyms border, edge), which is a structural part of cerebrum, surrounding diencephalon (Konturek, 1998) (Fig. 1, 2). Researchers claim that hippocampus plays an important role in the process of learning, memory, and attention (Spitzer, 2007 after Żylińska, http://www.ore.edu.pl; Gage & Muotri, 2012; Requarth et al., 2011). Sawicki (2005) points to the fact that the mechanism of learning depends on LPT (that is long-term potentiation) of chemical synapses, mainly between neurons of hippocampus, but also other formations of the brain. In accordance with the concept by Eccles, impulses passing many times through the same synapses lead to more intense accumulation and secretion of chemical mediator (carrier) from synaptic endings and they also lead to the increase of the number of those synapses (Konturek, 1998).

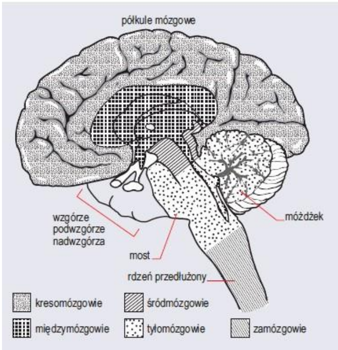


Figure 1. Human brain. Source:
http://www.sciaga.pl/slowniki-tematyczne/2232/mozgowie

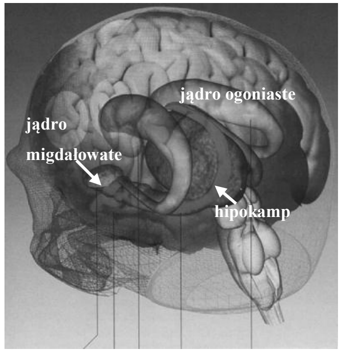


Figure 2. Topography of brain structures. Source:
http://www.is.umk.pl/~duch/Wyklady/kog-m/04-pam.htm

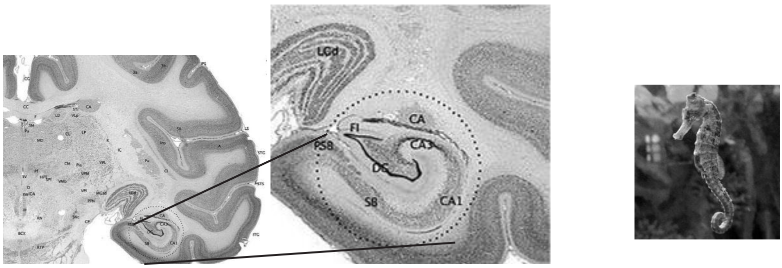


Figure 3. Front cross section of Macaca brain, Nissl staining. Hippocampus formation has been marked.
Sources: http://pl.wikipedia.org/wiki/Hipokamp

By combining the didactic aspect with the physiological basis, it has been proven that if hippocampus “evaluates” a given piece of information as atypical, interesting, it commences its storage by creating its neuron representation. (Spitzer, 2007 after Żylińska http://www.ore.edu.pl). New, interesting pieces of information stimulate neurogenesis in hippocampus (Gage & Muotri, 2012). Everything that is unknown, atypical, mysterious, not fully explained attracts our attention. By contrast, ordinary and everyday phenomena do not arouse the activity of the neuronal network, and thus they do not initiate the process of learning (Żylińska, http://www.ore.edu.pl).

A-level exam reports from the period 2007-2011 made by Polish Central Examination Board point to pupils’ problems with dealing with atypical tasks in the field of chemistry and other subjects (Raporty 2007-2011). Those tasks pose a problem or a question in a manner that does not occur in textbooks. They often require from pupils to process information given in a non-standard form or concerning substances or processes that were not discussed at school (but described in the task or introductory information), or they require the answer to be given in a form other than usual (Raport, 2011). Usually pupils sitting the exam skip the tasks they find atypical. They face difficulties as early as on the level of the task analysis. Among the most difficult tasks, there were ones which required abandoning simple association of pieces of information and creation of a new piece of information (Raport, 2008). Atypical tasks to which pupils are not accustomed receive lower indices of facility than tasks objectively more difficult, but with a trained algorithm of solving (Raport, 2010).

Authors of commentaries to A-level exam reports suggest that the problem noticed may have a psychological basis. They suppose that pupils sitting an exam trust more what they have learnt than what they could think of themselves. Not making an attempt to solve a problem on one's own is a worrying phenomenon, as a piece information given with a task makes it possible to solve the task – provided that one is able to read it with a proper level of comprehension and analyse it (Raport, 2010).

The issue of not making an attempt to solve tasks and their omission became a point of departure to conduct our own detailed research at the academic level as a part of chemical education of students at the Pedagogical University in Kraków in 2010/2011.

The aim of the research was a detailed analysis of pretest tasks with respect to correct, incorrect and skipped answers (both in terms of quality and quantity), description of the level of difficulty of particular tasks, identification of a potential problem or its range among students (perhaps future teachers) by means of determining the fraction of skipped tasks, identification of reasons why no attempt was made to solve the task, establishment of didactic proposals counteracting this phenomenon on the basis of neurobiological mechanisms of learning.

Materials and methods

The research was conducted on 61 full-time students and 23 extramural students of biology at the Pedagogical University in Kraków. The research took place in the second semester of the academic year 2010/2011 during the first classes in organic chemistry. Students subject to the research have already participated in previous courses in general and analytical chemistry as a part of their university education. In order to verify the level of knowledge and skills of students who were to begin the course "Organic chemistry I," students had not been previously informed about the scheduled research. Full-time and extramural students subject to the research were in most cases graduates of secondary school classes with chemistry major. The detailed description of the sample, description and outcomes of the statistical analyses concerning the research conducted were presented in the article by Zimak and Tejchman (2011). Pretest tasks were prepared on the basis of the course description of "Organic chemistry I - preliminary requirements" (Tejchman, 2007; Nodzyńska et al., 2011) and the course Curriculum (Tables 2-7).

Outcomes

A detailed quality and quantity analysis of answers to particular tasks in the pretest

Table 1 presents detailed results concerning answers given by students to particular tasks (Zimak et al. 2011). Due to the statistical analysis and the conclusion that arrangements are statistically concordant, particular data for full-time and extramural students were considered together in further analysis.

The analysis focused on correct, incorrect and skipped answers. For skipped tasks fraction of omissions was calculated according to the formula (Niemierko, 1999):

$$w = \frac{n_0}{n}$$

where

w – fraction of task omission (originally marked with f, but in accordance with statistical symbols "w" stands for fraction, while "f" – frequency (after Wołek, 2006);

n_o – number of students who skipped the task

n – number of students taking part in the research

Tab. 01. Quantity analysis of answers given by students.

task no.	Answers [no. students]			fraction of omissions *w*	moderate easiness of a task (full-time and extramural)	evaluation of task easiness* (Niemierko, 1999)
	correct	incorrect	skipped			
1	67	10	7	0.08	0.658	moderately difficult
2	69	8	7	0.08	0.772	easy
3a	22	46	16	**0.19**	0.248	difficult
3b	7	29	48	**0.57**	0.058	moderately difficult
3c	7	19	58	**0.69**	0.071	very difficult

*If easiness is contained between:
0,00-0,19 - very difficult; 0,20-0,49 –difficult; 0,50-0,69 - moderately difficult; 0,70-0,89 - easy
0,90-1,00 - very easy (scale after Niemierko, 1999).

This analysis aimed at establishing the level of omissions and identifying the type of tasks which students do not try to solve. In 11 tasks fraction of omissions above 0.15 has been observed. Data from the literature (Niemierko, 1999) show that if fraction of omissions is above 0.15, then the task may be constructed incorrectly with reference to didactics (subject matter, editorial issues or the level of difficulty). All tasks in which the fraction of omissions was above 0.15 were analysed with respect to their level of difficulty – average level of easiness was taken as a gauge. The analysis proved that the majority of skipped tasks were tasks from the group: very difficult (5), difficult (3), and moderately difficult (3).

A detailed analysis of tasks in the pretest together with a commentary to each tasks and examples of errors are presented in tables 2-7.

Tab. 02. A detailed analysis of tasks 1,2,11.

Task 1, 2, and 11 – theories of acids and bases

Task 1. (1 point)
In accordance with the Brönsted-Lowry theory a substance able to give a proton (proton donor = donor of protons) is **acid**. A substance able to receive protons (proton taker = acceptor of protons is **base.**

Task 2. (2 points)
Describe the role a water particle plays in the reactions expressed by the formulas below in accordance with the Brönsted-Lowry theory:

$$NH_3 + H_2O = NH_4^+ + OH^-$$

Water plays the role of: **acid (other correct answers: proton donor, donor of protons)**

$$CH_3COOH + H_2O = CH_3COO^- + H_3O^+$$

Water plays the role of: **base (other correct answers: proton taker, acceptor of protons)**

Task 11. (1 point)
In accordance with the Lewis a substance able to give a free pair of electrons is **base (donor)**. A substance able to accept a free pair of electrons is **acid (acceptor).**

Commentary:
The analysis of answers given by students to tasks 1, 2, and 11 concerning the theory of acids and bases proved that the Brönstedt-Lowry theory is better consolidated than the Lewis theory (Fig. 4.). Seven students did not make an attempt to solve tasks 1 and 2 while task 11 was skipped by as many as 25 students.

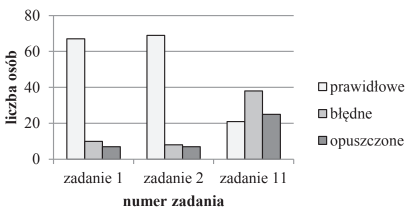


Fig. 4

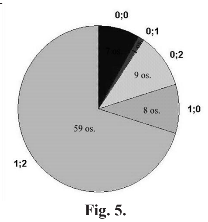


Fig. 5.

Figure 4. Answers given by students to tasks 1, 2, and 11.
Figure 5. A detailed analysis of answers given to tasks 1 and 2.
(interpretation of notation, e.g.: **„0;0”** – in the first place number of points for task 1; in the second place number of points for task 2, "0" – stands for incorrect or skipped answer).

A detailed analysis of answers given to tasks 1 and 2- total analysis (Fig. 5) proved that:

a) 59 students (total of full-time and extramural students - 84) subject to the research can correctly solve tasks 1 and 2.
b) 10 students in the sample analysed can solve task 2 (9 the whole task, 1 partially) <u>without knowing</u> the definition of acid-base according to the Brönsted-Lowry theory (task 2 – task with a higher taxonomy of teaching objectives than task 1). Most probably students, by means of analysis of the task 1 content and the knowledge of the concept of proton, could give a correct answer to task 2 by writing words: proton donor/ proton taker, donor/acceptor of protons instead of e.g. acid/base.
c) 8 students in the sample analysed could not solve task 2 despite the knowledge of the definition of acid-base according to the Brönsted-Lowry theory (task 1).
d) 7 students could not solve tasks 1 and 2.

Examples of incorrect answers given by students to tasks 1, 2, and 11

Among the most frequent mistakes made in the answers given to tasks 1, 2, and 11 one has to mention:

– application of reversed order acid/base (in all tasks) and proton donor / proton taker (task 2);
– writing down such concepts as neutron / proton, reducer/ oxidiser, anion / cation, hydroxide, water

Tab. 03. A detailed analysis of task 3.

Task 3 – quantum, organic chemistry

Task 3. (5 points)

On the basis of the semi-structural formula given below:

$$\underset{1}{CH_2} = \underset{2}{CH} - \underset{3}{CH_2} - \underset{4}{CH_2} - \underset{5}{CH_3}$$

a) Give the name of this organic compound **pent-1-ene, 1-pentene** (1 point)
b) Identify the type of hybridisation of valence orbitals for particular carbon atoms. (1 point)
1− $\mathbf{sp^2}$; 2 −$\mathbf{sp^2}$; 3 − $\mathbf{sp^3}$; 4 − $\mathbf{sp^3}$; 5 − $\mathbf{sp^3}$
c) Mark on the semi-structural formula above atoms situated in one plane (flat part).
(points were given for marking: 1 i 2) (1 point)
d) How many **π bonds** and how many **σ bonds** are there in a particle of this compound? (1 point)
Number of π bonds: **1** Number of σ bonds: **14**
e) Describe in what way π bonds are created. (1 point)
π bonds are created as a result of head-on overlapping between π atomic orbitals.

Commentary:

a) 22 people could correctly name the organic compound. 16 people did not make an attempt to solve the task. 46 people made mistakes in naming the organic compound.
b) 7 people could identify the type of hybridisation of valence orbitals of particular carbon atoms. 48 people did not make an attempt to solve the task. 29 people made mistakes in identifying the type of hybridisation of particular carbon atoms.
c) 7 people could indicate in the semi-structural formula atoms situated in one plane (flat part). 58 people did not make an attempt to solve the task. 19 people made mistakes.
d) 20 people could describe how many π bonds and how many σ bonds there are in a compound particle. 11 people did not make an attempt to solve the task. 53 people made mistakes.
e) 1 person could explain how π bonds are formed. 66 people did not make an attempt to solve the task. 17 people gave an incorrect answer.

Examples of incorrect answers given by students to task 3 (points: a-e)

point a.

– acetic acid, pentene, pentone, pentane, 1-pentane, pent-2-ene, hexane, hex-1-ene, pentan-1-ol, pental, 1,2 pent – ene, 1,2 pentene, propane,
– illegible writing and no pointing to the localization of pentene bond

point b.

– incorrect marking of particular atoms' hybridisation, e.g. sp instead of sp^2
– manner of writing down subscripts of $sp_{2;}$
– manner of writing down s, p, d, e, f, g ; π, σ; s^1, $2s^2$, $2s^2$,$2p^6$, $2p^6$; p, s, p, p, d;

point c.

– incorrect identification of atoms (in the formula or digits), e.g. all C atoms.

point d.

– incorrect number of bonds, e.g. 1, 3; 14, 1; 1, 4; 1, 5; 4, 1; 3, 1; 2, 3; 1, 2; 1, 0
– or a partial answer 1, ...

point e.

– "by shift of electrons," "overlapping of p orbitals";
– "π bonds are formed in double, triple, and quadruple bonds. One of these bonds is always a σ bond while the remaining ones are π bonds";
– "they are formed between atoms of hydrogen"; "shift of an electron from one atom to another";
– "shift of electrons in the direction of a more electronegative electron forms a π bond";
– "by giving hydrogen";
– "electrons move to a lower energetic level during hybridisation";
– "by breakdown of a σ bond";
– "shift of electrons that form the π bond in the direction of an atom with greater electronegativity";
– "by the removal of one hydrogen atom"; "by overlapping of appropriate orbitals";
– "something to do with hybridisation of p orbitals"; "by shift of a pair of electrons from atom onto atom";
– "by linear overlapping of orbitals"

Task 4 – Draw a structural formula of a benzene particle.

A detailed analysis of the task was presented in an article by Zimak, (2012). Mistakes made by students of biology at the Pedagogical University while drawing a structural formula of a benzene particle in the light of results of own research and literature analysis.

Tab. 04. A detailed analysis of tasks 5-10.

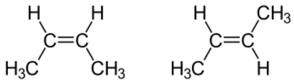
Tasks 5,6,7,8,9,10 – organic chemistry

Task 5. (1 point)
Benzene in a reaction with bromine in the presence of a catalyst undergoes a reaction of:
a) addition b) elimination **c) substitution** d) isomerisation

Task 6. (1 point)
As a result of a reaction with sodium alcohols form alkoxides. In those reactions alcohols have the character:
a) acidic b) alkaline c) neutral d) amphoteric

Task 7. (1 point)
Butane and 2-metylopropane are chemical compounds that:
a) are chain (skeletal) isomers in relation to one another
b) are position isomers in relation to one another
c) are geometric isomers in relation to one another
d) are functional isomers in relation to one another

Task 8. (4 points)
Below there are two formulas of compounds presented.



1 **2**

Mark with an **X** the correct answer:

a) Those compounds are geometric isomers in relation to one another.	**T**	F
b) Chemical and physical properties of isomers are identical.	T	**F**
c) Compound 1 is: *cis but-2-ene;* Compound 2: *trans but-2-ene*	**T**	F
d) The spacial shape of particles of compounds 1 and 2 is identical.	T	**F**

Information to tasks 9,10.

ethanol $\xrightarrow{\text{oxidation [O]}}$ $\xrightarrow{\text{oxidation [O]}}$ **X** $\xrightarrow[H_2SO_4]{+\mathbf{Z}}$ **Y** methyl ethanoate (methyl acetate)

Task 9. (3 points)
Name the substances marked on the diagram as X, Y, Z.
Substance X is: **ethanal (acetaldehyde)**
Substance Y is: **ethanoic acid (acetic acid)**
Substance Z s: **methanol (methyl alcohol)**
(point was not given for providing only the name of main groups of compounds e.g. aldehyde, acid, ester)

Task 10. (1 point)
Write the reaction equation between substrates Y and Z.

$CH_3COOH + CH_3OH \xrightarrow{H_2SO_4} CH_3COOCH_3 + H_2O$ (point was given for the correct reaction equation but without including the catalyst over the arrow)

Commentary:

Task 5.

37 students could point to the fact that benzene under the reaction with bromine in the presence of a catalyst undergoes the reaction of substitution. The rest of the students did not give the correct answer (38 people), among other:

– 31 people stated that benzene undergoes the reaction of addition;
– 4 people stated that it is the reaction of elimination;
– 3 people marked the reaction of isomerisation

or they did not make an attempt to solve the task (9 people).

Task 6.

28 students could name the character of alcohols on the basis of previously given piece of information - under the reaction with sodium alcohols form alkoxides. 46 people gave an incorrect answer pointing to:

– basic character (22 people);
– amphoteric (13 people);
– neutral character (11 people);

10 people did not make an attempt to solve the task.

Task 7.

40 students gave the correct answer by marking the answer that butane and 2-methylopropane are chemical compounds which are one another's chain (skeletal) isomers. 30 people gave incorrect answers by pointing that:

– they are one another's optical isomers (12 people);
– they are one another's position isomers (10 people);
– they are one another's functional isomers (8 people);

14 people did not give any answer.

Task 8.

a) 54 people marked correctly the statement that it is true that the compounds presented are one another's geometrical isomers. 4 people did not make an attempt to solve the task.

b) 57 people stated that physical and chemical properties of isomers are different. 3 people did not make an attempt to solve the task.

c) 68 people correctly marked that compound 1 is: cis but-2-ene; compound 2 is: trans but-2-ene. 5 people did not make an attempt to solve the task.

d) 60 people stated that the spacial shape of particles of compound 1 and 2 is not identical. 2 people did not make an attempt to solve the task.

Task 9.

4 people gave correct names of substances marked on the diagram as X, Y, Z (all of them). 7 people gave correctly 2 names, 1 person gave correctly one name whereas as many as 48 people did not make an attempt to solve the task. 24 people gave incorrect answers.

Task 10.

Only 6 people could correctly write the reaction equation between substrates Y and Z. 66 people did not make an attempt to solve the task. The rest of students gave incorrect answer (Table 2).

Examples of incorrect answers given by students to task 9

Task 9.

– giving general names of groups: (carboxylic) acid, aldehyde, ketone, ester (sometimes marked incorrectly)
– giving incorrect names or incorrect marking: ethane, ethyne, ethanoate, methane, ethanol acid, acetaldehyde, hydroxyethene, hydroxyethyne, aluminium oxide, ethanoic acid, water, methyl, sulphuric acid,
– giving a sumaryczny formula, including formulae of incorrect CH_3 (it is neither a chemical compound nor a methyl group) and not the name:, CH_3COOH, $HCOOH$, CH_3CH_2OH, CH_3CHO, CH_3COOH, CH_4, C_2H_6, C_2H_5, C_2H_4, CH_2COOH, H_2O, $C_2H_3O_3H$, $C_2H_3O_2H$,
– indistinct notation ethanol/ethanal
– ethyne with the formula C_2H_5

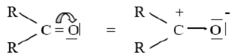
Tab. 05. Incorrect equations of esterification reactions – task 10.

No.	Answers given
1.	$CH_4 \rightarrow CH_3CHOCH_3$ (drawn up formula, 3-value carbon atom)

Tab. 06. A detailed analysis of task 12.

Task 12. Inductive effect

Task 12. (1 point)
On the basis of the equation below fill in the blanks.



Shift of electrons forming the π bond occurs in the direction of the **oxygen atom (more electronegative).** The oxygen atom receives a partial **negative, -,** charge, and the carbon atom receives a partial **positive, +,** charge.

Commentary:
The majority of students could solve task 12. In the group of 23 people who could not analyse the model notation of equation of inductive effect as many as 17 people did not make any attempt to analyse and solve the task.

Examples of incorrect answers given by students to task 12.

Among the mistakes made one may mention:
incorrect answers in all blanks: "C, positive, negative"
answers partially incorrect: "electronegative, negative, positive" – lack of precision "more electronegative", "oxygen, 6, 4", "oxygen, positive, negative", "carbon, negative, positive"
partial answers: "oxygen, no answer, no answer"

Tab. 07. A detailed analysis of task 13.

Task 13 – text task

Task 13. (2 points)
The process of alcoholic fermentation of glucose undergoes in accordance wit the equation:

$$\mathbf{C_6H_{12}O_6 \xrightarrow{\text{enzymes}} 2\ C_2H_5OH + 2\ CO_2}$$

Decide how many dm^3 of carbon (IV) oxide will be received if 18 kg of glucose was used to alcoholic fermentation and the process has 50% of efficiency. (Molar mass of glucose: 180 g/mol) (point was given for logical, correct steps of solving the task)

1. **Calculation of carbon (IV) oxide volume from the reaction equation. (100% efficiency)** (1 point)
   0,18 kg of glucose ------ $2 \cdot 22{,}4\ dm^3$ (from the equation)
   18 kg of glucose -------- $x\ dm^3$
   $x = 4480\ dm^3$
2. **Calculation of carbon (IV) oxide volume taking into consideration 50%-efficiency of the process** (1point)
   $4480\ dm^3$ -----100%
   $y\ dm^3$ ---- 50% **$y = 2240\ dm^3$**

Commentary:
12 people correctly solved two stages of the text task (including the reaction efficiency). 8 people solved the task partially and they were given 1 point out of 2. 20 people did not make an attempt to solve the task.

Examples of incorrect answers given by students to task 12.

- lack of calculation of the reaction efficiency;
- lack of change of units (unification of units in the proportion 18 kg and 180 g);
- incorrect change of 18 kg into grams (1800 g);
- not taking into account the stoichiometric coefficient 2 CO_2 ($2 \cdot 22{,}4\ dm^3$);
- not taking into consideration 18 kg (giving the efficiency for 180 g);
- calculations made for 18 g;
- incorrect notation of proportion ($18000\ g - 2 \cdot 22{,}4\ dm^3$); incorrect notation in order to calculate „x"
- calculation of the mass of CO_2
- writing down too many data:
- incorrect units (instead of dm^3 – g)

Conclusions and implications

The level of knowledge and skills of students who begin a given course within their university education in the field of issues of our interest may be discussed, analysed, and forecast on the basis of earlier A-level exam results on the national scale as well as with reference to a particular group of students and their A-level exam results, results from previous exams taken within a particular group of courses, e.g. in chemistry that precede the course in question or within a unified and properly prepared pretest. As it was proven by research conducted by Wołek et al. (2007) "there is a strong and substantial relation between end-of-semester marks and the results of a check test, pointing to the fact that success in a didactic process largely depends from the initial knowledge of a subject".

In the light of arguments quoted, what seems to be reasonable is a detailed analysis of a group beginning the course, an in-depth and thorough analysis of the level of knowledge and skills of students who begin a given course in the context of planning, modifying, and conducting a proper process of teaching aiming at achieving previously established goals.

Research concerning the general characteristics of groups of students as well as the level of chemical knowledge and skills of students studying biology were not conducted in recent years.

Research concerning students' preparations in the field of knowledge of chemistry was carried out by Nodzyńska and Tejchman in 2005 among students of Information Technology Education, at the Pedagogical Academy. In this field of study, just as it is the case with biology, chemistry is one of courses with a small number of hours, as a minor subject. Due to this fact, the final effects of the chemistry teaching process among students largely depend on their knowledge acquired on earlier stages of education.

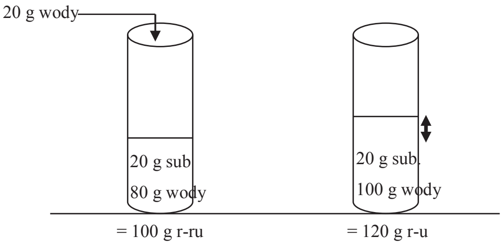
Research conducted by Nodzyńska and Tejchman (2005) proved that "knowledge of students who begin to learn chemistry is insufficient with reference to basic chemical knowledge and skills." Significant problems were noticed in the field of categorisation of terms, identification of types of bonds in chemical compounds and stemming from them substance characteristic features, application of chemical terminology, writing formulas and making simple calculations. Similar general conclusions were reached as a result of our own research conducted on a group of full-time and extramural students of biology. Particular difficulties were to be seen in the group of theory of acids and bases, theory of the atom structure, and issues related to organic chemistry.

Research by Nodzyńska and Tejchman (2005) revealed a low percentage of correct answers to the questions in the test suggesting thus that in primary school, junior high school, and secondary school out-dated and imprecise chemical theories are taught. It also lead to a conclusion that it is necessary to introduce at lower stages of chemical education precise and new scientific theories. Analysing the outcomes of our research, we noticed students' problems with theories of acids and basis as well as with quantum theory of atom structure. These difficulties are most probably linked with negative transfer pertaining to the order on which theories were introduced in the course of education. For example, in junior high school pupils are taught the theory of electrolytic dissociation by Arrhenius. In secondary schools, in classes with chemistry major, pupils are taught the theory of acids and bases by Brönsted-Lowry, and sometimes the theory by Lewis. Some of pupils learn about modern theories of acids and bases only at the university. Research carried out by Nodzyńska and Paśko (2004) among students of a secondary school and students of non-chemical subjects pointed to difficulties with their proper acquisition of the Brönsted-Lowry theory. It was stated that the reason for this is a negative transfer of the previously introduced the Arrhenius theory. Previously coded theories and resulting from them models of atom's structure constitute a barrier that pupils have to overcome, which requires time and appropriate didactic help.

In our research we also noticed numerous situations of not making an attempt to solve tasks, skipping tasks, despite the fact that many of them belonged to a typical canon of chemistry tasks.

“Non-typical” task 12 concerning the inductive effect, which often occurs in mechanisms of reactions in organic chemistry, most probably because of students’ lack of knowledge of the concept of “electrons forming a π bond” (as pointed to in tasks 3d, 3e) received a significant fraction of omissions though a figure to the tasks shows required answers. This task points to difficulties with a diagram analysis, a barrier which an unknown, or forgotten notion of “π bond” constitutes, hindering correct solution of the task. In the process of teaching it is necessary to form the skill of analysing task content and to show correct “open” attitude towards a “new, seemingly unknown, and difficult” issue. It is vital to create situations that require analysis and reflection on the basis of non-typical examples. This skill may be perfectly mastered with the help of chemistry tasks whose solving requires a multi-stage analysis and thorough pondering over the problem presented in the task. Nodzyńska and Paśko (2008) claim that the difficulty with solving this type of tasks stems from the lack of habit to analyse processes in the course of solving a problem task, in other words pupils often replace formulas with data without thinking. Pupils should be taught analysis. What is helpful in solving tasks (e.g. concerning percentage concentration) and develops the process of thinking among students is mathematical proportion. Solving tasks on the basis of proportion makes pupils accustomed to ponder over the relations and processes described in a task (Nodzyńska et al. 2008). It seems that pupils find it difficult to order their thought and write them down. Helpful techniques in ordering subsequent process may be figures (Fig. 4, 5, and 6), computer animations (Fig. 7) made by pupils to picture their process of thinking and showing subsequent stages described in the task or in the chemical reaction in question (Nodzyńska & Paśko, 2005).

20 grams of water were added to 100 grams of a 20% solution. Calculate the percentage concentration of the solution received.

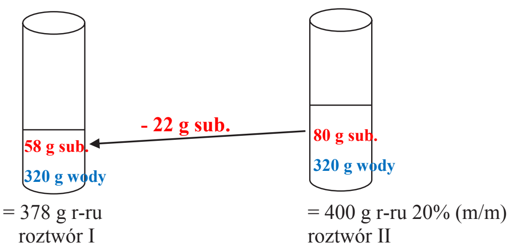


20 g sub. --- 120 g r-ru

x g sub. ---- 100 g r-ru

Fig. 04. Example of task solving with the help of figures

A-level exam task – 22 g of solid NaCl were added to sodium chloride solution of unknown concentration (solution I). 400 g of 20% mass solution were received. Calculate the percentage concentration of solution I in mass percent (...).

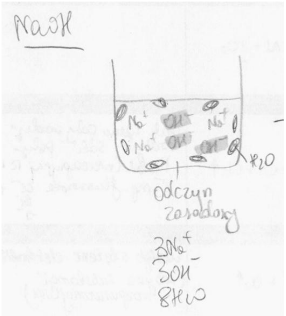


58 g sub. --- 378 g r-ru

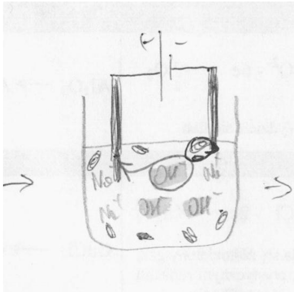
x g sub. ---- 100 g r-ru

Fig. 05. Example of task solving with the help of figures

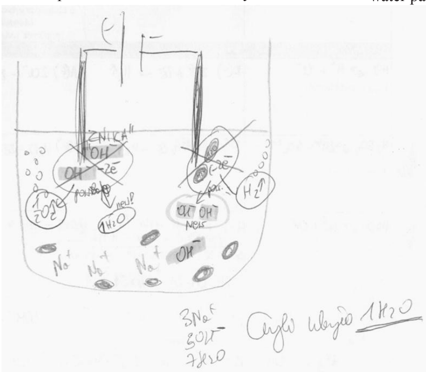
Decide and justify your answer if and how the solution concentration of water solution of sodium hydroxide subject to electrolysis will change.



1. description of state before electrolysis



2. transition stage – shift of OH ions$^-$ and water particles to electrodes



increase in the solution concentration

3. description of state after electrolysis

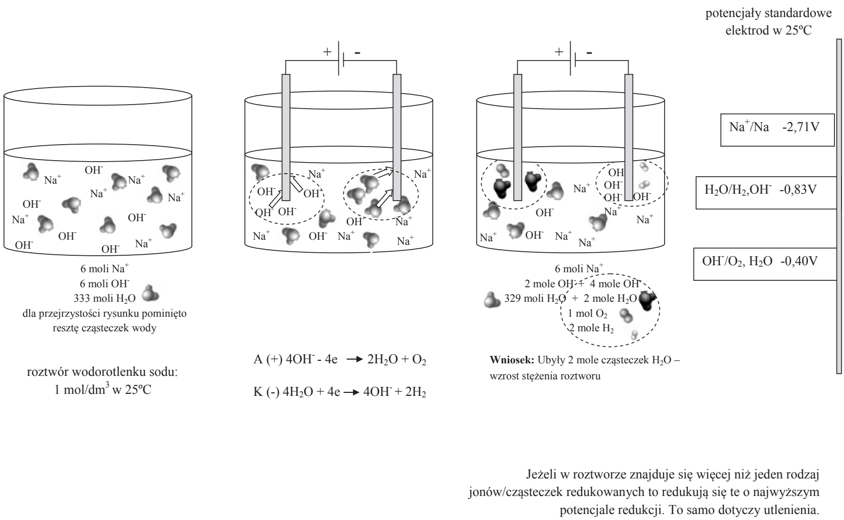


Fig. 06. Example of task solving with the help of figures – electrolysis of water solution of sodium hydroxide (own study)

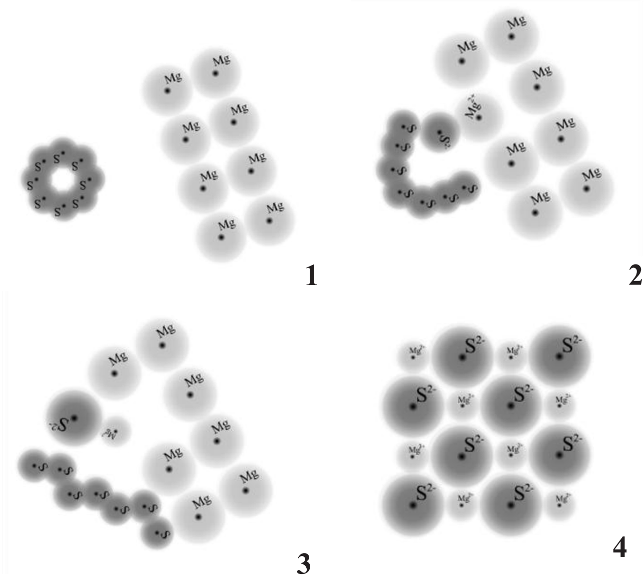


Fig. 07. Example of a credit task for students – computer animation of a chemical reaction (prepared by a student of the Pedagogical University)

While introducing information and skills, a teacher should use many different methods of passing on knowledge, show varied examples in the context of individual preferences of his/her pupils in the process of learning (Nodzyńska, 2008). In different situations non-typical tasks stimulating in a natural way processes of learning and shaping the attitude of openness to making an attempt to face a new task should be introduced. A sample task based on the method of solving motivation tasks (not used in Poland) presented by Prof. Maria Solárová, of the University in Ostrava during an academic seminar.

"How long will it take to cover the distance s = 1 mol of water particles placed one after another driving a car with the speed of 100 km/h. Assume that on average 1 particle of water has the size of $5.47 \cdot 10^{-15}$ m?".

Summary

1. Students very often do not make any attempt to solve a task. In 11 tasks fraction of omissions above 0.15 has been observed.

2. The analysis conducted revealed students' problems with the comprehension of rudimentary chemistry notions and their taxonomy as well as with the knowledge and interpretation of chemical models (including symbolic models) and chemical theories.

(Answer to motivation task 1: 3.76 years)

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