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EDITORIAL

The 23rd International Conference on Chemistry Education "Research, Theory and Practice in Chemistry Didactics" together with 9th Regional Symposium IOSTE (International Organisation for Science and Technology Education) for Central and Eastern Europe "Science and Technology Education for the 21st Century" took place on 15 – 17 September 2014 in Hradec Králové, Czech Republic. Both events were arranged by Section for Chemistry Didactics, Department of Chemistry, Faculty of Science, University of Hradec Králové (UHK) under patronage of the dean of Faculty of Science University of Hradec Králové Assoc. Prof. Pavel Trojovský, Ph.D. and The Working Group Teaching of Chemistry at Czech Chemical Society in honour of 50 years of Department of Chemistry. The conference reassumes since year 1991 to regular international meetings of didacticians, teachers and students on chemistry didactics and related branches in Hradec Králové. The proceedings volume contents 23 research and research oriented articles selected by reviewers recommendation from more as 50 announced studies. The content is divided into three sections: Curricular Aspects of Chemistry Education and Chemistry Teachers' Training, Methodological Aspects of Chemistry Education and Information and Communication Technology in Chemistry Education and in Chemistry Teachers' Training.

The conference was coordinated at present by international scientific committee with chairman Prof. PhDr. Martin Bílek, Ph.D. (University of Hradec Králové, Czech Republic) and members: Prof. Dr. Agnaldo Arroio (University of Sao Paulo, Brazil), Prof. Dr. Eng. Boris Aberšek, Ph.D. (University of Maribor, Slovenia), Prof. RNDr. Pavel Beneš, Ph.D. (Charles University, Prague, Czech Republic), Prof. Dr. Andris Broks (University of Latvia, Riga, Latvia), Prof. RNDr. Hana Čtrnáctová, Ph.D. (Charles University, Prague, Czech Republic), Assoc. Prof. Janis Gedrovics, Ph.D. (Riga Teacher Training and Educational Management Academy, Riga, Latvia), Prof. dr. hab. Ryszard Gmoch, DrSc. (University of Opole, Opole, Poland), Prof. dr. hab. Hanna Gulińska (Adam Mickiewicz University, Poznan, Poland), Prof. PhDr. Ľubomír Held, Ph.D. (Trnava University in Trnava, Slovakia), Prof. dr. hab. Ryszard Maciej Janiuk (Maria Curie-Skłodowska University in Lublin, Poland), Assoc. Prof. RNDr. Jarmila Kmeťová, Ph.D. (Matej Bel University in Banská Bystrica, Slovakia), Prof. Eng. Karel Kolář, Ph.D. (University of Hradec Králové, Czech Republic), Prof. Dr. Andreas Kometz (Friedrich Alexander University in Erlangen-Nürnberg, Germany), Prof. Eng. Milan Kraitr, Ph.D. (University of West

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Submitted conference proceedings should complete publications concerned the chemistry didactics. We would like thanks to reviewers of the proceedings for conceptual notices and revisions. The content and application of citation norms are on the responsibility of authors of the separate articles.

Hradec Králové, in July and August 2014   *Martin Bílek, Editor*

NATURAL SCIENCE TEACHER TRAINING: BETWEEN WISHES AND REALITY

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Abstract

The paper discusses the current models of undergraduate (not only) science teacher training. It offers thorough analysis of the representation of various components of the preparation related to the competencies of the of teacher training study program graduates. Topical issues such as the problems of the study structuring, the representation of pedagogical and psychological preparation, the position of subject didactics, etc. are particularly accented.

Keywords

Teacher Training, Teaching Qualification, Professional Competencies, Standard Quality Of The Teacher's Profession

INTRODUCTION

The Individual National Projects (INP) implemented under the Education for Competitiveness Operational Programme became extraordinary impulse for the development of tertiary education in the Czech Republic. Two of the INPs intensified significantly academic discussion related to the topic of teacher education, teacher competencies, and possibilities of their further career growth. The two INPs in question are Quality Assurance and Assessment in Tertiary Education (INP Quality) and INP Career System (INP Career). Although both INPs are seemingly unrelated they encounter at one point, crucial regarding to undergraduate teacher training: the level of competence of different teacher training study programs graduates. These competencies (which INP Quality deals with), however, are also the professional competencies of a so called novice teacher defined within INP Career. The somewhat different ideas about the competencies of the different teacher training programs graduates from different faculties formulated by teams of both INPs led to unusually intense debate on the shape of future teacher training model. Accreditation Commission of the Czech Republic and the professional associations for educational and philosophical faculties and the faculties of science in the Czech Republic have been all strongly involved in the debate. The issue of teacher training and essential teacher competence has been (not always to the benefit of the matter) medialized and thus becomes the topic for general public discussion owing to concurrently existing problem of unqualified teachers. This paper aspires to highlight some of the issues and trends in undergraduate teacher training with special emphasis on science teachers.

ANALYSIS OF CURRENT MODELS OF TEACHER TRAINING

Currently there are altogether 37 faculties in the Czech Republic preparing future teachers (of which there are 36 from public universities, one of them belongs to a private university) offering a total of 761 teacher training study programs. The number of the study programs providing teaching qualification itself demonstrates disunity and fragmentation of higher education of future teachers. The structuring of teacher training study programs primarily has a significant impact on the situation. Only primary school teacher training had been excluded from the systematic structuring and thus this master's program remains unstructured. (The requirement for a Master's degree for all teachers is regulated by Act No. 563/2004 Coll. on Educational Staff as amended.). No serious discussions supported by the valid results of research studies that could support suitability of teacher training structuring had been initiated prior to full structuring of all lower and upper secondary teacher training study programs into bachelor and master study programs in the first decade of the new millennium. Despite the efforts of some teacher training faculties had been left no option for the coexistence of structured and unstructured teacher training programs that could even have had some experimental nature and would have allowed for "in vivo" assessment of the effectiveness, efficiency, and suitability of the two models of teacher training, for example in relation to the demands of practice and the needs of ever changing social accents.

The structuring of the teacher training study programs generated four variants of paths to teaching qualification:
http://aplikace.msmt.cz/ak/koncepce1.htm (MŠMT, 2004)

1. The educational-psychological and field-academic components of preparation pervade both the bachelor and the follow-up master part of the study. The students pass generally cultivating educational-psychological subjects and they complete class observations to get an idea

of teaching profession. Nevertheless, they do not obtain teaching qualification. Within the bachelor teacher training program they gain solid subject area-academic grounding of one or two future approbation subjects. The follow-on master study enhances subject area-academic study and the focus of teacher training is highlighted. Models:

a) Bachelor teacher training study program with a double-subject approbation + follow-up master teacher training study program with double-subject approbation,
b) Bachelor teacher training study program with a single-subject approbation + follow-up master teacher training study program with single-subject approbation.

For the bachelor students, who during the study decide not to continue in teaching-oriented study programs, modules allowing to extend their non-teaching-oriented part of the preparation (either with a focus on practical application or focusing on a possible continuation in professional studies within master study) must be available. Regarding science teacher training, this model is mainly used for the preparation of lower secondary teachers mostly left to the faculties of education. The faculties of science offer lower secondary teacher training just at the University of Ostrava and the Jan Evangelista Purkyně University in Ústí nad Labem.

2. Subject-field part of the preparation (subject didactics excluded) is a clearly non-teacher training. Bachelor provides future teachers with solid field-academic basis in one or two approbation subjects. The set of the obligatory courses can be supplemented by an optional pedagogical-psychological module analogous to the component of preparation in the first variant, for those already interested in teacher training. Further process is analogous to the first (or fourth) variant.
3. Subject-field part of the preparation (subject didactics excluded) is a clearly non-teacher training. Bachelor study program provides future teachers with solid field-academic basis not in one or two approbation subjects but in a broader scientific basis (natural sciences, social science, linguistics, etc.). The follow-up master study offers students to focus on gaining teaching competence, i.e. they pass all pedagogical and psychological disciplines, they undergo teaching practice, study subject didactics and, moreover, they profile themselves within their two approbation subjects. Models:
   a) Bachelor non-teacher training study program with a focus on broad preparation (science studies model) + follow-up single-subject teacher training master study program;

b) Bachelor non-teacher training study program with a focus on broad preparation (science studies model) + follow-up double subject teacher training master study program;

This model has little application within science teacher training. Only the Faculty of Science of the Jan Evangelista Purkyně University offers such bachelor degree course called “Science Education” and accredited within the study program B 1701 Natural Science Studies. The model applies a lot more in the area of social science teacher training. There are bachelor degree courses such as "Arts and Humanities" (Faculty of Arts and Humanities, Masaryk University, Brno), "Fundamentals of Arts and Humanities" (Philosophical Faculty, Jan Evangelista Purkyně University, Ústí nad Labem), "Humanities in Education" (Faculty of Education, Technical University, Liberec). Unfortunately, the prospective students' interest in the study of broadly conceived science education is minimal due to the high demands that this field of study has.

4. Subject-field part of the preparation (subject didactics excluded) is a clearly non-teacher training. Bachelor study program provides future teachers with solid field-academic basis in one or two approbation subjects. The follow-up master study program has the students focused on gaining teaching competence, i.e. they pass all pedagogical and psychological disciplines, they undergo teaching practice, also study subject didactics (of the one or two subjects). Models:
   a) Bachelor non-teacher training study program – single subject (specifically field-oriented, e.g. biology, physics, chemistry) + follow-up single-subject master teacher training study program;
   b) Bachelor non-teacher training study program – double subject (e.g. biology – chemistry, mathematics – physics) + follow-up double-subject master teacher training study program;
   c) Bachelor non-teacher training study program – single subject (specifically field-oriented, e.g. biology, physics, chemistry) + follow-up single-subject master non-teacher training study program (specifically field-oriented, e.g. biology, physics, chemistry) + parallel study of teaching competence within the follow-up master study program;

All the above mentioned ways apply to variants of gaining teaching qualification already within undergraduate training. In principle, all of them can be functional within either concurrent or consecutive model of teacher training. Students are thus systematically prepared for performance of teacher profession from a certain stage of their study (ideally, since its beginning). Ongoing debates about the positives and negatives of both models have been running for over 20 years (Darling-Hammond and Cobb, 1995) or (Fullan and Hargreaves, 1992) and both models appear legitimate and acceptable in retrospect.

Completion of a non-teacher training bachelor and a non-teacher follow-up master study program is perceived as yet another credible alternative of teacher education mainly by the non-teacher training faculties. Students could meet the legal requirements for teaching qualification through completion of specific course called Study of Educational Sciences (formerly known as Additional Pedagogical Study) in the frame of lifelong learning. This qualification educational course must have at minimum 250 hours, which corresponds to approximately 18 to 20 credit points of study load and its scope is thus comparable to the pedagogical-psychological modules if undergraduate teacher training at a number of faculties.

However, seen from the pedeutological perspective, this model raises several fundamental concerns:

- In terms of educational content in the field of pedagogy and psychology the studies in educational sciences are proportioned sufficiently. However, subject didactics represent a major problem. Given that studies in the field of educational sciences have a "universal" character and provide a teaching qualification for graduates of any non-teacher training master study programs, the subject didactics for a particular general education or professional subject studied within the non-teacher training study program cannot be always properly proportioned. There is lack of interconnection between subject didactics with the parent branch of science, or the interconnection is insufficient.
- The logical sequence of propaedeutic, specializing, extending, and applicatory disciplines cannot always be kept due to the fact that the teacher training in this model is in fact provided in two isolated cycles. The teacher training is thus becoming inconsistent, logically unrelated and the study of educational sciences has only the character of an “appendix”, and is so perceived both by the students and even, not infrequently, by their teachers.
- The teaching practice of the participants of the above mentioned educational science lifelong learning studies also present a problem. They are often not implemented at all and a teacher who has never been to school enters school practice qualified by the law. Another unwelcome situation occurs when a kind of a formal teaching practice takes place which lacks lessons analysis with mentors and subject-methodologists.

- Another difficulty is that the final examination in this study has not got an appropriate format of the final examination (final state examination in pedagogy and psychology is now a mandatory part of all master degree courses leading to a teaching qualification).

CONTENT COMPONENTS OF TEACHER TRAINING

The educational content of undergraduate teacher training was constituted into five fundamental content components, specification of which has been agreed upon by all the teacher training faculties:

1. Field component containing field-related specialized courses. All professional subjects of the studied fields form the field component in the case of double- or multi-subject studies.
2. Subject-didactic component brings together the subjects classified within subject or professional didactic. Beside the specialized subjects dealing with the didactic of instruction within particular topics and with the general subject didactics, subjects focused on technology of school experiments, methods of ICT utilization, field trips, etc. are implemented. Subject-didactic component is sometimes included in the field component. This solution however does not prove optimal as subject didactics are highly specifically focused and have interdisciplinary character.
3. Educational-psychological component provides basic propaedeutic and extension disciplines within the field of pedagogy and psychology. Courses in special education, social pathology, philosophy of education, etc. are also implemented.
4. Generally cultivating component contains subjects of the so called general or university foundation. These include philosophy, foreign languages, informatics, ethics of the teaching profession and other subjects of educational character - physical education, health and healthy lifestyle education, environmental education, etc.
5. The teaching Practice contains all practically focused disciplines, ranging from observational, clinical, and concurrent practice to continual teaching practice. Subject focused on students' micro-teaching or subsequent analyses of lessons are also implemented.

Although the implementing of these components in the undergraduate teacher training is widely understood as essential, there are quite mixed opinions on what should the proportion and importance of the individual components be. The biggest controversy remains within opinions on the proportion between educational-psychological component and the field component. Generally accepted is the notion that the educational-psychological component should be the largest in the primary school teacher training study programs and that it should gradually decline ingredients and should gradually decline towards the upper secondary teacher training (Kurelová, 2002). Nevertheless, upper secondary teacher training graduate is, in accordance with Act No. 563/2004 Coll. on Educational Staff, also qualified as a teacher for the lower secondary classes (of basic school in the Czech Republic). Both study programs graduates' profiles and their output competence should thus be equivalent. Yet another discrepancy occurs between faculties of education on the one hand and the faculties of science and philosophy on the other. The faculties of education usually determine the proportion of the individual components of teacher education based on minimum requirements for the fundamental components of teacher training (http://aplikace.msmt.cz/ak/koncepce1.htm, MŠMT, 2004) adopted and recommended by the Accreditation Committee of the Czech Republic (http://akreditacnikomise.cz/cs/standardy-pro-posuzovani-zadosti/219-pozadavky-na-doplnujici-informace-pro-akreditace-strukturovanych-ucitelskych-programu.html, Akreditační komise, ČR, 2014). These requirements are shown in so called Marešova Table:

Table 1: Proportion of the fundamental components of undergraduate teacher training

Component name	Share in% of total number of hours	Approximate number of credits
Subject-field (1st approved subject) + Subject-didactic	60 %	180
Subject-field (2nd approved subject) + Subject-didactic		
Educational-psychological	min. 15-20% of the of the total number of hours of teacher training	45 - 60
University foundation component, such as biology, informatics, philosophy	7% of the total of total number of hours of teacher training	20
teaching practice	4 weeks, aprox. 3% (at 14 weeks in semester)	10
Subtotal	85 – 90 %	255 - 270
space for the needs of the faculties	10 – 15 %	30 - 45
Altogether	100 %	300

The faculties of science and philosophy have never accepted, let alone practically applied the recommended proportions. The proportion here always favours significantly the field component contrary to the recommendation while educational-psychological component remains considerably lower – in many cases reduced to a formal, virtually non-functional minimum.

Another layer of dispute concerns the subject-didactic component. In the above mentioned Accreditation Committee Recommendations, this component is reported separately, yet has no recommended share in the overall preparation of future teachers. This conception arises from the traditional concept of subject didactics seen as an integral part of the given field, not as an independent interdisciplinary field of science. The proportion of subject-didactic component is therefore virtually a compromise between the professional representatives of the field and the subject didactics of the field. This solution, however, is quite unsystematic, as it depends on the specific personnel situation at the workplace, rather than on the requirements for the competence in the pedagogical content knowledge (Shulman, 1986) by teacher training graduates, which we regard as crucial and necessary.

The above mentioned controversies therefore induce the high level of fragmentation and disunity in the conception of the importance of individual components of teacher education. This can be illustrated on the case of two existing accredited graduate courses leading to a qualification of a lower secondary chemistry teacher at two Czech regional universities. Diagram (Figure 1) shows the percentages of the various components of teacher education.

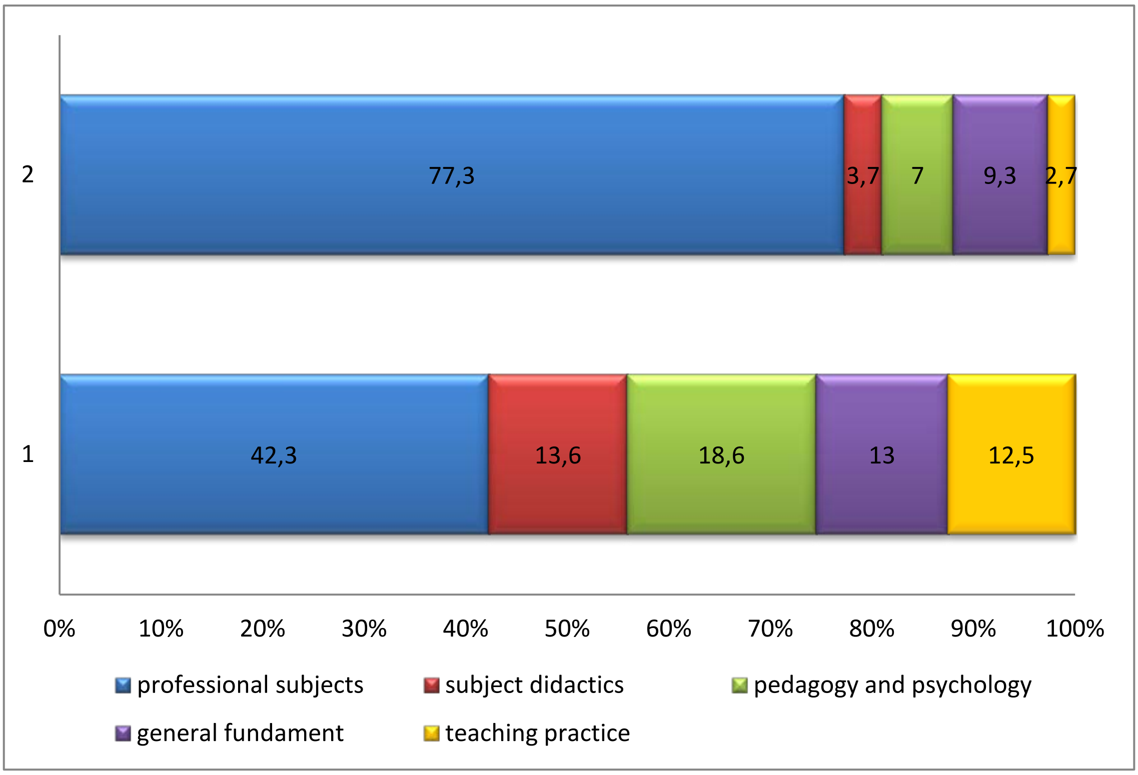

Figure 1: Differences in the proportion of components of a lower secondary chemistry teacher preparation

We have purposely selected cases that are as diverse in the proportion of the components as possible. The proportion of the components was determined based on the number of credits belonging to individual disciplines and subjects associated in the given folder. Clearly, although the two graduate courses should provide the same output – a lower secondary chemistry teacher – the graduates' profiles, their learning outcomes and their achieved competencies will be significantly different. The illustrative case of inconsistency within the teacher training is not an exceptional phenomenon, but rather common. Significant differences in proportion of the individual components of teacher training, and thus in the graduate's profile, are apparent between different universities in the Czech Republic, between the various faculties of the same university and even between different departments of the same faculty! Undergraduate teacher training has become indeed unsystematic and spontaneous issue. Variety and alternatives of different routes leading to a teaching qualification is probably unprecedented in any other comparable profession. Such unwelcome fragmentation has in recent years increasingly called for the establishment of a quality standard of the teaching profession and the complementary Profile of graduates of teacher training degree courses.

This Profile can be also defined as a set of professional competencies of the teacher training degree courses graduates necessary for standard (quality) performance of the teacher's profession under the circumstances of changing educational reality that brings about profound shifts in the conception of objectives, content and strategies of school education. The professional competencies include internalized knowledge, skills, reflected experience, attitudes and values of the graduates of teacher training degree courses. Standard quality of the teaching profession should be seen as a unifying framework for defining the profile of the graduates of teacher training faculties and as the basis for changes in undergraduate teacher training. It should provide clear answers to the following questions:

- What should the profile of a graduate of teacher training degree course be?
- What should the output competences of a graduate of teacher training degree course be?
- What should the content standard of individual components of teacher training be?
- What should the conception of future teachers' education be?

However, due to the fact that the work on the standard were stopped and the standard had not been completed to become official mandatory document, not even unified and binding requirements for the teacher training courses graduates' profile have been defined. For more on the issue of the standard of the teaching profession see (Suchánková, 2007) or (Vašutová, 2001) or (Weinert, 2001).

SOME MYTHS ASSOCIATED WITH UNDERGRADUATE TEACHER TRAINING

As noted above, the current situation has it that upper secondary science teachers are trained mainly at the faculties of science, while lower secondary science teachers study prevalently at the faculties of education. The very conception of teacher preparation as well as study plans and the proportion of individual components of teacher education thus differ quite significantly. With a bit of exaggeration it may be said that a prevailing conception regarding lower secondary science teacher training has it that the very discipline (e.g. chemistry, biology, physics) is not the objective but only a means to the achievement of broadly conceived general objectives of basic education. Focus on the field itself and its mastering professionally greatly dominates on upper secondary school level. The underlying premise derives some myths concerning preparation of future science teachers, predominantly at faculties of science. Here some of them will be presented briefly.

1. The biggest myth, virtually sacred mantra of all science teachers and their educators says that there is a dramatic decline in interest of applicants for science and technology-oriented study programs. However, 31 982 students are currently studying science, which is comparable to the number of students in the medical, pharmaceutical and health care (30,885) fields. Since 1998 till 2013 the relative number of science students increased from 4.6 % to 9.7 %. The sum of the students in scientific and technical fields (total 114,374) almost doubles the number of students in the humanities and social science (63 668) http://toiler.uiv.cz/rocenka/rocenka .asp (ÚIV, 2014).
2. The second myth has it that the natural science fields have relatively lower number of graduates due to more challenging study. The ratio of graduates in scientific disciplines to students of these fields (21 %) is comparable to the ratio of graduates of the humanities and social sciences to students of these subjects (22 %). Almost the same ratio can be traced in graduates and engineering students (22.3 %). In contrast, the proportion of graduates and students in fields such as e.g. medical, pharmaceutical and health care is now just 17.2 %. Demandingness of science and humanities study measured through the retention rates is, at least at public universities, virtually identical.
3. Another of the favourite myths is the belief that science faculties that they prepare science teachers for academically oriented secondary schools (read only for grammar schools) and that, therefore, the greatest importance must be placed on the professional component of teacher training, while the pedagogical-psychological or subject-didactic components are unnecessary because a man becomes a good teacher just through mastering their field. In accordance with the Act on Educational Staff however, graduates of upper secondary teacher training are qualified to teach science to the lower secondary pupils and in upper secondary schools not necessarily natural science oriented. The above mentioned types of schools, however, require most important competence of pedagogical knowledge of content and didactic intermediation of subject matter (Švec, 2005). In this respect a graduate must not be deprived of these competencies. Discrepancies in this area are so fundamental that recently a discussion has been open at the level of permanent working groups of the Accreditation Committee of the Czech Republic whether teaching for grammar should be excluded from the upper secondary segment under specific, different criteria which would allow for the revision of the importance of individual components of teacher

preparation and their distribution. These trends should be rejected in principle as they would to more profound fragmentation and lack of system in undergraduate teacher training than is currently the case.

4. The unwelcome conviction that the faculties of science prepare exclusively grammar school teachers bring about the situation when little or no attention has been paid to the issues of education of pupils with special educational needs in the respective study plans of upper secondary teacher training at the science faculties. According to another myth there are no such students at grammar schools. Some faculties of science have no subject in their study plans that would deal with special education whatsoever. But if we realize that among pupils with special educational needs there are medically disadvantaged pupils such as those with chronic diseases (allergies, metabolic disorders, asthma, etc.) and students with learning and behaviour disabilities, the percentage of these pupils is almost 10 %! (Šafrová and Trojanová, 2005). For comparison, at American high schools, the percentage of pupils with special educational needs is 13.8 % (National Center for Education Statistics, 2013) thus the required competence of future teachers to work with these children is essential.
5. The last myth that is to be noted is the one that attracts media attention most of all. The myth has it that the faculties of education are to blame for all negatives in the undergraduate teacher training. There are nine faculties of education altogether in the Czech Republic, which is less than a quarter of all Czech faculties preparing future teachers. In the case of science teachers, six faculties of education provide lower secondary science teacher training programs and only three faculties of education offer upper secondary science teacher training programs. The faculties of education in the Czech Republic are thus represented only marginally in secondary level science teacher training.

CONCLUSION

Despite the efforts of the Czech decision-makers the unified profile of undergraduate teacher training graduate failed to be enforced to become mandatory standard for all higher education institutions providing undergraduate teacher training (not only for science teachers). These efforts have unfortunately no support in the standard of quality of the teaching profession, which has still not been officially introduced and recognized. Moreover, the situation is complicated by the existence of relatively many different routes to obtaining teacher qualification and some of these paths are way too attractive for so called “professional faculties” as they allow for undergraduate teacher preparation only in technical subjects. Getting teaching qualification is then postponed until the lifelong learning form of study in the field of Educational Sciences (formerly known as supplementary pedagogical study). And yet it appears that the very faculties preparing future teachers perceive the need to standardize the requirements for learning outcomes and competences contained in the graduate profile. Unfortunately, the faculties providing undergraduate teacher training have so different concepts of what the preparation should be like, that the creation of a consensual and united model of teacher training is quite unlikely. Our system of tertiary education shall thus produce graduates of teacher training degree programs with very different competencies and learning outcomes.

REFERENCES

Darling-Hammond, L., Cobb, V., L., 1995. *Teacher Preparation and Professional Development in APEC Members: A Comparative Study.* Washington, DC: US Department of Education.

Doporučení stále pracovní skupiny Akreditační komise pro obory pedagogické, psychologické a kinantropologické k předkládání strukturovaných učitelských programů [online] Available at: http://akreditacnikomise.cz/cs/standardy-pro-posuzovani-zadosti/219-pozadavky-na-doplnujici-informace-pro-akreditace-strukturovanych-ucitelskych-programu.html [Accessed 1 June 2014]

Fullan, M., Hargreaves, A., 1992. *Teacher Development and Educational Change.* London: Falmer.

Koncepce pregraduální přípravy učitelů základních a středních škol [online] Available at: http://aplikace.msmt.cz/ak/koncepce1.htm [Accessed 30 May 2014]

Koncepce pregraduální přípravy učitelů základních a středních škol [online] Available at: http://aplikace.msmt.cz/ak/koncepce1.htm [Accessed 1 June 2014]

Kurelová, M., 2002. Profesiografické zdroje změn v profesionalizaci vzdělávání učitelů. In: H. Lukášová-Kantorková, ed. 2002. *Profesionalizace vzdělávání učitelů a vychovatelů.* Ostrava: Repronis.

National Center for Education Statistics. Students with disabilities. 2013. In: *Digest of Education Statistics.* U.S. Department of Education.

Shulman, L., S., 1986. Those who understand: Knowledge growth in teaching. *Educational Researcher*, vol. 15, no. 2, pp. 4-14.

Suchánková, K., 2007. Profesní standard a jeho role ve zkvalitňování učitelské profese. *Orbis scholae*, Vol. 1, No. 3, pp. 13 – 25.

Šafrová, A., Trojanová, J., 2005. Žáci se specifickými poruchami učení na víceletém gymnáziu. In: M. Bartoňová, 2005. *Edukace žáků se speciálními vzdělávacími potřebami. Zaměření na edukaci žáků se specifickými poruchami učení.* Brno: MSD.

Švec, V., 2005. *Pedagogické znalosti učitele: teorie a praxe.* Praha: Aspi.

Ústav pro informace ve vzdělávání. Statistická ročenka školství 2013/2014 - výkonové ukazatele. [online] Available at: http://toiler.uiv.cz/rocenka/rocenka.asp [Accessed 31 May 2014]

Vašutová, J,. 2001. Model tvorby profesního standardu učitelů. In: E. Walterová, E., ed. 2001. *Učitelé jako profesní skupina, jejich vzdělávání a podpůrný systém.* 2. díl. Praha: UK.

Weinert, F., E., 2001. Concept of Competence: A Conceptual Clarification. In: D., S. Rychen, L., H. Salganic, eds. 2001. *Defining and Selecting Key Competencies*. Goettingen: H. and H. Publishers.

INQUIRY BASED CHEMISTRY EDUCATION – ASSUMPTIONS AND APPLICATIONS

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Abstract

Since the start of the new millennium, many countries worked on the problem of school education change since the traditional school education, especially in science subjects, doesn't get the students sufficiently ready for life in the current society. There are significant educational changes in most of the countries. One of them is the preference of IBSE as a new approach to science education.

The curricular reform in the Czech Republic took place in the period 2000-2010. The new frame educational programs are valid for the whole country. They generally respect the requirements and suggestions of EU, but their use in the creation of school educational programs of various schools is very limited and often merely formal.

As a part of the GAČR project we have created a skill test based on the suggested skill structure corresponding to IBSE requirements. The goal of the test was to map the level of selected student skills at the end of lower and upper secondary schools. At the same time we used a questionnaire study to find out the teachers' opinions about new approach to the teaching of chemistry.

The results we obtained led us to the conclusion that the main problem in introducing new teaching methods is the lack of suitable educational materials and insufficient teacher preparation for this type of education. Seeing as these problems are the main goals of the European projects ESTABLISH and TEMI, the participation in their solving seems to be a good way to change the education even here.

Keywords

Lower and upper secondary schools, inquiry based science education, IBSE skills, IBSE educational materials, chemistry teacher training.

INTRODUCTION

At the end of 20th century and the start of 21st, many European and other countries started to feel the growing sentiment that the school education must be changed since the traditional school education doesn't sufficiently prepare the students for life in the current society. The problem of students' disinterest in science, including chemistry, is of special importance. The students across Europe consider scientific subjects difficult and unneccesary for their daily life. As far as the society needs go, it's therefore necessary to rouse the students' interest in these subjects (European Commission, 2007; Čtrnáctová et al, 2007).

The European Council, during its Lisabon session in March 2000, said clearly that the main European asset is the human resources and reached the conclusion that there should be a European frame, set to define new basic skills (Čtrnáctová et al, 2007; Čtrnáctová, Čížková, 2010). Following that, there was a recommendation about key competences for lifelong learning and the European reference frame of these competences, defined here as combinations of knowledge, skills and approaches suitable to a given context.

The scientific-technological competence, which is of prime importance for chemistry teaching, is the ability and willingness to use a set of knowledge and methods to understand the laws of nature and to formulate conclusions based on the evidence. It was recommended that the EU countries should use the conclusions of the European reference frame in creation of their own educational programs (Trnová, 2012).

In the Czech Republic, the so-called frame educational programs (FEP), meant for various degrees of education, were gradually created in the period 2000-2010 (Čtrnáctová, Zajíček, 2010). FEP introduced the term "key competences", in Czech education system hitherto almost unused; it is defined as "sum of knowledge, skills, abilities, approaches and values necessary for personal development and fulfilment of each member of the society". As an example, there are learning and problem solving competences, communicative competences, social and personal competences, civic and work competences.

This new current importance of competences is a significant impulse for the study of skills as the basics of key competences. These changes in education focus directly on the topicality and usefulness of the research of the issues pertaining to student skills in chemistry teaching at primary and secondary schools.

The topicality and importance of the research of the issues of student skill development in chemistry teaching is also supported by frequent teacher questions what the skills actually *are*. In many cases, the teachers are not aware of the existence of various types of skills and various phases of their acquisition. If they select the correct processes for the skills acquisition based on their experience, they will achieve good educational results.

However, they have problems finding the causes of failures. Not knowing the skill structure, and especially the stages of the acquisition process, can lead to mistakes which show in the students' formal knowledge (Trnová, 2012). That also significantly showed in creation of our own school educational programmes (SEP) which FEP require the schools to have. The general recommendations about the preference of skill and competences acquisitions are used very sparsely and often just in a formal way. That's why the experts more and more often warn that introduction of FEP and SEP more likely results in *decrease* of the education level since the students don't actually acquire skills and competences important for successful daily and professional life in today's world corresponding to worldwide educational trends any sooner than they used to.

THEORETICAL STARTING POINTS AND METHODS

In the current outlook, the chemistry skills are considered a dominant part of the competences the students should acquire during their chemistry education.

The skills can be classified in many ways; one of most used skill classifications in the Czech Republic is (Čáp, 1993; Skalková, 2007; Švec 1998):

- thought (reason, intellect, intellectual)
- sensomotoric (psychomotoric, motion)
- social (communicative, socially communicative)

In the subject of chemistry, the first class of skills contains use of chemical terms and theories, i.e. expert knowledge, to solve tasks and problems, the second class contains mainly skills related to performing chemical experiments and we might say that the third class contains the mutual communication and interaction between the teacher and the students and among the students.

The acquisition of all these skills, which of course overlap and interweave, is no doubt the dominant feature of the chemistry education at primary and secondary schools.

However, the new approach to education includes not only the acquisition of special chemical skills, but also important skills for successful professional and daily life. Apart from classical skills acquired in chemistry education there are now also so-called "twenty-first century skills". These skills include especially such skills as critical thinking, problem solving, cooperation, effective communication and self-education (Pellegrino, Histon, 2012). The international research OECD PISA also focuses at the verification of these skills in recent years and moves away from the traditional school knowledge and classical skills.

The inquiry-based education method is also getting more and more into the foreground in the science education (Franklin, 2000; Apedoe, Reeves, 2006). This method stems from the presumption that the real scientific inquiry uses elements such as interest in the researched problematics, intensive search of the problem solution, both theoretical and experimental, and especially deep understanding of the issues studied. In other words, the inquirer is not memorizing learned formulations but explains the knowledge which they achieved by themselves and which they understand.

Inquiry Based Science Education (IBSE) is an educational protocol based on students' own investigations with use of many activising methods. It is a process of problem diagnostics, experimenting, alternatives detection, research planning, stating and verifying of hypotheses, searching for information, model creation, discussion and argumenting.

It was found out that while the way scientists perform their research can be shown as an inquiry cycle, the inquiry-based education can be analogically shown through various models, which can be all considered variations on so-called "learning cycle" (Llewellyn, 2002; Dublin City University, 2010). We have used the five-stage learning cycle model "5E".

The learning cycle can be used to create the structure of the IBSE education since it's one of the most common and most effective models for realization of the teaching and learning. And it were exactly the skills needed for the use of IBSE in chemistry teaching that became the object of our research. We were interested whether the primary and secondary students have such skills in the first place or not and whether their teachers accept them (Čtrnáctová et al, 2013).

This research was a part of solving the GAČR project (2010-2013): Students' skills in biology, geography and chemistry: research into planned, realized and achieved curriculum in implementation phase of curricular reform. The project was conducted by Charles University in Prague – Faculty of Science and Masaryk University in Brno – Pedagogical Faculty. Results of the research are summarized in the publication Řezníčková et al, 2013.

The main goal of this project was to propose an interlinked system of student skills based on their multi-level analysis. These are skills that should be acquired in science at the end of lower secondary school and at the end of upper secondary school (grammar school) in order to be able to work using the IBSE method.

Following this learning cycle we have created a skill structure necessary for it to be realized in school practice. We focused at skills related mainly to the creation of research questions (stage 1 and 2 of the IBSE learning cycle), to searching the information in various sources and their critical evaluation (stage 2 and 3 of the IBSE learning cycle) and to the presentation of the conclusions (stage 4 and 5 of the IBSE learning cycle).

As a suitable tool for determining the above-mentioned group of skills we chose a skill test based on one complex task that requires the student to solve many partial tasks. The complex task was concepted as a story with many obstacles that require various tasks to be overcome. The partial tasks in the test were focused at the listed IBSE skills.

When creating the test, we tried to introduce it in a way that would make the students solve it with interest (Čtrnáctová et al, 2013). The basis was a motivational story resolving aquaristic-related chemical tasks. This is a theme that is not taught, so the students weren't able to solve the tasks based on their knowledge and actually had to prove the researched skills. The partial tasks were created in such a way so they would research the skills the students need for work with chemistry information.

The skill test contained eight tasks aimed at the general skills: asking relevant research questions, searching of information in a text, table or graph, analysis of data acquired from multiple sources – text, table or graph, data transfer from text to table or graph. Table 1 specifies the focus of the specific test tasks.

Table 1: Specification of chemical test tasks

Task	Skill type
1	information search in text
2	data search in table
3	data search in graph
4	analysis of data from multiple information sources (text, table, graph)
5	data transfer from text to table
6	data transfer from text to graph
7	asking expert questions
8	information search in text

While the students were tested, their teachers were filling in a **questionnaire** which contained 6 groups of question. The questions of the group 1 to 4 dealt with their opinions about age-appropriateness of the various test problems and preliminary guess of the students' success rate in solving them, group 5 questions were dealing with the guess of their students' success rate in other selected skills like those mentioned in the test and with the teachers' opinions about including similar skills in chemistry education.

Another method we used were semi-structured interviews about student skills. We have interviewed the teachers about the importance of general student skills and their acquiring in the science education.

The main intention of semi-structured teacher interviews was to understand the wider connections that prevent or support the development of certain student skills necessary for IBSE. The semi-structured interviews were based on eight groups of questions, supplanted by other questions as needed:

- How do the chemistry teachers understand the term "skill"?
- Which skills connected with the problem solving process do the teachers consider most difficult for the students to acquire?
- How do the chemistry teachers react to the question if most of the students can be taught to formulate chemical questions?
- Which information sources in chemistry teaching do the teachers consider important and which do they use the least?
- What is the chemistry teachers' experience with having the students work with the information they found on their own?
- Which general and specific skills pertaining to working with information are systematically exercised in chemistry?
- How do the teachers evaluate/suggest to evaluate the level of the acquired skills?
- Which obstacles do the teachers think prevent exercising the selected skills in chemistry teaching?

RESULTS AND DISCUSSION

The finished **skill test** was given to 684 Czech students (431 from lower secondary schools and 253 from upper secondary schools) during chemistry lessons in May-June 2013. The students were not forewarned about the test. The success rate for solution of the various test tasks (in %) at lower secondary schools and upper secondary schools is shown in table 2.

Table 2: The average success rate of students (%) in various tasks of the test

Task number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Lower secondary schools	74,5	85,6	43,6	85,0	60,6	64,3	54,7	56,9
Upper secondary schools	92,5	93,7	60,3	89,9	68,2	78,9	72,9	69,6

Table 2 clearly shows that the students' achievements in the area of general skills necessary for work with information depends on their age. Comparing the average success rate of various test tasks for younger and older students shows that all IBSE-focused problems were more successfully solved by the older students.

Both groups of students had the most success in solving the task 1 and 2, pertaining to searching information in text or table and answering six dichotomic questions in task 4 where the success rate was 70-90%. The tasks that asked the students to create their own table, to find the data from the graph or to construct their own graph and formulate the information they find in their own words (tasks 3, 5, 6 and 8) were more problematic. However, even here the success rate for the tasks surpassed 50% (with exception of the task 3 – data search in graph). The test results show that most of the students have necessary skills for IBSE, at least at a basic level.

The questionnaire was given to 28 teachers in total (lower secondary schools – 17, upper secondary schools – 11). The results of the teacher questionnaire show that the teachers considered most of the tasks appropriate for the students' age. Comparison of the questionnaires and the test results showed that the students were usually better in solving the tasks than that the teachers expected. However, it was also found out that while the teachers are convinced they exercise these skills with the students, the students are of contrary opinion.

For this reason, we also realized another part of the research. This part of the research had a qualitative character, which is why the selected teachers were asked to be the respondents; in chemistry, it was 12 teachers (lower secondary schools – 4, upper secondary schools – 8). The interviews with the respondents were recorded with a dictaphone and they were around 30 minutes long. The respondents chose time and place of the interview, but they did not know what it will be about. The sample was made up by 8 women and 4 men, all teachers at lower secondary schools and upper secondary schools with various amount of practice and various aprobations.

The analysis of the answers led to the conclusion that the respondents generally lack a clear idea about these skills and the way to train them. One of the reasons for this was, according to the teachers, the classic treatment of the subject matter in the textbooks and lack of suitable teaching materials for the development of general skills and IBSE teaching.

CONCLUSIONS AND NEW RESEARCH ITEMS

If we sum the results acquired in IBSE so far, we can give this as a conclusion:

- The test of skills results show that most of the students have necessary skills for IBSE, at least at a basic level.
- The teacher interviews show that their ideas about acquiring skills for IBSE are problematic.
- The results acquired so far show that inquiry-based education could be in practice realized even now and students don't have to be specifically prepared for it; however, it's necessary to put more effort into suitable IBSE educational materials and IBSE training for the teachers.

As for the suitable educational materials (teaching texts, worksheets etc.), the current situation is fairly sufficient. This is mostly due to the results of the projects ESTABLISH – European Science and Technology in Action: Building Links with Industry, Schools and Home (7^{th} FP EU, 2010-2014) and the project Science is no science – Student experiment as a starting point for the teaching of science at schools (Ministry of Education, CZ, 2011-2014), which were solved, among others, by the employees of the Faculty of Science, Charles University in Prague. During the ESTABLISH project, there were altogether 18 processed themes and more than 250 IBSE activities created for physics, chemistry and biology at the level of lower secondary schools and upper secondary schools (Dublin City University, 2014). As a part of the "Science is no science" project, there were over 100 activities created for the practical work in physics, chemistry and biology for primary and secondary schools (Conatex-Didactic, 2014).

The main requirement is that the activity in question must be related to FEP and SEP of science subjects and it must be possible to realize it during the science lessons.

The new TEMI project (7. FP EU) is focusing on the creation of teaching and methodical materials connected to a mystery. Its mainly focus is however on IBSE trainings for teachers.

TEMI project – Teaching Enquiry with Mysteries Incorporated (Queen Mary University, 2014) started in the year 2013 and it's being coordinated by the Queen Mary University of London. The project is supposed to run until the year 2016. It is a science education project meant for primary and secondary school teachers and its main goal is to prepare and carry out teacher trainings focused on IBSE that would lead to a change in the teaching of science and mathematics throughout Europe. TEMI teacher trainings give the teachers new knowledge and skills that will allow them to merge better with their students, access to exciting new resources and vast support necessary in order to incorporate this teaching method into their lessons. Teachers fully experience the whole process in the role of pupils/students to get familiar with the TEMI and IBSE method.

With the help of this project, we want to change directive teaching into enquiry teaching, change the paradigma from knowledge to skills and change the perspective of assesment of pupils'/students´ outcomes. In our training, we use known and new activities and units from the ESTABLISH project for lower secondary schools and upper secondary schools, activities for practical work in the primary and secondary schools from the „Science is no science“ project and also new activities for the TEMI project.

The main goal of this project is to train teachers to use IBSE in their lessons. That is why we devoted a lot of effort to preparing this kind of training and its execution (autumn 2013).

We have already had two teacher trainings in the Czech Republic. These were practical two-day workshops for teachers in January and June 2014. We had a total of 30 participants who learned about mysteries used to create curiosity and motivation.

Even though this project is only at its beginning, our first experience says that with careful content and organizing preparation for the workshop, effective non-material and material motivation and sufficient amount of appropriate methodical and teaching materials, these workshops are interesting for teachers and they truly inspire them to use IBSE in their classes.

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REFERENCES

Apedoe, S. A., Reeves, T. C., 2006. Inquiry-based learning in undergraduate science education. *Journal of science education and technology*, 15 (5), 321-330.

Conatex-Didactic Učební pomůcky, 2014. Věda není žádná věda – Žákovský pokus jako východisko pro výuku přírodních věd na školách. [online] [Accessed 10 June 2014] Available at: http://www.conatex.cz/veda/project.php

Čáp J., 1993. *Psychologie výchovy a vyučování*. Karolinum, Praha.

Čtrnáctová H., Čížková V., Marvánová H., Pisková D., 2007. *Přírodovědné předměty v kontextu kurikulárních dokumentů a jejich hodnocení.* Univerzita Karlova, Praha.

Čtrnáctová H., Čížková V., 2010. Inovace obsahu a metod výuky přírodních věd v současné společnosti. *Chemické rozhľady*, 11, (5), 139-146.

Čtrnáctová, H., Zajíček, J., 2010. Současné školství a výuka chemie u nás. *Chemické listy*, 104 (8), 811-818.

Čtrnáctová, H., Čížková, V., Hlavová, L., Řezníčková, D., 2012. Science skills of students in the period of curricular reform. In: *Chemistry Education in the Light on the Research (monograph).* Pedagogical University of Kraków, Kraków, 54-58.

Čtrnáctová, H., Cídlová, H., Trnová, E., Bayerová, A., Kuběnová, G., 2013. Úroveň vybraných chemických dovedností žáků základních škol a gymnázií. *Chemické listy*, 107 (12), 897-905.

Dublin City University, 2010. *ESTABLISH – Guide for developing Teaching and Learning Units*. AMSTEL Institute, Amsterdam.

Dublin City University, 2014. *ESTABLISH Teaching and Learning Units – Physics, Chemistry, Biology and Science.* [online] [Accessed 10 May 2014] Available at: http://www.establish-fp7.eu/

European Commission, 2007. *Science Education Now: A renewed Pedagogy for the Future of Europe.* [online] [Accessed 10 June 2012] Available at:

ec.europa.eu/ research/sciencesociety/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Franklin W. A., 2000. *Inquiry Based Approaches to Science Education: Theory and Practice*. [online] [Accessed 12 August 2010] Available at: www.brynmawr.edu/ biology/ franklin/ InquiryBasedScience. html

Llewellyn D., 2002. *Inquire Within: Implementing Inquiry-Bases Science Standards*. Corwin Press.

Pellegrino J. W., Histon M. L., 1999. *Education for life and work: developing transferable knowledge and skills in the 21st century*. National Academies Press, Washington.

Queen Mary University, 2014. *TEMI project – Teaching Enquiry with Mysteries Incorporated*. [online] [Accessed 10 June 2014] Available at: http://teachingmysteries.eu/

Skalková J., 2007. *Obecná didaktika*. Grada Publishing, a.s., Praha.

Švec V., 1998. *Klíčové dovednosti ve vyučování a výcviku*. Masarykova univerzita, Brno.

Trnová E., 2012. *Rozvoj dovedností žáků ve výuce chemie se zaměřením na nadané*. Masarykova univerzita, Brno.

SUPRAMOLECULAR CHEMISTRY. HYDROGEN BONDING AS A CORE FOR INQUIRY-BASED LEARNING TASKS

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Abstract

From an educational point of view Supramolecular Chemistry could be regarded such an opportunity to develop highly enriched tasks to be used from different subject perspectives at different educational levels regarding the non-covalent bond concept and intermolecular interactions such as the hydrogen bonding.

This paper describes an attempt to design several tasks spinning around the hydrogen-bonding concept. Design framework is based on some modules, which have been tested in initial teacher training and professional development courses to encourage the implementation of inquiry-based learning strategies in Math and Science. These tasks has been designed under a multifaceted understanding on inquiry-based learning and throughout them some related concepts such a non-covalent interactions, hydrogen bonding, hydrogen donor, hydrogen acceptor, motifs, patterns, tectons, synthons, and others could be introduced and further developed in the understanding of intermolecular interactions. Some opportunities and possible pros and cons will be also discuss for the implementation of this brief introduction to hydrogen bonding in chemistry for higher secondary education or first years in undergraduate chemistry courses.

Keywords

Supramolecular chemistry, hydrogen bonding, graph set-theory, inquiry-based learning

INTRODUCTION

Primary focus of chemistry education has been to give students possibilities to acquire some significant principles and concepts related to chemical bonding, structure, reactivity, acidity, oxidation, equilibrium, etc. Educational research has shown that students have difficulties to acquire a deep understanding of these and others principles and concepts. Among others, the main reason is due to the fact that many of these principles are not feasible for direct experimentation or observation and becomes in the domain of abstract conceptualization (Kozma and Rusel 2006, p. 7). This abstract nature has been pointed out such one of the reasons, among others, to explain why students find difficulties to construct meanings. One of these difficult concepts are intermolecular forces, the means by which individual molecules interacts to other molecules. Chemistry educational research has focused on a great a wider variety of previous studies involving student understandings of chemical bonding (covalent, ionic, metallic) but there is a smaller part of studies whose primary focus is on intermolecular forces (Bindis 2013). Chemical bonding misconceptions studies has led to discover misconceptions of intermolecular bonding (Bindis 2013) and other studies has shown how undergraduate students have difficulties to apply their knowledge of hydrogen bonding to physical properties even when they are able to give appropriated definitions (Henderleiter et al. 2001).

It seems that further research should be done in the field of student understanding of intermolecular forces. Supramolecular chemistry could offer a myriad of opportunities to contextualize and to plan tasks and lessons that adapt to emerging needs of students and requirements of how Science and Chemistry should be taught and learnt.

The pace and sophistication of development of supramolecular chemistry has relegated it to graduate courses or in less extension to undergraduate courses and no so much attention has been paid in educational levels such as higher secondary education. Hydrogen bonding is a topic which is explicitly introduced in higher secondary school (16-18 years) within the strand of intermolecular interactions, (at the same time learners study other interaction such as, dipole-dipole, van der Waals, etc.) Some secondary school textbooks (14-16 years) also represent some symbolic references in biomolecules or synthetic polymers. At higher secondary school emerge some opportunities to accurately introduce the hydrogen bonding once the main organic functional groups has been introduced both in Chemistry or Biology.

In this paper we present our attempt to design several tasks linked to supramolecular chemistry to face the hydrogen bonding.

BACKGROUND

Supramolecular Chemistry: Source of ideas for Chemistry Education

A very general definition of supramolecular chemistry, originally generated from organic chemistry, considers it as the study of intermolecular complexation where a host (macrocyclic compound) could encapsulate guests (guests). Nobel Prize (1987) Jean-Marie Lehn defined it as the "chemistry of molecular assemblies and the intermolecular bonds" and more colloquially it has been told using expressions such as "chemistry beyond the molecule, "non-molecular chemistry" or "chemistry of the non-covalent bond" (Steed and Atwood, 2009). Nowadays, supramolecular chemistry, which could be considered a very young discipline, is one of the most popular growing areas in experimental and applied chemistry. Supramolecular chemistry deals with the study of cation-binding host, binding of anions, binding of neutral molecules, crystal engineering, templates and self-assembly, molecular devices, biological mimics, liquid interfaces and crystals (topics taken for Steed and Atwood, 2009) addressing key concepts such as chelate, macrocyclic effects, preorganization and complementary, supramolecular interactions (ion-ion, ion-dipole, dipole-dipole, hydrogen bonding, π-π stacking, van der Waals forces), etc. Scientists try to describe, infer, understand, control and orientate intermolecular interactions for the development of new supramolecular compounds looking for practical applications in chemistry, biology, nanotechnology, nanoscience and material sciences (Nakanishi, 2011). Thus, supramolecular chemistry is highly interdisciplinary field, attracting and involving not just chemist but biochemist, environmental scientist, physicists, mathematicians and a whole host of others researchers (Steed and Andwood, 2009). Scientific interest on supramolecular issues could be roughly measured throughout the number of specific content in research journals and specialized publications (Crystal Engineering Communications, Acta Crystallographica, Supramolecular chemistry, Journal of Supramolecular Chemistry). Thus for example an unrefined search within Web of Science database using "Supramolecular" as a keyword (in title) yields over 62000 documents of which ca. 41000 are in the area of chemistry (last 10 years). These data have to be managed carefully, but it shows as a broad picture the encouragement and motivation of Scientists engaged in supramolecular chemistry

Hydrogen bonding interactions: definition and description

Supramolecular chemistry deals with a vast range of attractive and repulsive forces concerning to non-covalent bonding interactions. One of these interactions is the hydrogen bond. This interaction could be regarded as a very particular kind of dipole-dipole interaction. In the hydrogen bonding interaction a hydrogen atom attached to an electronegative atom is attracted to a neighbouring dipole on an adjacent molecule or functional group (Steed and Atwood, 2009, p 22). Some of the main features of this interaction could be described in terms of: strengthens directionality, weakness and flexibility (affinity, specificity, hydrophobicity, and reversibility). Hydrogen bonding has been described as the “master key interaction in supramolecular level” and among others is responsible for shape of proteins, recognition (enzymes substrates) and double helix of DNA. In terms of chemical symbolic representation, hydrogen bonding (some) is shown in figure 1.

X-H···A				
N-H···O	N-H···N	O-H···O	O-H···N	C-H···O
N-H···I	N-H···π	O-H···π	Os-□··□O	C-H□··Ni

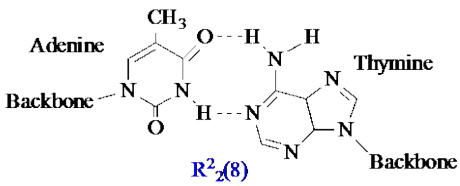


Figure 1: a.) A symbolic representation of hydrogen bonding from different atoms (N, O, Os, I, Ni, e.g.: O-H could be from alcohol or carboxylic acid) and moieties (π systems) b.) Hydrogen bonding in base pairing (graph set-theory notation in blue)

To make a review of Science history related on “hydrogen bonding” is out of scope and goals of this paper however as a teaching strategy it could be useful to trigger a motivating introduction to this topic. We could use it to engage our students and let them think of how 90 years later of hydrogen bonding discovery, supramolecular studies keep on being a “hot topic”. It was in 1939 when Pauling gave his first definition and approach for this special interaction:

“Under certain conditions an atom of hydrogen is attracted by rather strong forces to two atoms instead of only one, so that it may be considered to be acting as a bond between them”

One year later, in 1940, Austbury, wrote: “The most we can do here is to describe the various structural proposal that have so far been put forward, and to record the possible ways in which it has been suggested that the hydrogen bond may intervene [...] at least it will serve the purpose of collecting together for discussion and further development what we know”. That year, Robertson (1940) published in the same journal a research paper titled “The formation of intermolecular hydrogen bond. X-ray evidence”. These pieces of research and history could be used as analogy of what we would like to show afterwards along our instructional approach and tasks: a sense of collecting and discuss together (students and teacher) a set of evidences (using chemistry language and models from authentic x-ray diffraction data) to discuss and further progress in regards of such intermolecular interaction named “hydrogen bonding” to finally give a negotiated and agreed definition (peers) of what is and looks like “hydrogen bonding” (using models) and its possible implications in known substances. We will position ourselves in the epistemological principles related to this topic in supramolecular chemistry.

Several references have appeared in literature for hydrogen bond definitions (teachers must be aware whether or not use the term “hydrogen bridges”. For further discussion about meanings of these two terms see Desiraju 2002). The following broadened and operational definition was given in late 60s by Pimentel and McClellan (cited in Smith 1990, p2): "A H bond exists between a functional group A-H and an atom or a group of atoms B in the same or a different molecule when (a) there is evidence of bond formation (association or chelation), (b) there is evidence that this new bond linking A-H and B specifically involves the hydrogen atom already bonded to A". This definition emphasizes on evidences for a hydrogen bond and state that the interaction could happens in the same or a different molecules introducing the concept of intra and intermolecular bond. Probably form a pedagogical point of view it is not the best because students have no tools to look for evidences, although teacher could provide them through experimental data. Steiner and Saenger (1993) proposed this definition: “Any cohesive interaction X–H···A where H carries a positive and A a negative (partial or full) charge and the charge on X is more negative than on H”. Using this definition the concept of electronegativity (in atoms or groups of atoms) could be further developed in chemistry lessons related to intermolecular interactions.

A more academic definition from of hydrogen bonding is “an interaction involving a hydrogen atom located between a pair of other atoms having a high affinity for electrons; such a bond is weaker than an ionic bond or covalent bond but stronger than van der Waals forces. Hydrogen bonds can exist between atoms in different molecules or in parts of the same molecule (Encyclopedia Britannica, 2014). This definition is quite rich in terms that enable us to revisit ideas at different contexts and related concepts which are not explicitly stated such as intermolecular and/or intermolecular interactions, hydrogen donor and acceptor, electronegativity (which is highly depending as a whole of the electronic distribution within the molecule an not of an isolated atom) and interaction strength.

Description of supramolecular patterns involving hydrogen-bonds (for the solid state) is carried out using the method of Etter and MacDonald (1990), which is based on viewing hydrogen-bonds patterns topologically. Due to its chemical utility, this way of description is a standard for Scientific community. Through this methodology, easy and/or complex hydrogen-bond patterns could be disentangled, or decoded, systematically and consistently (Etter & MacDonad, 1990, p 256). Graph sets are assigned first to motifs, and then to networks.

$G^{a}_{d}(n)$
G: designator; S (intramolecular), C (Chain), R (Ring), D (Dimer)
n: degree; number of atoms in the pattern
a and **d**: number of acceptors and donors

Figure 2: Graph-set for categorize hydrogen-bond

To observe, analyse, find and describe hydrogen-bonding patterns, motifs and networks (e.g. using 2D or 3D models obtained from research publications) may enhance the ability to develop the visualization competence and becomes an activity which address contents closely related to intermolecular interactions.

METHODOLOGY

These tasks could be embedded in different instructional proposals. They focus on some scientific process (observation, inferring visualization, etc.) and contents associated to intermolecular interactions like hydrogen bond. Herein, in this communication, the concept inquiry teaching and learning is positioned within our understanding of how student-centered approaches should looks like when students face and inquiry-based learning lesson. They are many definitions for inquiry-based learning. However the framework, which has guided the design of these tasks, emerges from a broader accepted and agreed definition of IBL and a multifaceted understanding of it (Dorier and Garcia 2013).

Tasks presented here are in its first refinement cycle. Our idea is keep on working in the several refinement cycles once we implement and evaluate them. Tasks have been inspired on those classroom materials, ideas, and strategies proposed within some professional development modules designed by Swan et al. (2012). These modules explored the pedagogical challenges that arise when introducing inquiry activities to the classroom.

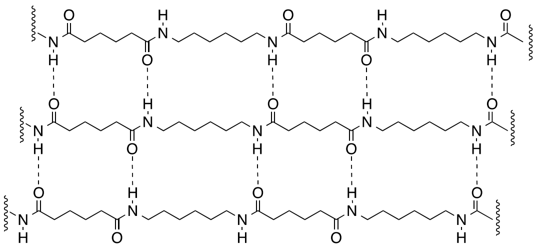
Student-led inquiry and Hydrogen bonding

This task is inspired in “making observations of pictures” (PRIMAS 2012) but it has been adapted to “hydrogen bonding” topic. Instead using real pictures of daily situations we will use "pictures" of hydrogen bond patterns (a forthcoming paper will describe how to design these resources for our chemistry lectures). Teacher must be aware not to give a wrong idea of what is "real" and what is part of the model and inform students about it, if would be needed. What we have called here a "picture" of a molecule and its drawn interactions is not real; they are part of the model. One of the pedagogic mistakes is to focus on models to develop "subject content" rather than the nature of models and the instructive use that models have on development of observations, visualization, interpretations, or predictions when building scientific ideas

The main aim of this task in those students explore situations trying to focus on sub-microscopic and symbolic level of chemistry. Connections with macroscopic level should be presented later in terms, for example of analysis of different properties of "synthetic clothes" which are deeply related to supramolecular interactions (e.g. Which are properties of Nylon 6 and Nylon 6-6?) Later on, emphasis should be drive to the fact that these models are the same that Scientific use to analyse, describe and predict intermolecular interactions (using different techniques to gather evidences, such as x-ray diffraction, NMR, IR, etc.) which explain phenomena and properties at macroscopic level.

Molecular formula for Nylon 6-6 is $(C_{12}H_{22}N_2O_2)n$. This polymer carried amide groups. Observe the interactions between hydrogen and oxygen. Hydrogen is covalent bonding to nitrogen and the oxygen is covalent bonding to carbon. The hydrogen bonding is shown as dotted lines. "Identify those "linear" intermolecular interactions? Identify and draw all those different "rings" you can see

(a)



(b)

Figure 3. (a) A guided and closed task. (b) Hydrogen bonding in Nylon

Solving activities like that shown in figure 3a could have some learning value but are far away from student-centered approaches. Questions are so much "oriented", questions have the answer, they "think" for you. If this task is used in such way we are losing lot of opportunities to give students chances to explore, to make hypothesis, to connect ideas and revisit previous knowledge (e.g.: concepts of inter and intra interactions, regarding covalent bonds, concept of molecular formula, electronegativity, functional groups, expanded formulas, symmetry concepts, etc.).

Hydrogen bonding is a good topic to invite teachers and student make good inquiry-based learning questions, even when the degree of conceptualization ought to be modulated. That for example from the above activity (Figure 3) teachers have chances to open the task, for example inviting student to find the "moieties" they already have studied or find patterns within the whole structure, or challenging them to think about how to name and classify different observed supramolecular rings. Use a plastic stick-model or a 3D viewer will enhance the learning experience. Although we show here a typical example, teacher can bring her/his own screenshots/pictures from research journal or taken form molecular viewers using crystallographic files. Teachers could ask their student for some common substances in which they could be interesting to look at supramolecular interactions (caffeine, acetic acid, citric acid, sucrose, glucose, phenylalanine, etc.) and generate the hydrogen bonding supramolecular structure. Figure 4 shows a more open task based on making observations of pictures for an IBL lesson and hydrogen bonding.

Strategies for learning concepts through inquiry

Sometimes it is argued that although teacher could be in favour of doing inquiry, arises some pressure related to curriculum. IBL should make strong contributions towards content learning goals as well (PRIMAS 2012). Integration of processes and content raise many pedagogical challenges. Following the ideas developed within "Learning concept through inquiry" we would like to show some examples of tasks that could further develop the concept of "hydrogen bonding" and how to describe them. Processes under consideration in that module were: observing and visualizing, classifying and creating definitions, making representations and translating between them, finding connections and relationships, estimating, measuring and quantifying, evaluating, experimenting and controlling variables. Herein we have adapted some of them to further develop ideas in regards of intermolecular interaction and hydrogen bonding. This task is intended to encourage students to discuss connections between concepts expressed verbally and symbolic representations (Ariza, Quesada 2013). Some of the statements to make cards have been taken from hydrogen-bonding definitions and original graph set-theory assignments (Etter and MacDonal, 1990). For the following activity, participants should work in pairs or threes. They should begin by cutting out the cards (named as A, B, C, D, E, F, G) and establishing as much connections they are able to do. They are invited to short cards into sets whit equivalent meaning and they have to explain how they know that. Teachers must be aware to give guidance, if needed, along the activity or right feedback at the end of the activity to avoid the reinforcement of possible misconceptions. More cards could be added for example introducing 3D molecular models but where only 0D, 1D or 2D appears as a network patterns.

Explore this situations (figures 1b or 3b or 4b or 4c or 4d)

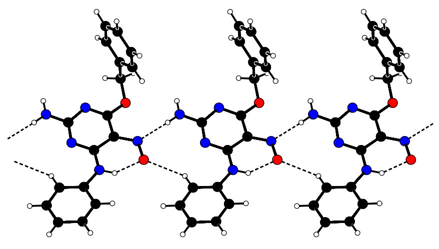
Make a list with all those things that take your attention
In relation to this situation: What questions come to you?
You can try to make some questions to your peer:

- Which is...? [e.g.: supramolecular “pattern”, molecular “pattern”]
- What is...? [e.g.: the moiety involved in intermolecular interactions)
- How many...? [e.g.: kind of “rings” can you observe]
- How many different...? [e.g.: hydrogen bonding can you observe/describe]
- What happened if...? [e.g.: oxygen is remove from this structure]
- How do you think...? [e.g.: structure keep on “propagating”]

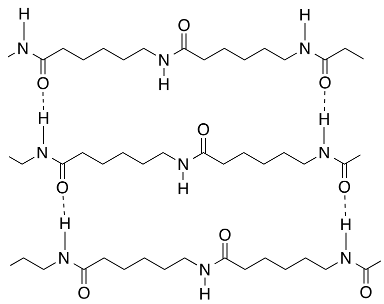
In peers: Try to define...[“motif”, pattern]

Using graph set theory try to describe some of the hydrogen patterns

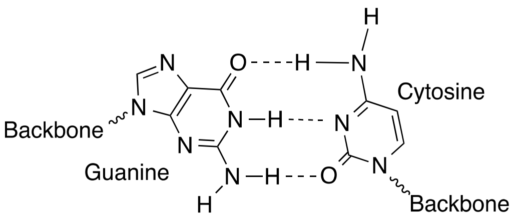
(a)



(b)



(c)



(d)

Figure 4. (a) Making observation of “pictures” (b) Hydrogen bonding for a pyrimidine compound (Melguizo et al 2003). (c) Hydrogen bonding in Nylon 6. (d) Base-pairing Cytosine-Guanine

FURTHER STEPS

Tasks herein present should work as an “black box” which have to be opened or even closed a bit more, because some concepts could have not been already adequate for our students and could in such way reinforce misconceptions about bonds and intermolecular forces. The way teachers need to open or close “the box” will determinate the pedagogical value of tasks. Research has shown how to give student gradual introduction and the opportunity to revisit ideas at different contexts at several points has a positive effect regarding the development of a better understanding of these ideas (Cited in Treagust 2003).

A1. An H bond exists between a functional group N-H and Oxygen

A2. An H bond exists between a functional group N-H and a group of atoms with Oxygen

B1. An H bond exists between a functional group N-H and Oxygen in the same molecule

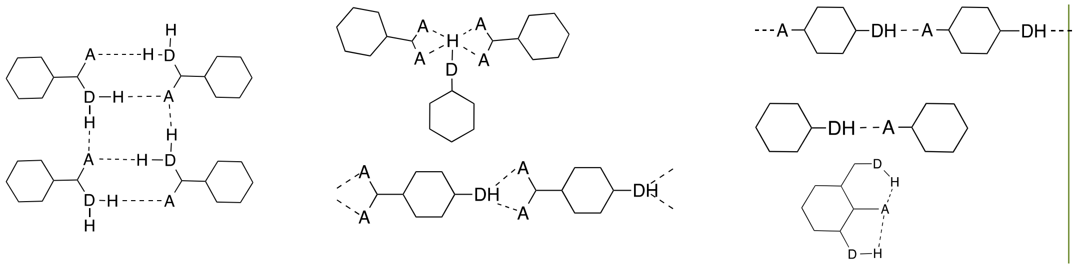
B2. An H bond exists between a functional group N-H and Oxygen in a different molecule

C1. Intramolecular hydrogen bonding is established between and H and an electronegative atom of the same molecule

C2. Intermolecular hydrogen bonding is established between and H and an electronegative atom of different molecules

D´s S(5) S(6) $S^1_2(9)$ C(7) D C(4) $C^2_1(8)$ $R^2_1(4)$ $R^2_4(8)$ $R^2_2(8)$

E´s



F´s

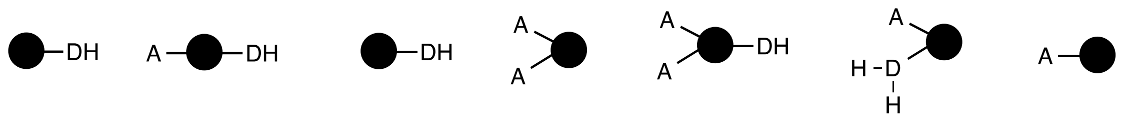


Figure 3. Cards for “Making connections” on the concept of hydrogen bond

This work, which shows a design effort for classroom materials, is part of a more extended one, where authors are engaged in the design of *IBL* lessons that have the following features: they are developed for inquiry-based learning and some of them try to emphasize those processes that resemble an authentic task contextualized in the world of work (using hydrogen bond as a content). Somehow these tasks try to imitate some of the activities that a Crystallographer does. We could ask the following questions to our students: Why should a Scientist be interested in looking at how molecules interact between them? Why should a chemist “look at” molecular interactions? How does a crystallographer describe hydrogen-bonding interactions? How does a crystallographer “find” those interactions? What evidences hold the idea that hydrogen bonding is there? Through these questions and tasks we would trigger a situation to engage student´s curiosity in the world of ideas that surround supramolecular chemistry. We are aware that any proposal of innovation should go further of design and the impact of these tasks have to be measured and assessed.

REFERENCES

Ariza, M.R. and Quesada, A., 2013. Learning concepts through *IBL*: Representing and making connections for chemical element, chemical compound and mixture [on-line]. Available at: http://www.primas-project.eu/artikel/en/1347/Matching+different +representations%3A/view.do?lang=en. [Accessed 15 June 2014].

Bindis, M., 2013. Students' misconceptions about intermolecular forces as investigated through paper chromatography experiments and the Molecular Attractions Concept Inventory. [on-line] <Available at: https://etd.ohiolink.edu/ap/10?106244606027452::NO:10:P10_ETD_SUBID:89 712 [Accessed 15 June 2014].

Etter, M.C., MacDonald, J.C., 1990. Graph-Set Analysis of Hydrogen-Bond Patterns in Organic Crystals. *Acta Crystallographica Section B*, 46, pp.256-62.

Desiraju, G.R. 2002. Hydrogen Bridges in Crystal Engineering: Interactions without Borders Accounts of Chemical Research, 35(7), pp.565-73.

Dorier, J.L. and García, F.J. 2013. Challenges and opportunities for the implementation of inquiry based learning in day-to-day teaching. *ZDM, The International Journal of Mathematics Education,* 45 (6), pp.837-49

Henderleiter, J., Smart, R., Anderson, J. and Elian, O., 2001. How Do Organic Chemistry Students Understand and Apply Hydrogen Bonding? *Journal of Chemical Education.* 78 (8), pp.1126-29

Kozma, R. And Rusell, J., 2006. Students becomes chemists. Developming representational competence. In J. Gilbert, ed. 2006. *Visualization in Science Education*. New York: Springer-Verlag

Nakanishi, T., 2011. *Supramolecular soft Matter*. Hoboken, New Jersey: John Wiley & Sons.

Pauling, L., 1939. *The nature of the chemical bond*. Ithaca, New York: Cornell University Press.

Promoting Inquiry in Math's and Science Education Across Europe (PRIMAS) 2012. PD Modules 1 & 3: Student-led inquiry and Learning concepts through inquiry-based learning. Available at: <http://www.primas-project.eu/artikel/en/1221 /Professional+development+modules/view.do> [Accessed 10 July 2014].

Melguizo, M., Quesada, A. Low, J.N. and Glidewell, C., 2003. Supramolecular structures of N_4-substituted 2,4-diamino-6-benzyloxy-5-nitrosopyrimidines. Acta Crystallographica B, 59, 263-276

Steed, J. W. and Atwood, J. L., 2009. *Supramolecular Chemistry.* West Sussex, United Kingdom: John Wiley & Sons.

Swan, M., Pead, D., Doorman, M. and Mooldijk, A., 2013. Designing and using professional development resources for inquiry-based learning. *ZDM. International Journal of Mathematics Education.* 45(7), 945-957.

FROM STARCH TO GLUE STICK – A CONTRIBUTION TO THE DIDACTIC CONCEPT OF THE "FORSCHERWELT"

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Abstract

"Forscherwelt" ("research world") is an educational initiative set up by Henkel to introduce children up to the age of 10 into the fascinating world of science. In a laboratory especially designed for their needs children have the opportunity to become little researchers.

The title of the didactic concept is "How it is to be a researcher". The didactic concept is based on scientific literacy. It includes the following aspects of scientific inquiry: Scientific methods and critical testing, analysis and interpretation of data, science and questioning and creativity. The children also get insight into the scientific work place. The contents in the "Forscherwelt" are the research topics of Henkel (adhesives, washing/cleaning and cosmetics) and also a topic which is important for the whole economy: sustainability.

These elements build the frame of the course programs as demonstrated in the article by the example of the "Adhesive" course. In my presentation I will present the second part of the adhesive unit: from starch to glue stick (Lesson 2 – 6). I will follow the structure of the children`s experimental questions in my presentation.

Keywords

"Forscherwelt". scientific methods and critical testing. Adhesives

THE DIDACTIC CONCEPT OF THE "FORSCHERWELT"

„Forscherwelt" is an educational initiative set up by Henkel to introduce children up to the age of 10 into the fascinating world of science. The name roughly means "Research World". Henkel asked us to develop, implement and evaluate a didactic concept for the out-of-school learning enviroment „Forscherwelt".

The title of the didactic concept is “How it is to be a researcher” (Sommer et al. 2012). The didactic concept (Figure 1) is based on scientific literacy (OECD, 2006). The concept focuses on knowledge about science which consists of Scientific inquiry and scientific explanations (OECD, 2006). It also takes into account the results of Osborne`s study (Osborne et al., 2003). The didactic concept includes the following aspects of scientific inquiry: Scientific methods und critical testing, analysis and interpretation of data, science and questioning and creativity. This all needs patience, resilience and certain scientific procedures (AAAS, 1968). This way, children gain insight into the process of scientific inquiry. We also want to introduce the children to the scientific work place. That is important because: Children believe that scientists are people who work alone (Driver et al., 1996; Chambers, 1983). The world of work looks very different. Scientists work in teams, they talk and discuss with each other, ask experts and give lectures or write articles about their results. Consequently, we designed the didactic concept so that children work in groups with shared responsibilities, get expert talks at the „Forscherwelt“ and present their results (Figure 1).

The contents in the „Forscherwelt“ are the research topics of Henkel (adhesives, washing/cleaning and cosmetics) and also one more topic which is important for the whole economy: sustainability (Figure 1).

Figure 1: The didactic concept of the „Forscherwelt“ (Sommer et al., 2012)

THE TEACHING UNIT ADHESIVES

These elements build the frame of the teaching unit “Adhesives” (Sommer et al., 2012; Henkel Forscherwelt, 2013). In the presentation I will describe the example of the “Adhesives” teaching unit (Table 1). There are two variants of the teaching unit. During the holidays, children of Henkel-employees can participate in a five-days course from 9am to 4pm. During term-time, primary classes visit once every fortnight over a period of six months.

Table 1: Overview about the teaching unit

Number	Content
Lesson 1	Different types of adhesives
Lesson 2	Investigating the stickiness of four “raw materials”
Lesson 3	Raw material source for adhesives: detecting starch
Lesson 4	Obtaining starch from food
Lesson 5	a) Making a starch paste b) Comparing glue sticks with starch paste
Lesson 6	a) Starch paste containing soap as a structural strengthener b) Making test strips (→ Lesson 8)
Lesson 7	a) Producing adhesives from food (gummy bear adhesives and more) b) Making test strips (→ Lesson 8)
Lesson 8	Method for testing adhesives: developing and building a homemade test apparatus

This teaching unit is designed to introduce children to the world of adhesives. Firstly, they gain initial insight into the wide variety of adhesives and applications (Lesson 1). Secondly, the focus is on a particular adhesive: the glue stick with the brand name “pritt”. The children will get to know the whole process – from the raw material and the ingredients in the glue stick to the finished glue stick (Lesson 2 – 6). Lesson 6 finishes with a talk about the industrial production of glue sticks by a leading Henkel expert. And finally they test the power (Lesson 8) of different glues (Lesson 7). The unit also provides the opportunity to explore phenomenologically the question of why adhesives are sticky.

In my presentation, I am going to describe the second part of the adhesive unit: from starch to glue stick (Lesson 2 – 6). I will follow the structure of the children`s experimental questions in my presentation.

FROM STARCH TO GLUE STICK

What can you use to make an adhesive?

Children know from everyday life that their hands become sticky when they eat ice cream. There is a number of substances in the kitchen that, sometimes quite accidentally, stick to everything. Pudding powder, for example, is one of these substances. In the preliminary experiment, the children are given four similar looking powders to investigate. The powders are assigned a number; the children do not know what these numbers stand for. Their task is to test which of the powders can be mixed with water to produce a sticky substance that could perhaps be suitable as a raw material for an adhesive. The children can rub the stirred mixtures between their fingertips so that they feel what is sticky and what is not. In the end the children get the information what these numbers stand for. They interpret their experimental data and discover that mixing starch and water produces a sticky substance.

How do you detect starch?

The children learn how to use a solution of iodine and potassium iodide (Lugol's solution) to detect starch. This "detection method" is one of the tools used by researchers. Both a (positive) blank sample containing cornstarch and a negative sample containing a substance that looks similar to cornstarch (confectioners' sugar) are used. This procedure confirms the validity of the detection method (Stäudel et al., 2010). Using the detection method on the glue stick (only Pritt contains starch) confirms that starch is present. This makes the goal clear: A natural raw material containing starch needs to be found from which starch can be isolated.

Which natural raw materials contain starch?

The children explore a range of different natural raw materials that might contain starch, including potatoes, cucumber, milk and crushed grains of rice or corn kernels. They use the detection method they just learned about. They learn that the well-known food potatoes contain starch.

How can you isolate starch?

The children use a process which used to be a standard household procedure. They isolate starch from potatoes. The children grate potatoes and use several different methods for separating mixtures: filtration, sedimentation and decantation.

Generally, Tapioca starch is used produce glue sticks. It can be found in the manioc root. Unfortunately, it cannot be used in experiments for children as prussic acid solution is released on slicing the manioc root (Franke, 1997). As a consequence, we use potatoes as model substance to isolate starch for the glue stick production. It might also be noted that children will have encountered potatoes before – something that could not be claimed for manioc roots.

How do you produce starch paste?

The children learn that by heating with water starch transforms into a gel like sticky paste. In figure 2 you find the worksheet with the correct steps (Wagner & Zajutro, 2004).

The starch swells when it is heated. This swelling is caused by the solvent (water) being bound by capillary action and then evaporating.


forscherwelt

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Worksheet 10: Making a starch paste

After you have obtained the starch from food, you can use it to produce a starch paste.

- Put 1 g (¼ teaspoon) of starch obtained from potatoes and 5 ml (1 teaspoon) of water into a 50 ml (1.7 fl. oz.) beaker and mix together well with a glass rod.
- Heat the resulting mixture on a hotplate to about 80°C (175°F) until it begins to stick to the glass rod.
- Test the starch paste by using it to glue two sheets of paper together.

Investigate the properties of the starch paste you made and the properties of the adhesive substance in a glue stick.

Name the properties that you would like to investigate and enter them in the table. Carry out your investigation. Which properties do the substances have in common and what are the differences? Enter your observations in the table.

- Put a spatula tip of starch paste into a test tube, add 5 ml (1 teaspoon) of water and seal the test tube with a stopper. Shake the test tube for about 30 seconds.
- Repeat the process with the substance from the glue stick. Enter these observations in the table too.

Property	Observations – Glue stick	Observations – starch paste

Which property does your starch paste also need to have for it to become a "glue stick"?

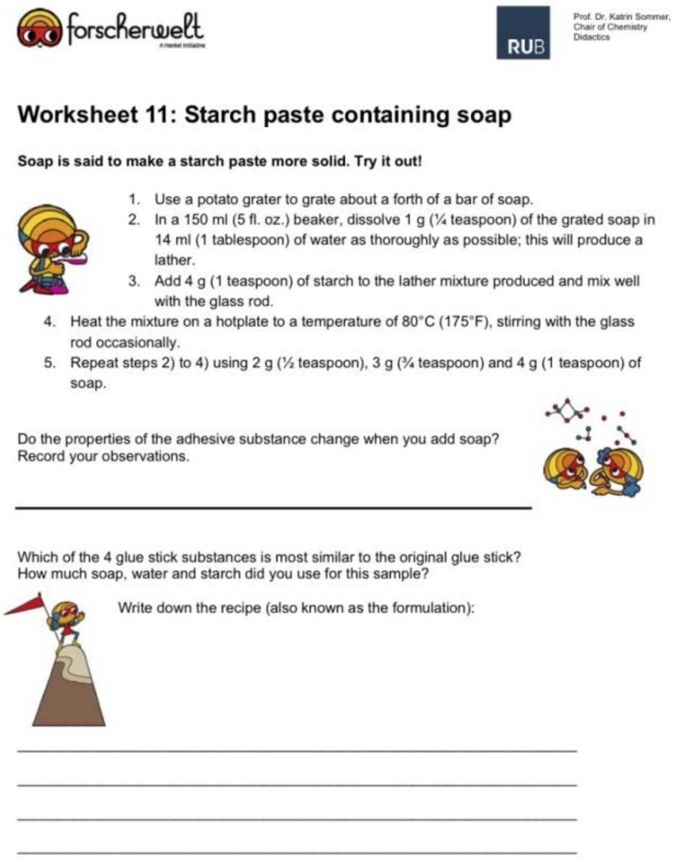
Figure 2: Worksheet for children (1)

What are the differences between starch paste and glue stick?

When children compare the properties of their starch paste with those of the glue stick substance, they discover both similarities and differences (figure 2). For instance, the homemade starch paste has a consistency like honey whereas the glue stick substance is solid. In addition, when the glue stick substance is dissolved in water (assisted by shaking), a particular phenomenon occurs: The mixture foams. This is a phenomenon with which the children are familiar from washing their hands with soap. As a comparison, the students need to dissolve their starch paste in water and shake it. The glue stick substance does indeed contain a small proportion of soap to improve abrasion resistance. Odor: There is also a difference in smell. Starch paste smells like boiled pasta while glue sticks smells from artificial fragrances.

How does the feel of starch paste change, when it contains different fractions of soap?

On the one hand the children should learn that soap can be used as a structural strengthener in a glue stick. The children find out that adding different proportions of soap affects the properties of the mixture (figure 3).


forscherwelt

RUB Prof. Dr. Katrin Sommer, Chair of Chemistry Didactics

Worksheet 11: Starch paste containing soap

Soap is said to make a starch paste more solid. Try it out!

1. Use a potato grater to grate about a forth of a bar of soap.
2. In a 150 ml (5 fl. oz.) beaker, dissolve 1 g (¼ teaspoon) of the grated soap in 14 ml (1 tablespoon) of water as thoroughly as possible; this will produce a lather.
3. Add 4 g (1 teaspoon) of starch to the lather mixture produced and mix well with the glass rod.
4. Heat the mixture on a hotplate to a temperature of 80°C (175°F), stirring with the glass rod occasionally.
5. Repeat steps 2) to 4) using 2 g (½ teaspoon), 3 g (¾ teaspoon) and 4 g (1 teaspoon) of soap.

Do the properties of the adhesive substance change when you add soap? Record your observations.

Which of the 4 glue stick substances is most similar to the original glue stick? How much soap, water and starch did you use for this sample?

Write down the recipe (also known as the formulation):

Figure 3: worksheet for children (2)

On the other hand, the children learn how to systematically develop a formulation – this is a fundamental process within professional product development.

Through this process, the children have empirically developed a recipe how to produce glue stick paste and fill it into a cartridge case.

In the industrial process, a chemical reaction is used to produce soap. Fatty acids and sodium hydroxide solution are added to the starch batch. Lime soap is produced (Just & Hradetzky, 1983). In jargon, this process is falsely termed a soapification – probably inferred from the product. It is, however, a neutralisation reaction (Sommer et al. 2012).

CONCLUSION

The guiding principle behind the adhesives unit is „scientific method and critical testing". This can be seen at several stages of the unit. We introduce the test reaction using a blind. The children repeat and compare measurements to strengthen their results. When the children add different amounts of soap to investigate the relation between soap fraction and consistency of the glue stick paste, they systematically control variables. All these aspects offer the children insights into goal-oriented and systematic ways of experimenting.

We have tested, evaluated and optimized the adhesives unit several times. It is now available on an open-access basis – in German, in English and in a brand-new Russian version. This is due to the international users of the „Forscherwelt". It has recently found another home at a science museum in Moscow.

REFERENCES

American Association For The Advancement Of Science (Eds.), 1968. *„Science – A Process Approach. Purposes – Accomplishments – Expectations".* Miscellaneous Publication.

Chambers, D. W., 1983. Stereotypic Images of the Scientist: The Draw-A-Scientist Test. In: *Science Education* 67/2, 255-265.

Driver, R. et al., 1996. *Young People `s Image of Science.* Buckingham, Philadelphia : Open University Press.

Franke, W., 1997. *Nutzpflanzenkunde.* 6. Auflage. Stuttgart : Thieme Verlag, 67.

Henkel Forscherwelt, 2013. *Adhesives_teaching_unit_complete*. [online] Available at http://www.henkel-forscherwelt.de/forscherwelt/forscherwelt-a-henkel-initiative/ [Accessed 23 July 2014].

Just, M., Hradetzky, A., 1983. *Chemische Schulexperimente*. Band 4. 2. Auflage. Berlin : Volk und Wissen, 388.

OECD, 2006. *Assessing Scientific, Reading and Mathematical Literacy. A Framework for PISA 2006*. OECD Publishing.

Osborne, J. et al., 2003. What „ideas-about-science" should be taught in school science? A Delphi study of the Expert Community. *Journal of Research in Science Teaching,* 40/7, 692-720.

Sommer, K., Kakoschke, A., Schindler, S., Buchwald, M., Russek, A., Schäfer, A., Steff, H., Krupp, U., 2012. „Wie ein Forscher wein" – Das didaktische Konzept für eine Bildungsinitiative in einem Forschungsunternehmen und dessen Umsetzung. *Chemkon*, 19/3, 131-136

Stäudel, L., Pfeifer, P., Sommer, K., 2010. In Standardsituationen des Unterrichts das Wesen der Naturwissenschaften erkennen. *Unterricht Chemie*, 21/118/119, 41-49.

Wagner, G., Zajutro, R., 2004. Schulexperimente zur Herstellung von Klebstoffen. *Unterricht Chemie*, 15/80, 14-19.

COGNITIVE SCHEMES OF TEACHERS ON ORGANIC CHEMISTRY TASKS

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Abstract
This study involves experienced teachers on Organic Chemistry. The research included two similar situations in which participants were asked to explain orally front of audiovisual apparatus as they did to reach their conclusions. Interviews were conducted in order to access the details of the participants' thinking process. Data analysis was effected via Textual Discourse Analysis (TDA) with the Transana ® software. The data categorization based on The Conceptual Fields Theory suggests that he teachers demonstrated that although different situations have been offered to research participants both use the same type of action schema. The energetic-structural scheme has as main feature the successive and conceptually interconnected fields on the structural and thermodynamic aspects of chemical transformations.

Keywords: *Theory of Conceptual Fields. Organic Chemistry Problems.Cognitive Eschemas.*

INTRODUCTION

Learning concepts in the molecular structural field in Chemistry are instrumental to solving tasks that involve proposing mechanisms of organic reactions and interconversion of molecular structures (spatial visualization). These are typical tasks of organic chemistry that are reported by the literature as source of difficulties to learning Chemistry (Baker et al., 1998).

Currently is growing in research in Science Education the number of works that have as reference the Theory of Conceptual Fields (Sousa and Favero, 2002; Sousa et al., 2005; Andres et al., 2006; Caballero et al., 2006; Caballero et al., 2008; Raupp et al., 2009; Santos, 2010) however there are no reports about the schemes of action used by teachers of Organic Chemistry of higher education on molecular structural field in Chemistry. Access to the conceptual content and the formal operations of thought that characterize the teacher's schemes actions can provide valuable information for the planning of activities to education in this field.

CONCEPTUAL THEORY OF FIELDS: CONCEPTS, INVARIANT OPERATIVE AND SCHEMES OF ACTION

The core of cognitive development is the concept (Vergnaud, 1990). In the Conceptual Fields Theory, the formation of a concept is associated with the triad (S, I, R) (Moreira, 2002). In this proposition, S corresponds to the situations that give meaning to the concepts; I, the operational invariants (concepts-in-action and theorems-in-action), responsible for the conceptual content and operation of the schemes; R is the component connected to the verbal forms and nonverbal allowing symbolically represent the concept, its properties and treatment procedures. The cognitive process is responsible for the functioning of a person in the resolution of tasks that organizes and establishes conceptual relations during activities.

To Vergnaud (1996) an essential problem to the study of the concept is to examine the verbal and non-verbal signifiers that give the concept´s public character, to identifying the implicit propositions, known globally as operational invariants. The conceptual core can be categorized into theorems-in-action and concepts-in-action, contained in schemas (Vergnaud, 1996; Moreira, 2002).

The premise Vergnaud is that knowledge is organized in Conceptual Fields. A conceptual field emerges from the resolution set of tasks that require the progressive mastery at concepts, procedures and symbolic representations (Vergnaud, 2009). In the context of organic chemistry, for example, the field of chemical conceptual representation could consist of situations involving, for example, the stereochemistry. The domain of this field can include the ideas of: chirality, stereogenic center, chemical bonding, enantiomeria, diasteromeria (the conceptual dimension). Can include also: establish relations of identity, structural equivalence and the free molecular rotation/translation at space as operational invariants (Bueno Filho et al., 2012).

Mastering a given conceptual field is not a trivial task. This does not occur easily when dealing with complex contents. Often learning about a subject requires a long period of time (Vergnaud, 1998). Another important factor is the resolution of a greater number of diverse situations. The progressive mastery of varied situations consistent with cognitive development. However, there is need to establish relationships among various operational invariants and the intertwining of Conceptual Fields in the cognitive structures.

An element of fundamental importance in the Conceptual Fields Theory is the *situation*. Vergnaud (2009) defines situation as a task, with a complex situation could be analysed as a combination of tasks. Situations not only give meaning to the concepts, also require cognitive response of the subject as the context of each.

Interestingly, the theoretical framework proposed by Vergnaud, support on the Piagetian schema concept as a means to make it operational. To Vergnaud schemes are accessible to the subject, acting as effective organizers of thought and conscious act (Vergnaud 2003 apud Bronckart, 2007). Schemes then would figure as the forms of conduct which, impregnated with conceptual content, characterize the action of a forward subject to a class of situations, acting as principal builder of human thought (Bronckart, 2007).

RESEARCH METHODOLOGY

Two tasks of Organic Chemistry conceptually similar were prepared. Were requested to professors solve tasks and orally explain how they got the results. Two teachers participated in the research of the Federal University of ABC. They had a Ph.D. in Organic Chemistry and often teach subjects in this area of knowledge. The explanations were recorded in audiovisual apparatus with authorization. The first teacher (T1) resolved the situation (S1) as set out in Figure 1:

Based on this reaction, describe the reaction mechanism explaining all the procedures adopted. Take into account any other factors it deems appropriate.

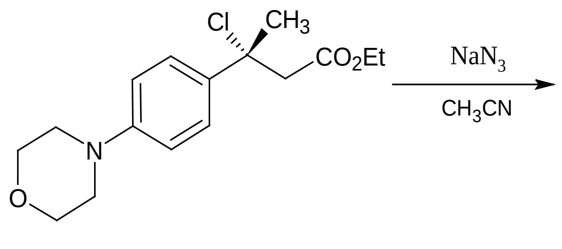
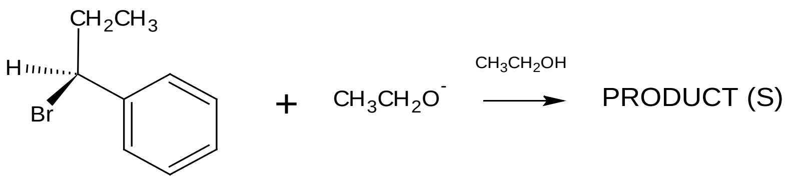


Figure 1: Issues contained in the instrument of data collection presented to the first teacher (Instrument S1, Teacher T1)

The conceptual core of the matter contained in S1 is focused on the formation of an intermediate tertiary carbocation. The reaction´s mechanism is preferably performed via nucleophilic substitution of the first order, SN1. The second teacher (T2) resolved the situation (S2) as it´s shown in Figure 2:

Based on this reaction, describe the reaction´s mechanism explaining all the procedures adopted by you.
Take into account any other factors it deems appropriate.



Scenario	Content
1	S_N1 reaction pathway with formation of enantiomeric pair.
2	Via S_N2 reaction with formation of only one product and 100% yield.
3	Competition between S_N2 and E1 reactions.
4	Competition between S_N1 and E1 reactions.
5	Reaction via E1.

Figure 2: Issues contained in the instrument of data collection presented to the second teacher (Instrument S2, Teacher T2)

Were proposed in S2 five scenes with different mechanistic outcomes. The teacher should be explain based on the reaction mechanism.

At the moment the participants made the explanations, interviews were conducted. The questions were designed to engage participants to give more details about how they solved the tasks. After this step, the speech and gestures of the participants were transcribed. Proceeded to Textual Discourse Analysis (TDA) as proposed by Galiazzi and Moraes (2006) with the Transana ® software (Woods, 2012). The TDA assumes the fragmentation of the text into manageable subsets, termed meaning units. For the assignment of meaning to textual units is necessary to establish criteria that must be correlated with a theoretical framework (Table 1):

Table 1: Dimensions considered for the data analysis

Dimension	Definition
I – Concepts	Emerge from the resolution of tasks, operational invariants and symbolic representations (S, I, R). In this study, related to Structural Molecular (Mechanisms of Organic Reactions) field.
II - Operatory Invariants	Implicit or explicit theorems are triggered during the action of teachers and often bound the general logical operations of thought.
III - Structure of Explanations	Structure that characterizes the sequences of the teacher's actions. Behave modes of action classified as justifications, data usage as knowledge-based, goal setting and construction of inferences.
IV – Gestures	Carriers of meanings movements performed by the teachers in action. Relate directly to the concepts and operational invariants implicit in the actions.

The units of meaning in the dimension operatory invariants were allocated according to the definitions proposed by Vergnaud (1996) for theorems and concepts-in-action. The conceptual dimension includes the fundamental concepts proposed by Mullins (2008) for learning Organic Chemistry: electronegativity, polar covalent bond, steric effects, inductive effects, resonance and aromaticity. As a result of the work previously performed, in addition, also considered the stereochemistry to describe the schemes of teachers (Nascimento, 2014). With respect to gestural dimension should remember that Vergnaud (1990) gives special attention to the gestures that accompany the actions of people. The gestures reveal the fundamental concepts and the operational invariants in schemes. McNeill (1992) propose five different types of gestures: cohesive, demonstrative, iconic, beats, and metaphorical. The metaphoric gestures, in particular, occupies a prominent place in this study because they provide evidence of concepts corresponding at submicroscopic mode.

RESULTS AND DISCUSSION

From the data analysis were accessed textual units for two fields. The first stems from the teacher makes references to aspects that link the nature and properties of chemical reactivity links - the molecular structural field, the initial focus of this work. The second field, about system stability, often supported by justificatives that consider solvation effects or resonance stabilization of the reaction intermediate via thermodynamics. The Table 2 shows some examples of the teachers' explanations that support the above claim:

Table 2: Conceptual features found in teachers

Participant and Instrument	Transcription	Feature
T1, S1	T1: But if you break the carbon chlorine bond you form a tertiary benzyl carbocation (0:04:44.8). T1: What is the advantage of the benzyl carbocation? It is quite easy! Because having stabilization of the aromatic pi system with the methyl and the rest of the molecule you have the reaction between p-orbital of the carbocation with the benzyl system... (0:05:53.8).	Among possible reaction paths T1 justified based on the stability of the intermediate occurrence of preferential. Connecting Structural Molecular Field with the Field of Thermodynamics.
T2, S2	T2: The reaction shows this mixture of isomers. Are spatial and isolated diasteroisomers isomers. Mostly we have this product in character and that is consistent with the decrease of energy in the system (0:14:51.2).	Among possible estereoisômereos T2 justified based on steric factors the occurrence of preferential. Predominantly the Field of Thermodynamics.
T1, S1	T1: polar aprotic solvent solvated cations and anions not solvated. In this case there is a disadvantage for the SN1-type process (0:03:47.4). T1: Is there a possibility to promote solvate of breaking the bond between carbon and chlorine (0:03:54.7).	The polarity of chemical bonds are instrumental to explain the solvatation. Connecting Structural Molecular Field with the Field of Thermodynamics.
T2, S2	T2: So in the case shown there is some product derived from SN2-type reaction. It is noteworthy that there was reversal of the chiral center. The hydrogen that was behind the reactant molecule came to the front. (0:08:54.7) T2: probably with a solvent with a high dielectric constant it ends solvatando the carbocation, and accordingly, no mixing products of SN1 type. And there are probably racemic mixture in this reaction between these two chiral products. The reaction medium also favours elimination reactions (0:13:43.5).	The polarity of chemical bonds are instrumental to explain the solvation. The stereochemistry also shot mechanistic proposition. Predominance of Structural Molecular Field.

The T1 teacher uses several times as a strategy to explain the reactions mechanisms, justificatives that include the system´s stability (via stabilization of carbocation intermediate resonance or solvation effect of the solvent) as well as aspects that concern the nature of molecular structural factors (polarization links, inductive effects). The Figure 3 shows the full succession of conceptual fields used by the teacher in solving the task T1.

Based on the diagram, the explanation is characterized by knowledge base and construction of inferences. In addition, the knowledge base and justifications are often aligned with conceptual content and operational invariants. The relevant conceptual elements and logical-formal (operational invariants) aligned to justifications confer operability necessary to solve the tasks (Nascimento & Bueno Filho, 2014).

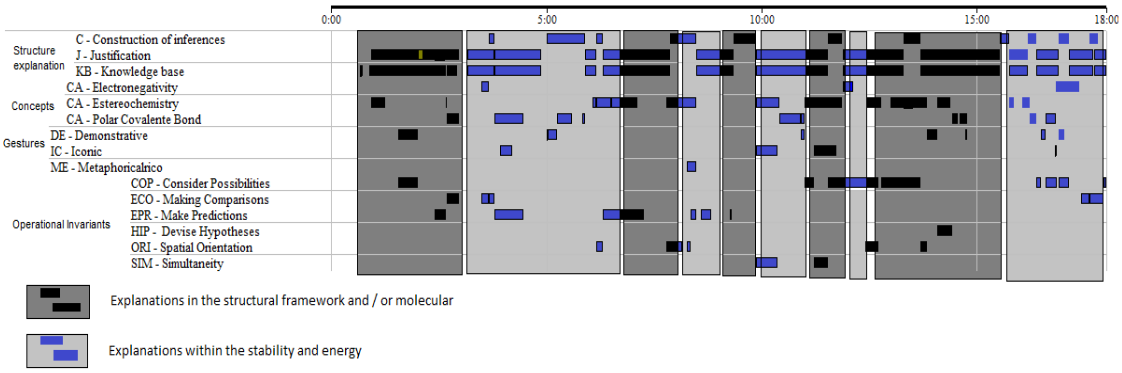


Figure 3: T1´s diagram from the S1 situation

The alternating use of different fields (molecular structural field and thermodynamics field) is consistent with the instrumentality needed to solve the task. On conceptually similar situation (S2), the second interviewee analysis (T2) has a similar characteristic to the first case (Figure 4).

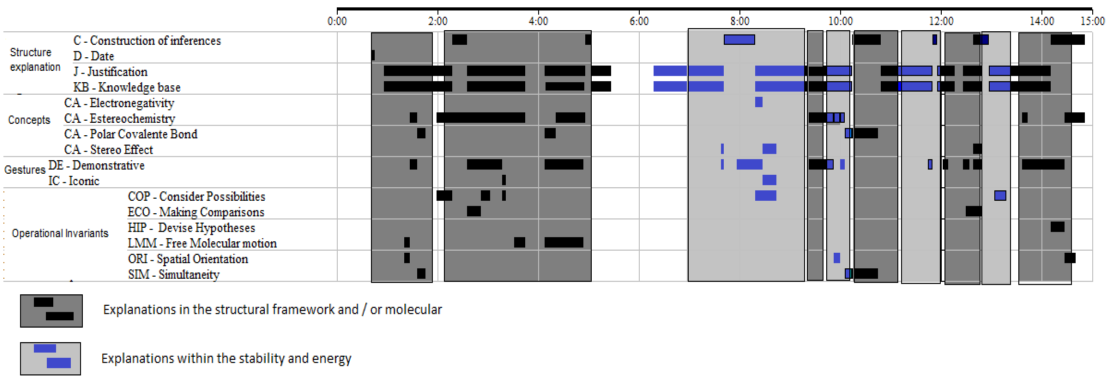


Figure 4: T2´s diagram from the S2 situation

According to Vergnaud (1998) time is essential to the construction of the experience, however, is not the only one factor. The resolution of a large number situations (and different complexity levels) contribute progressively to cognitive development. For this to occur, there is a need too to establish relationships between different fields leading to a more comprehensive resolution of complex situations.

CONCLUSIONS

Although different situations have been offered to research participants both use the same type of action schema. This energetic-structural scheme has as main feature the successive and conceptually interconnected fields on the structural and thermodynamic aspects of chemical transformations. The data suggest that the interconnections of fields on tasks of Organic Chemistry shows instrumental value to problem solving. We suggest that the planning of teaching organic chemistry should value strategies that enhance establish relations between different semantic fields. The Table 3 shows features of the energetic structural scheme.

Table 3: The energetic-structural scheme

Subject	Conceptual Fields	Feature
D1 **D2**	STRUCTURAL / MOLECULAR	Discusses the possibility of formation of carbocation (intermediate reaction). The explanations for the most part are of a structural nature in terms of reagents and products. Alludes structural issues solvent and molecular analysis based on structural concepts of organic chemistry (MULLIN, 2008). Presents significant importance breaks chemical bonds.
D1 **D2**	STABILITY / ENERGY SYSTEM	Discusses the possibility of formation of carbocation (intermediate reaction). In many shifts refers to the energy factors as carbocation stability, solvent effect on the intermediate analysis of the reaction medium, EZ isomerism and stability. Justify on structural characteristic of stereoisomers, chirality and chiral inversion center, racemic mixture, the influence of Lewis acids and bases and polarity structures. Alludes to the energetic factors: stabilization through resonance and the role of the solvent effect, the forward reaction intermediate.

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REFERENCES

Andres, Z., Maite, M. A., Pesa, M. A., Moreira, M. A., 2006. Laboratory work in physics courses on the theory of conceptual fields. Ciênc. educ. (Bauru), Bauru, v. 12, n. 2.

Baker, R. W., George, A. V., Harding, M. M., 1998. Models and Molecules – A Workshop on Stereoisomers. J. Chem. Educ. v. 75 (7), p. 853-855,

Bronckart, J. - P., 2007. De collective activity action and individual thought. In: Merri, M. (Ed.). Human activity and conceptualization - Questions to Gérard Vergnaud. Toulouse: Presses Universitaires du Mirail, p. 121-141.

Bueno Filho, M. A., Fernandez, C., Marzorati, L., 2012. Operational Invariants related to chemical representation: dynamics aspects of the conceptualization. Abstract Book of 22nd International Conference on Chemistry Education 11th European Conference on Research in in Chemical Education, p. 573-573.

Caballero, C., Moreira, M. A., Grings, Et. O., 2006. Possible indicators of operational invariants presented by students in concepts of thermodynamics. Brazilian Journal of Physics Teaching, v. 28, p. 463-471.

Caballero, C., Moreira, M. A., Grings, Et. O., 2008. Advances and setbacks of students in the conceptual field of thermodynamics. Electronic Journal of Enseñanza de las Ciencias, v. 7, n. 1, p. 23-46.

Galiazzi, M. C., Moraes, R., 2006. Discursive textual analysis: reconstructive process multiple faces. Science & Education, vol. 12, n. 1, p. 117-128.

McNeill, D., 1992. Hand and mind: what gestures reveal about thought. Chicago: University of Chicago Press.

Moreira, M.A., 2002. Theory of Conceptual Fields Vergnaud, science education and research in this area. Research in science education, vol. 7, n. 1.

Mullins, J. J., 2008. Six Pillars of Organic Chemistry. Journal of Chemical Education, V. 85, n.1, p. 83-87.

Nascimento, M. G.; Bueno Filho, M. A., 2013. Structuring elements of Organic Chemistry Implicit in arguing professor and undergraduate students. Enseñanza de las Ciencias, v. extra p. 1629-1634.

Nascimento, M. G., Bueno Filho, M. A., 2013. Investigations on the intertwining of Conceptual Fields on a course of Green Chemistry. In: 11th Brazilian Symposium on Chemical Education, 2013 Teresina - PI.

Santos, E., 2010. The theory of conceptual fields and teaching/learning sciences. Educacion XXI, v.13, ed. 1, p. 226-228.

Sousa, C. M. G. De S.; Favero, M. H., 2002. Analysis of a situation of solving physics problems, in a situation of dialogue between an expert and a novice in the light of the theory of conceptual fields Vergnaud. Research in Science Teaching, vol. 7, n. 1, p. 55-75.

Sousa, C. M. G. S.; Moreira, M. A.; Matheus, T. A. M., 2005. The experimental resolution of problem situations in the conceptual field eletromagnestismo: an attempt to identify knowledge-in-action. Brazilian Journal of Research in Science Education, vol. 5, n. 3, p. 61-72.

Vergnaud, G., 1990. The theory of conceptual fields. Researches in Mathematics Education, v. 23, p. 133-170.

Vergnaud, G., 1996. Some key ideas Piaget around didactic. Perspectives, v. 26, n. 1, p. 195-207.

Vergnaud, 1998. G. A comprehensive theory of representation for mathematics education. Journal of Mathematical Behavior, v. 17, n. 2, p. 167–181.

Vergnaud, G., 2009. The Theory of Conceptual Fields. Human Development, v. 52, n. 2, p. 83-94.

Woods, C. F. A. D. K., 2012. Transana. Madison: Wisconsin Center for Education Research of University of Wisconsin.

AN EDUCATIONAL FILM IN TEACHING NATURAL SCIENCES ON THE EXAMPLE OF CHEMISTRY – IN THE EYES OF A TEACHER

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Abstract

The twenty-first century is undoubtedly an era in which it is common to have a device with Internet access. Every day we deal with the situation when in need we take out the phone not only because of the necessity to use its primary function but to exploit the possibility of obtaining information via Internet access. Due to the prevalence of such devices, they may represent not only a form of interpersonal contacts, obtaining current information, or a way of spending free time but they may serve gaining scientific knowledge, among others.

Chemistry is a subject that requires skills of abstract and cause and effect thinking, which often poses a great deal of difficulty for students. Therefore, it seems necessary to appropriately modify the forms of work supported by IT to enable students to acquire knowledge and skills as well as optimize learning outcomes. One of such facilities may be the use of educational films in teaching. Their usage should be reasonable and well-woven into the lesson. They should be tailored to the needs of the teacher, free of errors and presented in plain language. The educational film may be a source of scientific knowledge, not only at school but also at home due to the fact that the Internet is an integral part of contemporary reality. It can be created and watched practically in most places where we live.

Keywords

Educational film, tutorial, teaching, student, Internet.

INTRODUCTION

Unexcused absence is spreading wider and wider in schools. More and more often students stop regularly attend school. The causes of such a situation are different, but is there anything which could additionally affect the motivation of the student in a systematic attending school? Has another standard and monotonous lesson its raison d'être? Often a similar type of comments can be heard in the school hallway: I was not at school last time –

what was the lesson about? "Nothing," it was boring. Did she say anything? As usual, some blah, blah, blah during the entire lesson, which only Johnny of the front row understands. And did she give any homework? Yes, an exercise in the workbook, but it is apparently solved on the net. Well, cool, we will do it in the toilet.

Can a traditional lesson be still interesting in the eyes of the student? Can it generate interest and desire to learn?

METHODS AND RESULTS

A study in which Class 3 of junior high school students was proposed a choice between two methods of teaching, not mentioning what exactly the difference is in the first phase of the study, was conducted. The questions posed to students were:

1. Would you be able to try to perform additional short "task" yourself so that the teacher could present a different way of teaching? Out of 39 respondents surveyed, 38,5 % said definitely yes, 30,8 % yes, 12,8 % I do not know, 7,7 % no and 10,3 % definitely no (Table 1).

Table 1: Responses of the students to question 1

Answer	Number of responses	Percentage of responses
definitely yes	15	38,5
yes	12	30,8
I do not know	5	12,8
no	3	7,7
definitely no	4	10,3

2. Would you be able to independently perform additional short "task" tailored to your experience so that the teacher can present a different way of teaching? Out of 39 respondents surveyed, 53,8 % said definitely yes, 23,1 % yes, 7,7 % I do not know, 7,7 % no and 7,7 % definitely no (Table 2).

Table 2: Responses of students to question 2

Answer	Number of responses	Percentage of responses
definitely yes	21	53,8
yes	9	23,1
I do not know	3	7,7
no	3	7,7
definitely no	3	7,7

It must be added that the additional task was a dedicated task in which the students had to do the worksheet according to their abilities. The prize for solving the exercises from the worksheet was a series of three lessons using multimedia – based on materials prepared in the course of learning by the teacher of chemistry or together with students, with the use of information and communication technology.

Within these pilot studies, it may be noted that the vast majority of students is willing and able to do the additional task if they know that their teacher can "reward" them in some not exactly clear to them way. They are also ready to motivate themselves to do the worksheet if they know that there are tasks they can solve.

Preliminary results of these studies require the extension, but they allow for reflection on whether the traditional way of transferring knowledge fully satisfies the expectations of students and whether the lessons should be enriched based on the use of contemporary media, educational materials and modern information and communication technology. The development of computer technology made it possible to change the methods and techniques of education (Jagodziński and Wolski, 2012), and an appropriate choice of methods and teaching aids in the course of teaching is one of the factors determining its correctness, durability and effectiveness (Kopek and Paśko, 2008). One of the ways to enhance chemistry classes can be the application of educational films created independently by the teacher or together with the students.

Chemistry (and related subjects) is the science in which part of the phenomena or processes require specific conditions, reagents, or long duration. Due to these reasons, they are difficult to demonstrate in the 45 minute lesson. Experiments in a chemistry class may also pose certain disadvantages associated, inter alia, with the premises and equipment base (Cieśla and Paśko, 2006), therefore, in order not to resign completely from performing such experiments in favour of verbal communication, an educational film can be used (Paśko and Rogowicz-Czochra, 2008).

The educational film is a definite help for natural sciences teachers (and not only), and the widespread tendency to attach CDs to textbooks and teacher's books promotes its application. However, they should be used with moderation because not everything which is contained there is consistent with the reality and the acquisition of the presented material by students may be different. Therefore, the creation of educational videos tailored to our needs and the specifics of the subject or class should be attempted. If we believe that making movies on our own is too difficult for us, we should try to prepare it with the students, for instance, as one of the stages of the educational project, or in the classes of circles of interest. Such a jointly made film will be a big challenge, but we can always learn from each other, and present the results of our work to the class or school. Another motivating factor can also be a proposition of making the movie as a part of promoting the school.

An interesting tool to create one's own movies, for example, from the photos taken during the experiments, is a web application on www.animoto.com. This application allows for creation of 30 second videos for free or longer videos with additional effects and enriched with graphic elements for $30 for a year. Additionally, teachers can apply for a free Animoto Plus account which allows for creation of 20 minute movies.

To take advantage of the possibility to create movies, it is necessary to complete the registration form, giving an email address in order to create an account and confirm the registration (Figure 1).

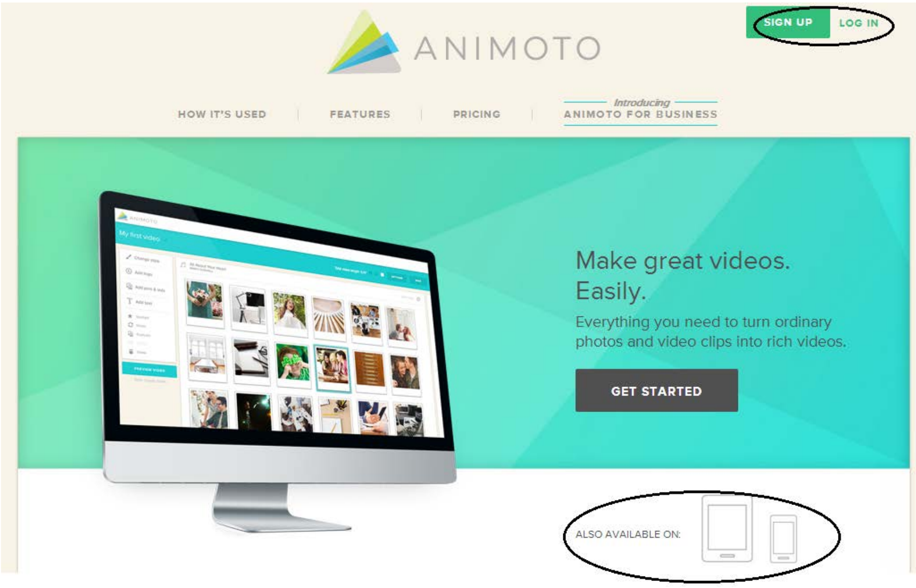

Figure 1: Logging in to the Animoto application. Possibility to use it on other devices.

After logging in, the user can create movies by selecting the Create button and then they can choose a background for photos. After selecting the background, they should click on the caption below the picture. If they decide to create a free movie, they should press this option. The program consists of three stages of film making: uploading images (directly from the user's computer or imported from an online account, e.g. Facebook) and text, selecting music and completion of the film. Any time, the user can see the effect of their work thanks to the option Preview Video (the options available on the left side of the screen (Figure 2).

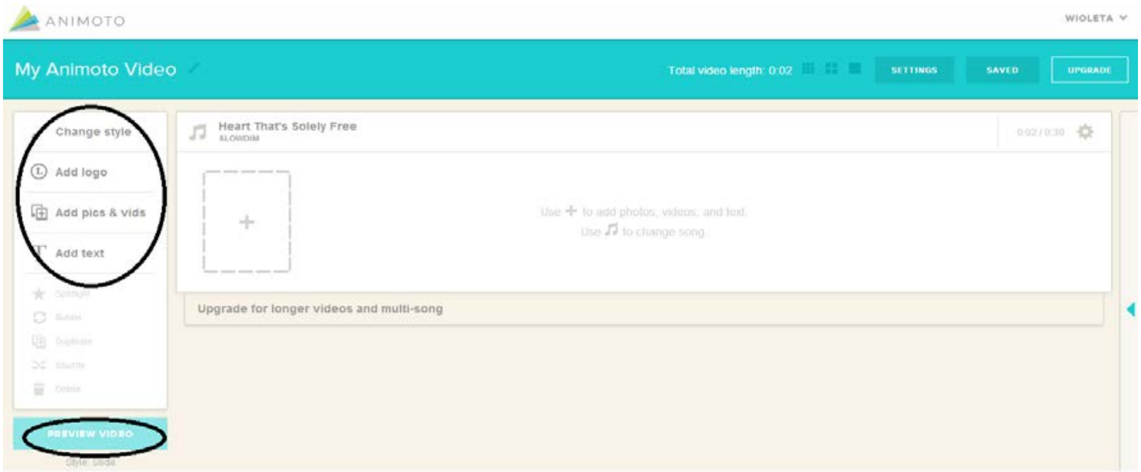

Figure 2: Creating a movie in Animoto.

After the process of creating the film, the user should press the Produce button. The film is recorded on their account and they can share it via email, website or they can download it to their computer. Animoto is quite an intuitive application allowing for creation of unique videos. At any time, the film created and saved on the user's account can be edited and adapted to the audience (Figure 3).

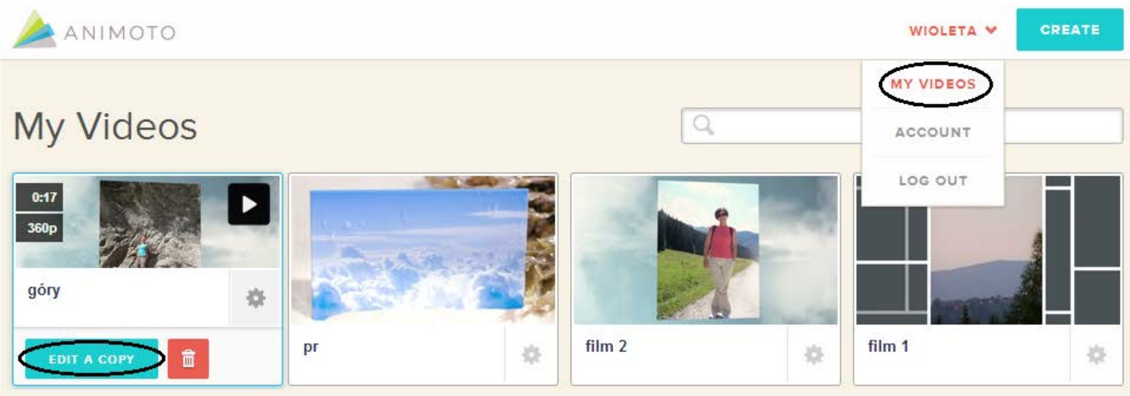

Figure 3: Editing of the video is available in the user's library.

At little cost and effort, classes conducted in such a way help to develop an effect that will long be in the memory of not only the student. It sometimes happens in schools that teachers are unexpectedly asked to substitute an absent teacher and they have no idea for the classes. Let us use this time for a different type of a lesson that could lead to the situation in which the students would not say that it was boring and would happily wait for another "unexpected" lesson.

The made video can be used not only for the documentation of the course of the experiment, but for example, for the presentation of new material and consolidation of gained knowledge and skills. The way the teacher will use the material depends on their creativity and, possibly, their students. It will definitely be a lot more exciting than watching the finished movie and will remain longer in the memory of the students.

CONCLUSION

We should dare ourselves to create our own teaching aids (Paśko and Kopek, 2008) and we should not be afraid to engage in the process students who, as a generation of "digital natives", can assist us in the creation or give us a technical support.

Properly made or selected, an educational video can be a source of scientific knowledge. In the school practice, in the lessons of chemistry, it can constitute a support in the classroom as visual perception and visual development of information is an essential element of education within chemistry (Bílek, Slabý, Myška and Sedláček, 2003). However, it should not be treated as a convenient alternative and completely replaced, for example, by demonstrations of experiments by the teacher. What is more, it should not be used instead of experiments performed manually by students because an experiment plays a number of very important roles in the teaching of chemistry (Fried, 1989).

Due to the fact that recently an educational video is a popular and relatively easily accessible means of teaching, before presenting it to the class, a critical selection of the already existing films should be carried out and presenting the videos that shows the correct frame of the issue should be considered. It is best to make them individually, for example, based on the presented Animoto program because then, from the beginning to the end, we are the creator of our product.

REFERENCES

Bílek, M., Slabŷ A., Myška K., Sedláček J., 2003. Obrazki i uczenie się chemii, w: Różne oblicza chemii u progu XXI wieku. In *XII Szkoła Problemów Dydaktyki Chemii*, Kraków, Sucha Beskidzka : UJ.

Cieśla, P., Paśko, J. R., 2006. Porównanie osiągnięć uczniów przy zastosowaniu rzeczywistych doświadczeń a ich filmowych wersji, In *Aktualni aspekty progradualni piripravy a postgradualniho vzdelavani ucitelii chemie*, Ostrava : OU.

Fried, 1989. Dydaktyczna funkcja eksperymentu. In S. Wajda red. *Integracja, eksperyment oraz zagadnienia ochrony środowiska w dydaktyce chemii.* Wrocław : US.

Jagodziński, P., Wolski, R., 2012. Chemical experiment and mobile electronic devices. In J. R. Paśko, red. 2012 *Innowacja treści i metod nauczania w przedmiotach przyrodniczych*. Kraków : UP.

Kopek, W., Paśko, J. R., 2008. Kojarzenie wzorów sumarycznych z wzorami strukturalnymi i modelami cząsteczek przez uczniów wyższych klas szkoły podstawowej. In M. Nodzyńska, J.R. Paśko red. 2008 *Research in Didactics of the Sciences*. Kraków : UP.

Paśko, J. R., Kopek, W., 2008. Program wizualizacyjny Macromedia Flash jako element kształcenia przyszłych nauczycieli In I. Maciejowska, red. 2008 *Technologie informacyjne dla chemików*. Kraków : UP.

Paśko, J. R., Rogowicz-Czochra, K., 2008 Badania nad porównaniem wpływu filmowych wersji doświadczeń i ich rzeczywistych odpowiedników na proces kształcenia In M. Nodzyńska, J.R. Paśko red. 2008 *Badania w dydaktyce przedmiotów przyrodniczych*. Kraków : UP.

CHEMISTRY TOPICS FROM THE SECONDARY SCHOOL TEACHERS' AND STUDENTS' POINT OF VIEW

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Abstract

The paper is focused on a part of a research conducted on secondary school chemistry students and teachers. Students' and teachers' attitudes towards particular topics from secondary school chemistry subject matter are presented. Students (N = 596) and teachers (N = 118) were provided 12 topics and were asked to evaluate their importance, difficulty and the amount of attention given to the topic in education. A product of difficulty and the amount of attention gives the motivational potential (MP) of each topic which is the main focus of this paper. The MPs given by both students and teachers are compared and statistically significantly different values further discussed. In the comparison, both the student and teacher groups were divided into grammar school and vocational school. As the vocational schools differ, vocational school students are further divided according to particular types of secondary vocational schools. From the twelve topics in eight of them students' and teachers' answers differed. The differences and its meaning are discussed in the paper.

Keywords

Chemistry education, chemistry teachers' knowledge of students' attitudes, didactic transformation

INTRODUCTION

An inseparable part of teacher competences is also teachers' awareness of their students' attitudes towards a subject. From lately conducted researches in this field (Bílek, 2008, Höffer and Svoboda, 2005, Prokop et al., 2007, Rusek, 2013b) results that students' attitudes towards scientific subjects are quite negative. In order to reverse this trend, it is necessary to find the reasons (cp. Žák, 2009).

The knowledge about students' attitudes plays a very important role during didactical transformation of subject matter (Knecht, 2007). Omitting proper didactical transformation leads to lecturing – an approach being rightly driven out of a modern teacher's portfolio. Mere information transfer bears the risk that subject matter becomes only a sequence of empty words and symbols repeated by students on teacher's demand.

Attitudes determine individual's motivation, students' choice of future study or work field and later may determine their attitudes in adult life. The number of attitudes-oriented researches in contemporary didactics suggests attitudes are one of the most important outcomes of education which is worth studying (Kekule and Žák, 2010, Bílek, 2008, Kubiatko et al., 2012, Prokop et al., 2007, Salta and Tzougraki, 2004, Veselský and Hrubišková, 2009).

Researches in the field of attitudes towards science usually focus on students. Just a few studies aim at the role of subject matter – particular topics. This paper is, therefore, focused on the comparison of student's and teachers' attitudes towards particular topics from chemistry subject matter.

The research, which part is presented in this paper, followed a research conducted in 2013 by M. Rusek. The research focused on secondary school students, i.e. in these groups: grammar schools, vocational schools with scientific/chemical direction and vocational schools with non-scientific/chemical direction. Dividing teachers into all these categories would be too time-consuming. Aware of distortion of the results, the author of this paper chose only two groups of chemistry teachers: grammar school and vocational school teachers.

METHODS

Research question and hypothesis

The research was driven by this research question: *How much do secondary school students' and teachers' attitudes towards particular topics of Chemistry education vary?*

Students' and teachers' attitudes towards the Chemistry topics are inquired by the means of their evaluation of each topic's matter of interest, difficulty and the amount of attention given to each topic. Based on this question it is possible to formulate the following hypothesis:

H1: There is no difference between students' and teachers' attitudes towards particular topics in Chemistry education.

In this paper, focus is put on a *motivational potential*, i.e. a product of difficulty and the amount of attention given to a topic in education (see Rusek, 2013b). A difficult topic given too much or too little focus is considered demotivating as well as a too easy topic which is given unproportional focus. Teachers' knowledge of their students' attitudes towards particular topic helps didactical transformation of subject matter as it shows a need of increased level of motivation in such lessons.

After the school reform on the secondary level in the Czech Republic, Chemistry has been added into educational programmes of fields where it has not been before (Rusek and Pumpr, 2009). Therefore it is also necessary to distinguish between general secondary education (grammar schools - Czech Gymnázia) and vocational secondary education (vocational and apprentice schools).

In case of confirmation of the hypothesis, the questioned teachers understand their students' attitudes and adjust their lessons to a form fit for their students. Nevertheless, the bigger the difference between students' and teachers' motivational potential, the bigger is the gap between teachers and students. This would indicate teachers are not able to perceive their students' opinions and fail to seize the topic in a way acceptable to their students.

Comparing the student-teacher relation is reasonable between two groups: 1. group of grammar school students and teachers and 2. particular vocational school students (4 groups) and teachers as it is important to treat school subject of general-education and a marginal school subject (Chemistry at vocational schools) differently (Rusek, 2013b).

Questionnaire creation

Both grammar school and vocational school education was taken into account. As the general vocational school chemistry subject matter is more or less just reduced grammar school chemistry subject matter (Rusek, 2011a), the topic choice was subjected to the vocational school chemistry content.

In this paper, the focus was put on a motivational potential (MP) of particular topics i.e. a product of difficulty and the amount of attention given to particular topic.

Difficulty (scale: very difficult, difficult, easy, very easy)

Teachers: How difficult were these Chemistry topics for your students according to you?

Students: How difficult were these Chemistry topics for you?

The amount of attention given to a topic (scale: too much, a lot, little, not enough)

Teachers: How much attention did you give to the Chemistry topics in your lessons?

Students: How much attention was given to Chemistry topics in Chemistry lessons?

1. Structure of matter
2. Characteristics of chemical substances
3. Chemical elements and the periodic table of elements
4. Nomenclature
5. Reactions and balancing chemical equations
6. Chemical calculations
7. Natural substances
8. Chemical industry and production
9. Plastics and fuels
10. Pharmaceuticals and addictive drugs
11. Chemistry in the kitchen and constitution of groceries
12. Ecology

Questionnaire administration

For the purposes of the research first year secondary school students' attitudes were examined. The research was conducted in September and October 2012 (see Rusek, 2013). Teachers' attitudes were collected in October and November 2013.

The questionnaires were sent via emails and by post to selected schools. With the exception of randomly selected vocational science oriented schools from Moravian-Silesian Region and South-Moravian Region, all the students attended secondary schools in Central-Bohemian Region. In order to ensure a sufficient teachers sample, teachers from the Central-Bohemian, South-Bohemian and Moravian-Silesian Region were addressed. Further information on the respondents is enlisted in the tab 1.

Table 1 Responednt information Students and Teachers

Students					**Teachers**	
G	Lyc	Voc Sci	Voc SLE	Voc CA	Voc T	G T
117	77	64	197	141	76	42
Σ 596					**Σ 118**	

Legend: G – grammar school, Lyc – lyceum, Voc Sci – science oriented vocational schools, Voc SLE – vocational school with school-leaving exam, Voc CA – vocational school with the certificate of apprenticeship

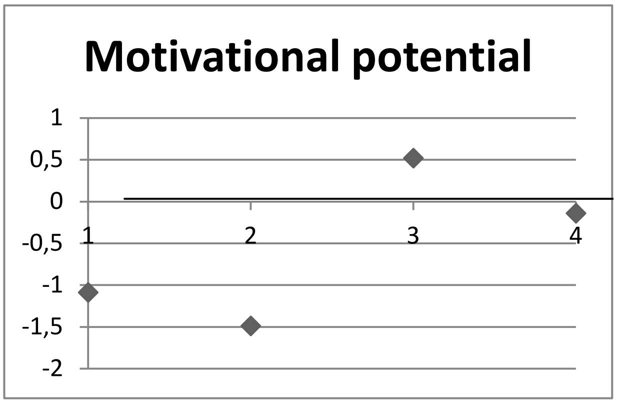
The results were processed in MS Office Excel. For more thorough analysis IBM SPSS Statistics 21 software was used. For the statistical analysis ANOVA test was used. Statistically different results of particular groups were further tested with Fischer's LSD test.

RESULTS

The results of this research are, naturally, influenced by the inaccuracy of sociology research, respondents sample, possible mistakes made during questionnaire filling etc. Therefore generalization of findings must be executed carefully. To simplify the text, results are formulated for students and teachers in particular categories. By the *students* and *teachers* are meant those who took part in the research.

Based on the ANOVA test, it is possible to reject the hypothesis. Statistically different results were found for some of the topics among the groups of students and teachers. On the ground of result transparency, the hypothesis was tested for every topic separately.

The results of the ANOVA test had not shown statistically significant differences for topics 1, 4, 9 and 10. They are therefore put together in graph 3.

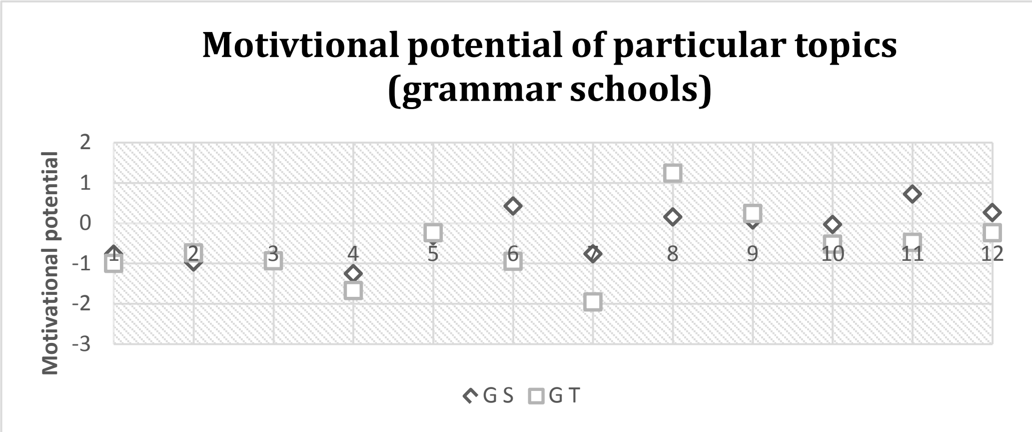


Graph 1 Motivational potential of statistically insignificantly different topics

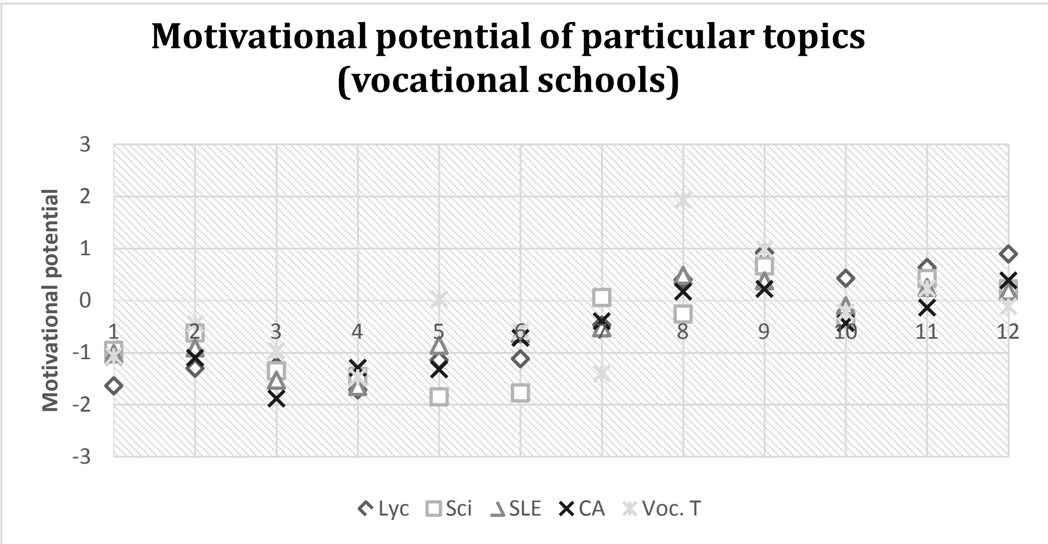
Legend: 1 – T1. Structure of matter, 2 – T4. Nomenclature, 3 - T9. Plastics and fuels, 4 - T10. Pharmaceuticals and addictive drugs

The results show quite negative motivational potential (MP) of topics Structure of matter and Nomenclature. On the contrary the topic Plastic and fuels was rated with a slightly positive MP. Surprisingly, the topic Pharmaceuticals and addictive drugs was rated neutrally despite some previous researches indicating students' interest in it (Rusek, 2013b).

As for the rest of the topics, significant differences were found. The values will be further discussed topic by topic. The results for all the other questions will be presented separately for grammar schools and vocational schools (graph 1 and 2).



Graph 2 Motivational potential of particular chemistry topics seen by grammar school teachers and students



Graph 3 Motivational potential of particular chemistry topics seen by vocational school teachers and students

Legend for graphs 1 and 2: 1. Structure of matter, 2. Characteristics of chemical substances, 3. Chemical elements and the periodic table of elements, 4. Nomenclature, 5. Reactions and balancing chemical equations, 6. Chemical calculations, 7. Natural substances, 8. Chemical industry and production, 9. Plastics and fuels, 10. Pharmaceuticals and addictive drugs, 11. Chemistry in the kitchen and constitution of groceries, 12. Ecology

2. Characteristics of chemical substances

As for the topic of characteristic of chemical substances, significant differences were found between vocational school chemistry teachers (Voc T) and lyceum (Lyc) students. This group of students rated this topic with the lowest MP of all groups (-1,3), whereas Voc T only -0,44. This may be caused by the position of lyceums among vocational educational fields. Despite worse studying results of lyceum students compared to grammar school students (Rusek et al., 2010), lyceums are still considered more prestigious among vocational schools and teachers probably teach this subject matter more indepth regardless of the field specialization.

3. Chemical elements and the periodic table of elements

The overall MP of this topic belongs to the lowest. For this topic, statistically significant difference was found on vocational level between teachers and students of vocational schools with the certificate of apprenticeship (Voc CA). These students rated the topic with the lowest MP of all groups -1,88 whereas Voc T with -0,96. This may be caused by the students' unwillingness to learn a subject not related to the field of their studies (Rusek and Pumpr, 2009) without seeing any bond with their real life.

5. Reactions and balancing chemical equations

This topic was rated with one of the lowest MPs. Again, the differences were found in the vocational school group. Voc T rated this topic with a neutral MP (0,03) whereas students on scientifically oriented fields (Voc Sci) and students on vocational schools with school-leaving exam (Voc SLE) negatively (-1,85 resp. -1,32). The result for the Voc T x Voc Sci may be explained by the teachers' effort to stress the nature of chemistry via equations as the students will need this knowledge in a lab, nevertheless they fail to explain the reason to the students who are therefore demotivated. The result for Voc T x Voc SLE may be explained by the means of the different number of lessons dedicated to Chemistry. While Voc CA students usually have only one lesson a week, Voc SLE students have usually two which makes their teachers broaden the subject matter. Chemistry equations are a typical Chemistry instrument for generating school marks.

6. Chemical calculations

Differences were found only among groups of students see Rusek (2013).

7. Natural substances

The rating of this topic belonged to the most neutral. All students rate this topic significantly differently than their teachers see table 2.

Table 2 Means of the motivational potential of the topic Natural substances

Group	G T	G S	Voc T	Lyc	Voc Sci	Voc SLE	Voc CA
Mean	-1,96	-0,76	-1,4	-0,47	0,06	-0,52	-0,4

It is obvious teachers find the topic more demotivating than their students. This may be caused by the teachers' understanding the topic and students' responding to title which sounds closer to their life.

8. Chemical industry and production

As it is obvious from the graphs (1 and 2) and the table 3, the rating of this topic is rather neutral, quite positive by the teachers. Significant differences were found in all the categories. Although G T and Voc T find the topic quite motivating the students are rather neutral (see table 3).

Table 3 Means of the motivational potential of the topic Natural substances

Group	G T	G S	Voc T	Lyc	Voc Sci	Voc SLE	Voc CA
Mean	1,24	0,15	1,93	0,4	-0,26	0,49	0,17

These results may be caused by teachers' perception of this topic as close to real life. However students may regard it as a set of procedures and geographically placed conceptions they have to learn.

11. Chemistry in the kitchen and constitution of groceries

Anticipated MP for this topic (Rusek, 2013a) hasn't been proved. All the student groups, with the exception of Voc CA (with also negative MP fort this topic) consider the topic slightly motivating. The only significant difference was found in the G group, where G T consider the topic slightly demotivating (-0,48) and G S the opposite (0,72). This factor may be influenced by the "amount of attention" element, which may be considered too high by the teachers who prefer teaching "real" chemistry.

12. Ecology

This topic received one of the highest ratings from the students. The only significant difference was found between Voc T (-0,11) and Lyc (0,9). The explanation may be similar to the previous topic. It is surprising, though, all the students did not differ from their teachers' rating.

CONCLUSION

All the presented results need to be regarded with reference to the size and choice of the tested sample and also the topic selection. However, some of the results correlate with previously found results and therefore may be, carefully generalized.

Several findings are worth mentioning. Although it is familiar from common practice, the topic of drugs was rated with a neutral MP by all the groups. Another surprising finding is related to the topic Chemical elements and the periodic table of elements. The results show one of the lowest MP, even though this topic was mentioned as interesting by students entering secondary school (Rusek, 2011b). Another surprise is related to the topic Chemistry in the kitchen. Anticipated positive MP (Rusek, 2013a) hasn't been proved. Especially, grammar school chemistry teachers rated the topic slightly negatively. This is most likely caused by unclear definition of the topic.

It is important to realize, public opinion on Chemistry is not formed by the elite grammar school students, or the students on a science-oriented vocational schools. It is formed by the vast majority of vocational school students (cp. Vojtěch and Chamoutová, 2013). Although it would be unfortunate to make this the only or one of the main goals of Chemistry education, equipping students with positive attitudes towards chemistry retroactively influences expectations of new pupils and so on. This may therefore be a way how to attract more students to study and later work in the field of Chemistry.

Solemn descriptions of the contemporary educational reality do not serve this purpose. It is necessary to disclose factors placing Chemistry among unpopular subjects, suggest changes of curricula, methods etc. and verify that these steps have positive effect. Otherwise, this may lead to mere reduction of the volume of Chemistry subject matter, simplifications at the expense of accuracy and overall decline of quality of education. This paper brings new perspectives on Chemistry subject matter describing different teachers' and students' opinions. Based on the findings along with results of several previously conducted researches in the same field, it is possible to mark topics which a) need better methodological support and b) may become integrating topics in science education.

REFERENCES

Bílek, M. 2008. Zájem žáků o přírodní vědy jako předmět výzkumných studií a problémy aplikace jejich výsledků v pedagogické praxi. *Acta Didactica.*

Höffer, G., Svoboda, E. 2005. Některé výsledky celostátního výzkumu: Vztah žáků ZŠ a SŠ k výuce obecně a zvláště pak k výuce fyziky. *In:* RAUNER, K. (ed.) *Moderní trendy v přípravě učitelů fyziky 2.* Západočeská univerzita.

Kekule, M., Žák, V. 2010. Selected Attitudes of Students to Physics at School in the Czech Republic *Scientia in educatione,* 1, 51-71.

Knecht, P. 2007. Didaktická transformace aneb od "didaktického zjednodušení" k didaktické rekonstrukci. *Orbis scholae,* 2, 67-81.

Kubiatko, M., Švandová, K., Šibor, J., Škoda, J. 2012. Vnímání chemie žáky druhého stupně základních škol. *Pedagogická orientace,* 22, 82-96.

Prokop, P., Leskova, A., Kubiatko, M., Diran, C. 2007. Slovakian students' knowledge of and attitudes toward biotechnology. *International Journal of Science Education,* 29, 895-907.

Rusek, M. 2011a. Chemie pro žáky SOŠ nechemického zaměření. *In:* BENDL, S. & ZVÍROTSKÝ, M. (eds.) *Místo vzdělávání v současné společnosti : paradigma - ideje realizace.* Praha: Tribun.

Rusek, M. 2011b. Postoj žáků k předmětu chemie na středních odborných školách. *Scientia in educatione,* 2, 23-37.

Rusek, M. 2013a. Vliv výuky na postoje žáků SOŠ k chemii. *Scientia in educatione,* 4, 33-47.

Rusek, M. 2013b. *Výzkum postojů žáků středních škol k výuce chemie na základní škole.* Ph.D. Disertační práce, Univerzita Karlova v Praze, Pedagogická fakulta.

Rusek, M., Havlová, M. , Pumpr, V. 2010. K přírodovědnému vzdělávání na SOŠ. *Biologie-chemie-zeměpis,* 1, 19-26.

Rusek, M., Pumpr, V. 2009. Výuka chemie na SOŠ nechemického směru. *In:* BÍLEK, M. (ed.) *Výzkum, teorie a praxe v didaktice chemie XIX.* Hradec Králové: Gaudeamus.

Salta, K., Tzougraki, C. 2004. Attitudes toward chemistry among 11th grade students in high schools in Greece. *Science Education,* 88, 535-547.

Veselský, M., Hrubišková, H. 2009. Zájem žáků o učební předmět chemie. *Pedagogická orientace*, 45-64.

Vojtěch, J., Chamoutová, D. 2013. Vývoj vzdělanostní a oborové struktury žáků a studentů ve středním a vyšším odborném vzdělávání v ČR a v krajích ČR a postavení mladých lidí na trhu práce ve srovnání se stavem v Evropské unii. Praha: NÚV.

Žák, V. 2009. Důvody, proč se čeští žáci učí fyziku. *Pedagogika,* 59, 269-282.

THE USE OF MICROWAVE RADIATION IN THE CONDENSATION REACTIONS OF THIAZOLIDINE-4-ONES WITH ALDEHYDES IN STUDENT LABORATORY

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Abstract

The paper presents the possibility of using microwave radiation to teach selected laboratory classes with students in the fields of biology with chemistry and biology. The experiments proposed concern aldol condensation reaction between thiazolidine-4-one derivatives and aliphatic as well as aromatic aldehydes. The use of microwaves allows to significantly reduce the time of reaction. As a result, the students can carry out reactions on their own within the time of a laboratory class which cannot be conducted with standard methods. The use of microwaves allows to limit the amount of reagents used. Consequently, it reduces the amount of waste and the teaching costs. Eliminating standard sources of heat and flammable organic solvents increases the safety of the class.

Key words

Thiazolidine, microwave, condensation

INTRODUCTION

The microwave radiation are electromagnetic waves with frequencies between 0.3 and 300 GHz. The practical application of microwaves was first investigated during World War II. It was then when the first radars were built to facilitate military action.

In 1947 Percy Spencer discovered that microwaves can be used to heat food. This led to the invention of the microwave oven. The appliance is currently widely used in gastronomy. According to the international convention the household and scientific devices use the radiation with 2.45 GHz frequency (Vollmer, 2004).

The lower frequency microwaves are used in communication, while the higher frequency in analytical techniques such as microwave spectroscopy.

Microwave radiation, which is electromagnetic radiation, has magnetic and electric components. The electric component is responsible for heating substances.

Raising the temperature is possibly only when the substance has a polar or ionic structure. The polarized molecules start to rotate when affected by an alternating electric field. The collision of molecules trying to follow the electric field leads to the temperature increase. The increase in temperature occurs in a similar way in the ionized solutions. The ions move in an alternating electric field, collide and the temperature of the solution raises (Gaba, Dhingra, 2011).

The microwaves are absorbed not only by the substances in solution but also solvents. In the case of many popular solvents so called superheating effect occurs. The solvent is heated to the temperature beyond the boiling point. It is connected with the polarized molecules relaxation time of the solvent in an electric field (Lidstrom, Tierney, Wathey, Westman, 2001). The solvents of high ability to absorb the microwave radiation are: DMSO, EtOH, MeOH, propanol, nitobenzene, formic acid, glycol. The solvents of medium ability to absorb radiation are: water, DMF, butanol, acetonitrile, methyl-ethyl ketone, acetone, nitromethane, dichlorobenzene, 1,2-dichloroethane, acetic acid. However, chloroform, carbon tetrachloride, 1,4-dioxane, ethyl acetate, pyridine, triethyamine, toluene, benzene, chlorobenzene, pentane, hexane and other hydrocarbons are solvents with low ability to absorb the microwave radiation. When carrying out the reaction using the standard sources of heat, the energy is first transferred to the vessel walls, next to the solvent, only then to the reagents. The heating time depends on the thermal conduction of the vessel and the convection in the full volume of the solvent. The temperature distribution is not homogenous and controlling the reaction is more difficult. Having finished the reaction, it is difficult to cool down the vessel content. The glass walls of the vessel are transparent for the microwaves. The microwave radiation affects all the molecules simultaneously causing a uniform raise in the temperature. It is easy to control the reaction and once the source of the microwaves is turned off only secondary heat is left.

When the microwave radiation is used, selective heating may occur. It results from the fact that different substances respond differently to microwaves. Those absorbing the highest amount of radiation heat up more.

Those which, because of their structure, absorb less radiation or none at all do not heat up (Gaba, Dhingra, 2011).

The reaction time while using microwaves is much shorter compared to the use of standard methods. A good example is the synthesis of aspirin. Under the microwave radiation it takes one minute (Whittaker, 2004). The reaction takes 130 minutes using standard methods (Gaba, Dhingra, 2011).

The short reaction times under microwaves allows to carry out various types of reactions in student laboratory conditions.

As a result, students during a lab class can get to know reactions which cannot be carried out using standard methods because they take too much time. A good example of such reaction is oxidation of toluene to benzoic acid. Under the microwaves the reaction takes 5 minutes (Surati, Jauhari, Desai, 2012).

Heating the reagents with the traditional method, in water, takes 150 minutes. The lab class at Pedagogical University of Cracow lasts 135 minutes.

At the Chemistry Unit of the Institute of Biology we decided to examine the possibility to use the microwave radiation to present to students the aldol condensation reaction in heterocyclic compounds. One of the first aldol condensation reactions carried out under the microwaves, rhodanine with aromatic aldehydes, was the reaction between 3-methylorhodanine and benzaldehyde (Villemin, Alloum, 1993). The reaction was contucted in the presence of potassium fluoride on alumina.

Basing on this work we decided to carry out the aldol condensation reaction of the compounds containing thiazolodine-4-one core with aromatic and aliphatic aldehydes. 2-phenylamino-3-phenyl-thiazolidine-4-one, 3-phenylo-2-thiazolidine-4-one (commonly called rhodanine) and thiazolidine-2,4-dione were used as model compounds. They were chosen due to their high stability, low toxicity and sufficient reactivity. The reactions were conducted in solvent-free environment.

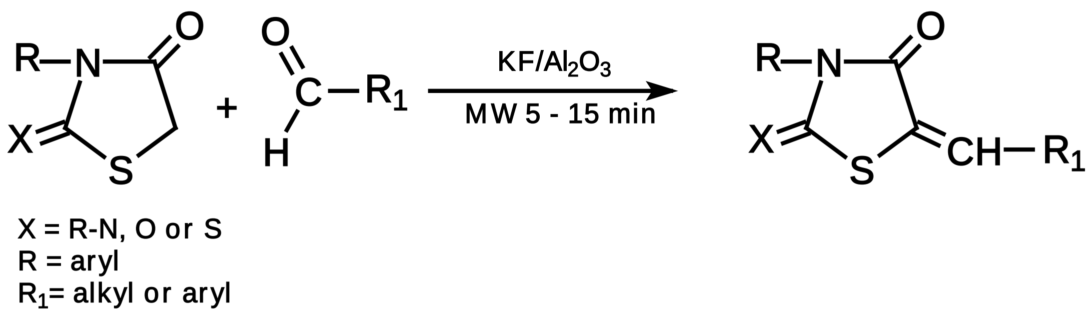

Figure 1. The course of the reaction of thiazolidine-4-one derivatives with aldehydes

EXPERIMENTAL

1 mmol of 2-phenylamino-3-phenyl-thiazolidine-4-one, 3-phenyl-2-thiazolidine-4-one (commonly called rhodanine) or thiazolidine-2,4-dione was placed in a porcelain crucible, 0.1g of potassium fluoride on alumina was added next. The content was mixed carefully. 1.5 mmol of appropriate aldehyde was added and mixed again. The crucible was placed in the microwave oven and heated for 5 to 15 minutes. Having finished heating, the crucible content was extracted with 3 portions of acetone 5 cm^3 each. After evaporating acetone a specimen of the product obtained was dissolved in ethyl acetate and it underwent thin-layer chromatography on plates with silica gel and UV_{254} radiation indicator additive. Figure 2 presents the TLC results for the three selected compounds.

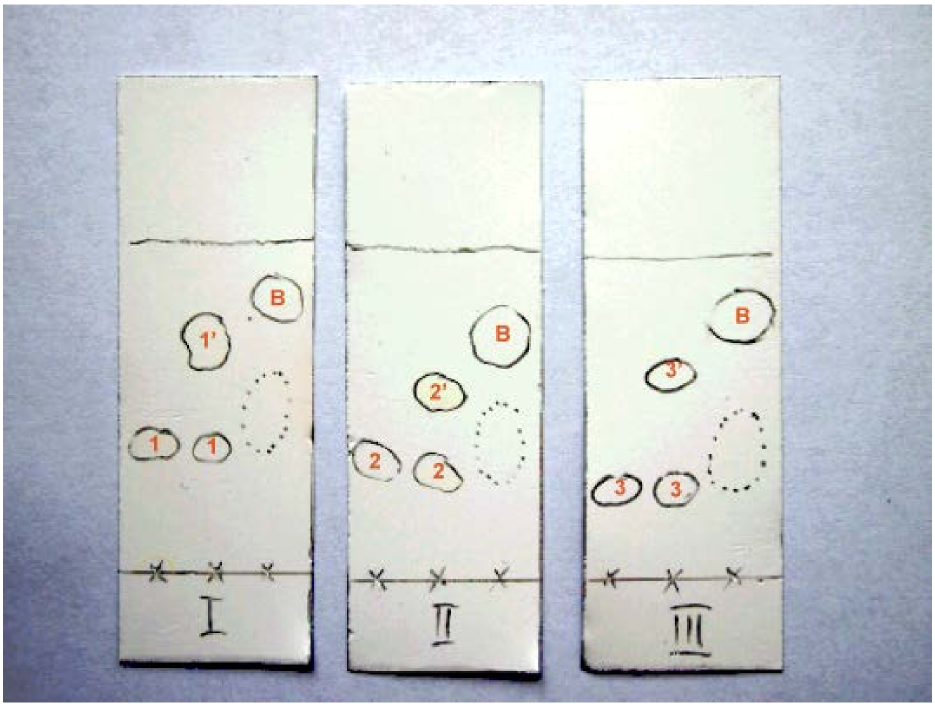

Figure 2. The development of chromatogram for the three selected compounds

1 – 3-phenylrhodanine,
1' – 3-phenyl-5-benzylidenerhodanine
2 – 2-phenylimino-3-phenylthiazolidine-4-one
2' – 2-phenylimino-3-phenyl-5-benzylidenethiazolidine-4-one
3 – 3-phenylthiazolidine-2,4-dione
3' – 3-phenyl-5-benzylidenethiazolidine-2,4-dione
B – benzaldehyde

In order to confirm the effectiveness of the method proposed mass spectrometry and IR spectroscopy were carried out for a few chosen compounds. The mass spectrometry and IR spectra comparison of the obtained product used for the synthesis and thiazolidine-4-one derivative as well as aldehyde proved that aldol condensation had occurred.

Figure 3 presents mass sepctrum of the 2-phenylimino-3-phenylthiazolidine-4-one and benzaldehyde reaction product. The $[M+1]^+$, m/z=357, mass peak of 2-phenylimino-3-phenyl-5-benzylidenethiazolidine-4-one with 356 Da molecular mass is marked.

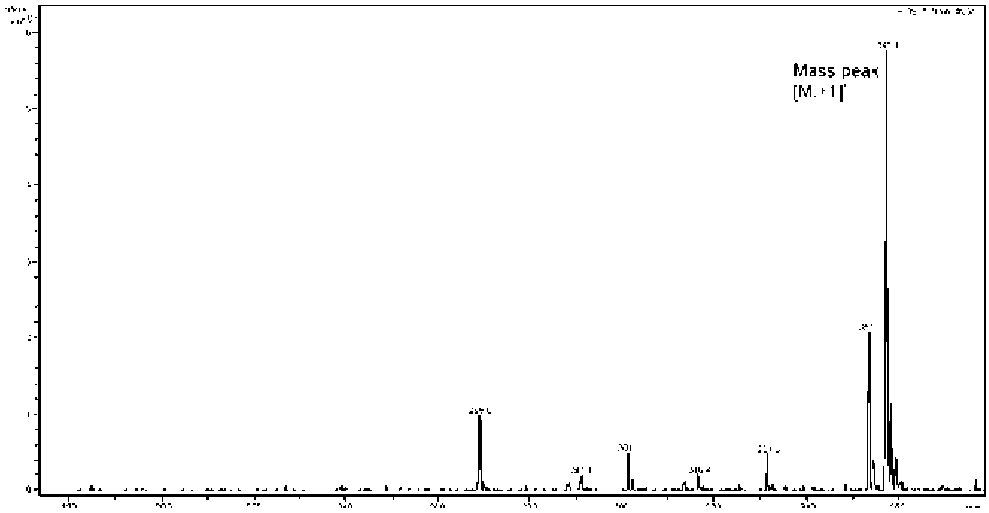

Figure 3. The mass spectrum of 2-phenylimino-3-phenyl-5-benzylidenethiazolidine-4-one

Figure 4, however, presents the comparison of 2-phenylimino-3-phenylthiazolidine-4-one (the dotted line) and 2-phenylimino-3-phenyl-5-benzylidenethiazolidine-4-one (the continuous line) spectra.

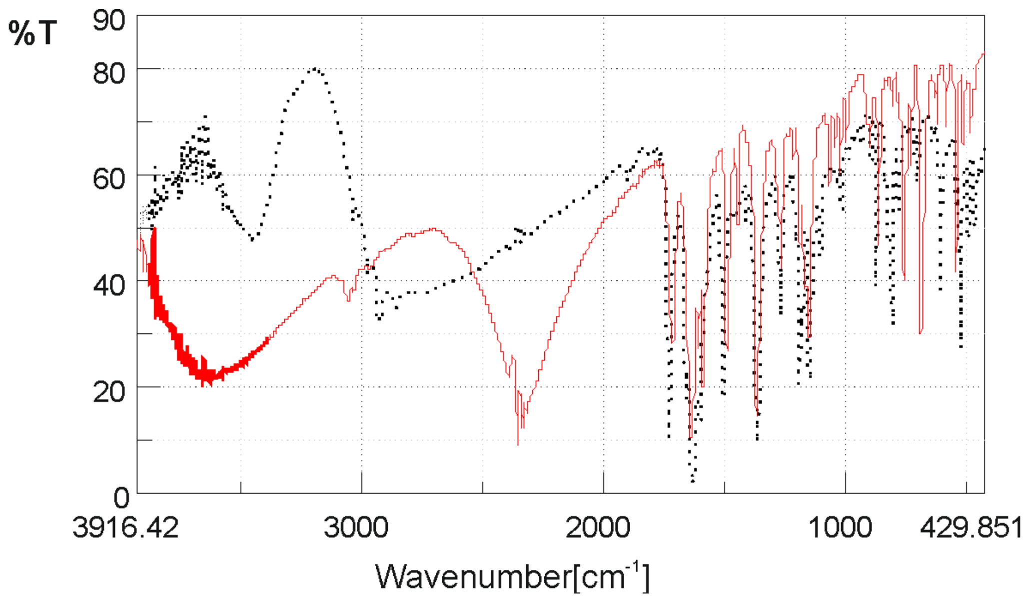

Figure 4. The 2-phenylimino-3-phenylthiazolidine-4-one and 2-phenylimino-3-phenyl-5-benzylidenethiazolidine-4-one IR spectra comparison.

CONCLUSIONS

The use of microwave radiation allows shorten the reaction time. As a result the students have a chance to conduct on their own reactions that require log time of heating in other conditions.

The use of microwaves allows limit the use of energy and it raises the reaction effectiveness. The students use small amounts of reagents. To conduct one reaction around 0.5 to 1.5g of reagents is required. The amount of resulting waste is limited.

The students safety is increased as they do not use flammable and toxic solvents. (Belwal S., 2013).

REFERENCES

Belwal S., 2013. "Green revolution in chemistry by microwave assisted synthesis: A review", Modern Chemistry, 1, 22 – 25

Gaba M., Dhingra N., 2011. "Microwave chemistry: General features and applications", Ind. J. Pharm. Edu. Res., 45, 175 – 183

Lidstrom P., Tierney J., Wathey B., Westman J., 2001. "Microwave assisted organic synthesis – a review", Tetrahedron, 57, 9225 – 9283

Surati M. A., Jauhari S., Desai K. R., 2012. "A brief review: Microwave assisted organic reaction", Arch. Appl. Sci. Res., 2012, 4, 645 – 661

Villemin D., Alloum A. B., 1993. "Potassium fluoride on alumina: Condensation of 3-methyl-2-thiono-4-thiazolidinone with aldehydes. Synthesis of α-thioacrylic acids and phosphonothiazolidinones". Phosphorus, Sulphur and Silicon, 79, 33 – 41

Vollmer M., 2004. "Physics of the microwave oven", Physics Education, 39, 74 – 81

Whittaker G., 2004. "Microwave chemistry", School Science Review, 85, 87 – 94

BIOINORGANIC CHEMISTRY – CHALLENGES FOR TEACHERS AND STUDENTS

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Abstract

Bioinorganic chemistry is an intensively developing branch of chemistry, concerning role of metals and their compounds in biological systems, chemical reactions and physical processes taking place in these systems as well as methods allowing us to investigate these processes.

Because of the great importance and the variety of related issues, bioinorganic chemistry has been introduced as a course of studies, mainly in case of (biological) chemistry, but also biotechnology and pharmacy.

On the basis of our a few year observations we present selected teaching problems indicating also students' difficulties occurring in the learning process. We suggest various teaching methods which we tested and we think may be helpful while solving the arising problems. Particular attention is focused on teaching techniques, which are to motivate students to independent and abstract thinking, critical analysis as well as to develop interpersonal and leadership skills. We believe that proposed solutions may arouse or increase students' interest in bioinorganic chemistry and at the same time help them to learn that interdisciplinary field of knowledge.

Keywords

Bioinorganic chemistry. interdisciplinarity. metaplan. brainstorm. a project method.

INTRODUCTION

Bioinorganic chemistry is a scientific discipline at the interface of chemistry, biology and medicine. It concerns metals and their compounds, their functions and influence on biological systems. Contribution of metal ions is essential in wide range of living processes, such as respiration, photosynthesis, metabolism, nitrogen bounding, signalling, protection against toxic and mutagenic factors, etc. On the other hand, selected metal ions or their compounds can be introduced to a human body as probes in order to investigate the structure and functions of this system. These inorganic compounds are also used in medicine for both diagnostics and therapy (Lippard, 1994), (Hay, 1984), (Roat-Malone, 2007), (da Silva and Wiliams, 1991).

Taking into consideration significance of these issues, bioinorganic chemistry has been introduced as a course in the program of chemical studies at many universities in Poland. At some universities students of chemistry have possibility to choose this course as the optional one. In case of the specialization "Biological Chemistry" they are obliged to finish this course, in most cases on the 1st year of the 2nd degree. Depending on the its detailed program, before joining this course a student is obligated to pass at least the courses of inorganic chemistry and basics of biology. It is strongly recommended to complete the courses of physical chemistry, coordination chemistry, and biochemistry. Additionally, other ones are also helpful, such as biophysics or medicinal chemistry.

Here are a few selected problems that may appear while teaching and learning bioinorganic chemistry and our suggestions how to deal with the difficulties.

- **Interdisciplinarity** is probably the main feature of bioinorganic chemistry. A student attending the course should have an established interdisciplinary knowledge from the border of chemistry (mainly inorganic, physical, coordination, organic and medical chemistry), biology and physics as well as deeply understand the main chemical concepts, e.g. thermodynamic equilibrium, thermodynamic constant, kinetic constant of the process, complex, ligand and central metal (ion), biomolecules (e.g. proteins, DNA) as ligands in bioinorganic reactions, etc.

So far we have observed some insufficiencies of the students "general" knowledge, arising mainly from the fact that they simply forgot some information or they are not educated in multifaceted thinking.

In most cases, a comprehensive **rehearsal** at the beginning of the course turns out to be sufficient for the students and satisfactorily prepares them to effective and active participation in classes.

The rehearsal concerns the basics of inorganic chemistry (essential elements in biological systems, metal centers and their roles, electronic and geometric structure of metals in biological systems, thermodynamics and kinetics of chemical reactions of forming complexes, Hard and Soft Acid and Bases Theory, etc.) and biochemistry (biochemistry of proteins and nucleic acids, enzymatic kinetics, molecular genetics, photosynthesis and respiration, transport and storage of oxygen, nerve impulse transmission, etc.) (Roat-Malone, 2007), (Lippard, 1994), (Hay, 1984). The rehearsal may be realized as an introduction to the course simultaneously with presentation of the main issues provided for the course.

While realizing the program of the course, in our opinion, it is particularly desired to solve **problem multifaceted tasks.** Such kind of tasks develops the ability to associate and combine items from different fields of science.

e.g. *The rate of electron transport was investigated in the myoglobin containing ruthenium and compared to a cytochrome c modified derivative containing ruthenium on the surface. Reduced myoglobin is a pentacoordinated complex in high spin state and the oxidized form binds water forming a hexacoordinated complex. Cytochrome c is a hexacoordinated complex in low spin state (both the oxidized and the reduced form), undergoing only a small structural change in the process of electron transfer. Is the rate of electron transport to the ruthenium from the center of myoglobin similar or different in comparison with cytochrome derivative, provided that the distance and the driving force are the same? Why/why not?* (Lippard, 1994)

Apart from using the recently gained knowledge, concerning electron transfer process and the parameters describing the process (distance, driving force, reorganization energy, influence of milieu), a student consolidates knowledge assimilated earlier, such as complexes in low/high spin state, heme complexes and the coordination number of the central iron ion, conformational changes accompanying reduction/oxidation of the ion, etc.

- **Complexity of biological systems.** Specificity of this branch of science obliges us to look at a particular issue much more "widely". We should look at a process or reaction in relation to its environmental background. Such a reaction/process takes place in a complicated milieu, in which many additional and/or "unpredictable" compounds may appear or factors may play a role. To illustrate this rule, the following example can be presented. When discussing the interaction between the reactive metal center and the ligand (or its part), it is often necessary to take into consideration the influence of selected protein chains or aminoacids interactions that additionally force a system to form a particular geometry. The surrounding molecules may be a steric hindrance or oppositely, may facilitate particular interactions.

The complexity of biological systems requires sometimes the ability of solving the problems in an abstract way. Scientists often carry out research using model systems in case when it is impossible or, for some reasons, very difficult to exam the real compound or the real system. Solving the **tasks**

with model compounds show the way of scientific approach and teaches also the ability of abstract thinking.

Example 1: *How do myoglobin and hemoglobin containing cobalt ion instead of iron ion in the centre of heme ring work?* (Hay, 1984)

One of a possible didactic ways of realization of the suggested task may be **a brainstorm** (Rau et al., 2000). It is a method which requires creative thinking of all the members of the team. During the first phase of the method each student has the right to propose ideas. All of the suggestions are saved, even the most unrealistic ones. In the second step, the concepts, that are completely impossible to implement, are rejected whereas the similar ideas are grouped. The solution is obtained via voting or is a result of common discussion with the teacher.

Example 2: *Why does zinc ion play a role of a metal centre in hydrolytic enzymes?*

To analyse the problem and find its solution, **the metaplan** method can be suggested. It is a graphical record of a discussion, which is running in the group (or several parallel working groups). The teacher presents a problem that is discussed and prepares the materials for the posters (coloured paper geometric shapes, coloured markers, an adhesive tape, etc.) The common poster should be a kind of the summary of the together work. During the discussion, students are asked to come to the board and write down the appropriate observations/conclusions/suggestions. They organize also the content of the poster. At the end of all reported ideas students may again discuss to eliminate contradictions.

- **Ambiguity of terminology.** The same word may be used in different context depending on the branch of science, e.g. "complex" and "ligand". Chemists understand the "complex" as a coordination compound with central metal (ion) and ligands that form the so called coordination bounds with central atom. Ligands are defined as neutral molecules or anions, possessing at least one free electron pair, able to coordinate the central atom. On the other hand, biochemists often describe "complex" as a complicated system of an enzyme and a substrate. The concept of "ligand" is considered as macromolecule (e.g. DNA, protein) taking part in the reaction with the active center.

It is suggested to draw students' attention to this nuance.

- **Language difficulties** may occur when studying the scientific literature. It is suggested to provide students proper materials and inspire them to search for and read popular science and scientific literature, particularly in English.

- **Difficult, incomprehensible literature.** Students are sometimes not interested in classes and discouraged from reading and learning because of the specific terminology and detailed description of particular issues. Therefore, it is preferred to pay special attention to reviews, additional related academic books and also popular science literature instead of starting with very specific, detailed articles.

- **Lack of motivation.** Students may be not interested in or even bored with the classes because they treat the course as only a new portion of science, without real application.

As an example of dealing with problems no. 4-6 we suggest **a project** addressed to one student individually or to a group of students. The teacher provides various topics regarding bioinorganic aspects of biological systems. The topics should be attractive for students and concern the crucial and real everyday life problems, e.g. *"Metallochlorophylls as potential photosensitizers in Photodynamic Therapy" or "Platinum/ruthenium complexes in anticancer therapy"* – tasks realized while discussing *"Perspectives of Bioinorganic Chemistry"* (Stochel et al., 2009). Students have also opportunities to choose one of the topics which they are especially interested in.

The mentioned task forces students to do the **literature search and the analysis of source texts**, which are not easy, but have tremendous value. The goal is not only to develop the skills of reading scientific texts, but also to familiarize themselves with the statistical data (Bilek et al., 2003). The students practice their skills of searching and selecting the information, as well as its critical analysis. Time schedule of the project has to be adapted to the program of the course, but the final part, which is an oral presentation session, is suggested to be planned on the last or penultimate meeting, followed by a final test of the course. The session creates the possibilities of improving language and interpersonal skills. It is worth mentioning that the final test may include some questions regarding students' projects.

After a short oral presentation of the project to the whole group, students have the opportunity to take part in the so-called **Socratic discussion** (Paul et al., 1989). It is a conversation centered around the topic. This allows us to clarify ambiguities, discuss and explain the causes of processes or mechanisms.

CONCLUSION

In our opinion, the most valuable sort of exercises that can be done during bioinorganic chemistry classes are multifaceted problem tasks developing creativity and a broad look at a particular issue. Additionally, the ability of critical analysis, reading and comprehension of scientific and popular science literature as well as language and presentation skills are effectively improved due to the personal/team project concerning the most recent and promising topics of this developing branch of science.

REFERENCES

Bílek, M., Chrzová, M., Cyrus, P., Slabý, A., 2003. *Projects in Science and Technical Education and Internet.* In: Bezjak, J., ed. 2003. *Technical Creativity in School's Curricula with the Form of Project Learning "From Idea to the Product" – from the Kindergarten to the Technical Faculty. Proceedings of 1st International Science Symposium* (9. – 11. April 2003, Portorož, Slovenija). Ljubljana, University of Ljubljana, p. 90 – 92.

Hay, R. W., 1984. *Bioinorganic Chemistry.* Chichester: Ellis Horwood.

Lippard, S. J., Berg, J. M., 1994. *Principles of Bioinorganic Chemistry.* Mill Valley, California: University Science Books.

Paul, R. W., Martin, D., Adamson, K., 1989. *Critical Thinking Handbook: High School, A Guide for Redesigning Instruction.* Foundation for Critical Thinking.

Rau, K., Ziętkiewicz, E., 2000. *Jak aktywizować uczniów. „Burza mózgów" i inne techniki w edukacji.* Poznań: Oficyna Wydawnicza G&P.

Roat-Malone, R. M., 2007. *Bioinorganic Chemistry. A Short Course.* A John Wiley & Sons, Inc.

da Silva, J. J. F., Williams, R. J. P., 1991. *The Biological Chemistry of the Elements. The Inorganic Chemistry of Life.* Oxford: Oxford University Press.

Stochel, G., Brindell, M., Macyk, W., Stasicka, Z., Szaciłowski, K. 2009. *Bioinorganic Photochemistry*, Wiley.

ON USING EYE-TRACKING METHODOLOGY FOR ANALYSING STUDENTS' STRATEGY OF BALANCING CHEMICAL EQUATIONS

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Abstract

The paper presents the results of eye-tracking research run in order to determine students' strategies of balancing chemical equations for the reactions between acids and hydroxides which were illustrated by the example of the reaction between sulfuric acid (VI) and sodium hydroxide as well as between sulfuric acid (VI) and aluminium hydroxide. The research has shown that 3rd grade university students at the bachelor level of chemistry with biology use different strategies, even when they solve similar problems.

Keywords

Chemical education, eye-tracking supported research, chemicalequations.

INTRODUCTION

During the process of learning students acquire certain skills needed to solve problems. Every school subject as well as every field of science has its specificity. Therefore very often the skills acquired during the course of one school or university subject do not facilitate solving problems in the context of another subject. This is especially visible between so called humanistic subjects and science. Chemistry is commonly regarded as a difficult school subject. It is worth to consider whether that fact is rooted only in objective difficulty of chemistry or it also results from some mistakes made in the teaching and learning process.

One of the fundamental errors of the ongoing process of chemical education should be considered too high attention paid to examining students' achievements. In contrast, too little importance is given to examine the students' difficulties while solving problems. Teaching process and especially designing curricula should be undoubtedly based on psychology and pedagogy research on the functioning of our brain (Kalat, 2006). People responsible for curricula designing make an impression as if the phenomenon of negative transfer was not known to them. But already in the 80s of the twentieth century Sawicki (1981) wrote about it in the context of science.

Taking into consideration the negative transfer phenomenon and availability of new technologies it seems essential to carry out research on the monitoring of eye during problem solving.

Students while learning chemistry are struggling for a long period with writing equations of chemical reactions and especially with calculating the stoichiometric coefficients and writing the equations correctly.

Between 2004 and 2005 was carried out by classical, i.e. using an appropriately constructed worksheets of questions to determine the weakest link of writing simple equations of chemical synthesis (Paśko, 2006). The results of the research showed that students' difficulties with problem solving at various stages are different and specific to the student. This way of running research was embarrassing and for larger groups of students required an involvement of several persons.

The study was repeated in 2006 and 2007 using properly constructed software (Paśko and Jyź, 2007, iViewX software, 2014). This software fulfilled two roles: an educational one and monitoring the work of a student. At that time difficulty in balancing chemical equations for reaction between acids and hydroxides were studied. This research has also shown that the difficulties arising during problem solving are somewhat dependent on the individual student. We were able easily diagnose difficulties occurring at different stages, but we could not find the answer, why they occur. Especially we wanted to know why difficulties are a student's individual and specific feature, even if students actually were taught in the same way.

Sight is one of the bodies, which is used during problem solving by students. Therefore it was decided to carry out research to examine the eye moves across the screen during the process of solving a task.

To carry out the research the Eyetracker SMI Hight Speed 1250 with proprietary software (Paśko and Komisiński, 2011) was used. The software allows balancing chemical equations using elements from the defined set of coefficients.

During our experiment at a computer screen was placed an incomplete chemical equation, containing empty boxes in which respondents had to enter the correct digits. They should have decided which digit should be used from the set of all digits and then drag and drop it into the correct place. Every digit could be used more than once.

The problems given to university students were to balance two chemical equations. The first one was for reactions between sulphuric acid (VI) and sodium hydroxide and the second one between sulphuric acid (VI) and aluminium hydroxide. Figure 1 shows the computer screen with the formulation of the first equation.

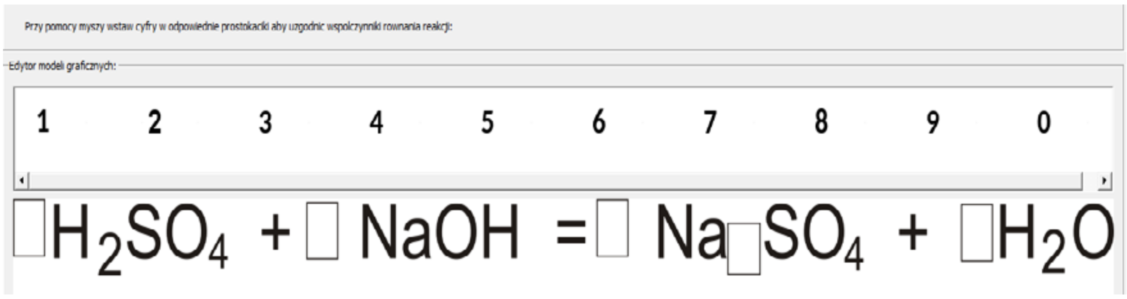

Fig. 1. Computer screen with the first equation needed balancing.

In order to analyse the results of the research we defined separated fields needed to be taken into consideration, so-called Area of Interests, containing the elements of equations and digits from their sets. The following figure (see Fig. 2) shows Area of Interests for reactions between sulphuric acid (VI) and sodium hydroxide.

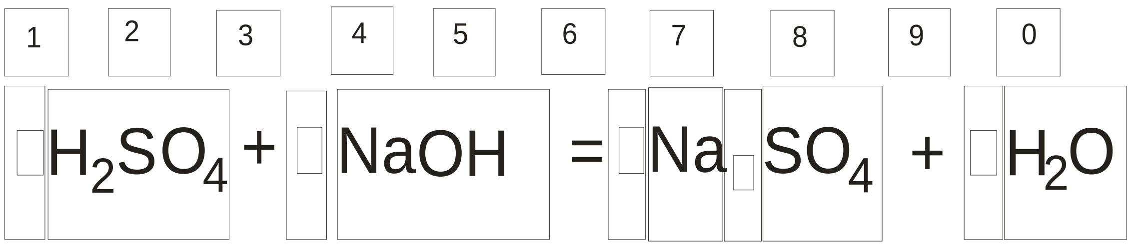

Fig. 2. The way of analysis of balancing the chemical equation.

Using SMI High Speed 1250 device 4 persons were examined, which were one expert (lecturer in chemistry), and three 3rd grade university students at the bachelor level of chemistry with biology. They received the instruction about how to use the software in order to balance the two chemical equations. The first equation for reaction between sulphuric acid (VI) and sodium hydroxide is considered as the easiest one from all the equations with the stoichiometric coefficients. When the respondents balanced the first equation they faced the second one, for reaction between sulphuric acid (VI) and aluminium hydroxide, which is considered to be the most difficult from that type.

With the use of the previously constructed interactive software to learn balancing chemical equations (Paśko and Jyź, 2007, iViewX software, 2014) we could determine the sequence of actions performed by respondents but could not monitor the way of analysis of the problem formulation before performing the activity. In these studies, through defined Area of Interests (AOIs) we focused only on the aspect of analysis of the formulation of the problem, which is reflected by eye movements.

While solving a problem eyes move across the area of a screen and stops at some points. In our research we analysed the areas taking into account eyes' fixations, revisits, and the sequence of fixation during analysis of the tasks.

The research found that the way of analysis of the problem formulation performed by the expert was explicitly deviated from the students' way of analysis. Both tasks analysis performed by the expert proceeded in the same way, starting from the left side of the text. Firstly he located where the coefficients need to be inserted, then drew attention to the formula of sulphuric acid (VI), and moved to the set of digits. Then he analysed the salt formula paying attention to the symbol of metal and the formula of acid radical, then the formula of hydroxide. The last element of the analysis was the formula of the water molecules and the determination of their number in the equation of the reaction.

The students' strategies of problem analysis were specific for every particular person. Two of them performed almost in the same way during solving both problems. In contrast, one of the respondents chose a different strategy for the first problem and another for the second one. For the first chemical equation, all students began analysis of the content from the elements of salt formula. The second equation was analysed using the same strategy by two students and the third one firstly drew attention to the formulas of the reactants (substrate of reactions).

Analysing the use of numbers it can be noticed that numbers greater than 5 mainly have not been taken into account. One student often hit the field with digit 0 considering putting this number for the empty place, where the correct answer was 1 or it could remain empty.

While solving a problem we can observe many revisits to particular AOIs. In the case of the first equation the average number of expert's revisits was 3. The greater number was 7 to the field with the formula of acid radical and only once to the field where entering the number of water molecules was needed. However, in the second equation some of the fields were repeatedly revisited. Expert's eyes stopped the most often in the field of aluminium hydroxide formula and the less often in the fields relating to the water molecule.

The problem content and the commonly used strategies for balancing the second equation caused the need for great number of revisits.

For the first equation the maximum number of revisits was recorded to the fields with the formulas of acid and hydroxide - from 19 to 40, then to the field with the symbol of sodium salt. The less numbers of revisits was to the fields related to the salt formula.

For the second equation the maximum number of students' revisits was observed for the field with the formula of aluminium hydroxide, similarly to the expert. Total numbers of revisits was from 60 - 72 (for the expert it was 40). Then, the most frequently visited fields, from 19 to 56 times, were the formulas of sulphuric acid (VI) and the sulphate radical (VI). From 14 to 36 revisits were recorded to AOI with the symbol of aluminium.

The dwell time at the AOIs was the third parameter which was taken into consideration. The dwell time was differentiated – from several hundred to several thousand of milliseconds, and it was significantly shorter for the expert than for surveyed students. The total dwell time is a characteristic feature for the individual. For example one student's number of revisits to the field of acid was 28 with the total time of 6592 milliseconds and to the field with the hydroxide formula was 31 with the total time of 5810 milliseconds. In contrast for another student for the same fields the numbers of revisits were 31 with the total time of 7544 milliseconds and 40 with the total time of 9461 milliseconds relatively.

CONCLUSION

The study is a continuation of research on explaining the difficulties faced by school and university students in writing and balancing the chemical equations and the understanding of the structure of the microworld.

This research confirmed that the process of problem solving does not proceed in all students in the same way and made us realize how difficult and complicated for the student the process of balancing the chemical equations is. So diversified difficulties may be rooted in a student's idiosyncratic factors, wrong habits and the kind of everyday knowledge, what seems to be proved by such a diverse analysis of the problems.

The results of our research stress the need of individualization in the process of teaching and can be helpful for developing the learning strategies taking into consideration students' knowledge and individual differences.

REFERENCES

Kalat J. W., 2006. *Biologiczne podstawy psychologii*. Warszawa : PWN.

Sawicki M., 1981. *Metodologiczne podstawy nauczania przyrodoznawstwa*, Ossolineum 1981.

Paśko J. R., 2005. Badanie trudności w rozwiązywaniu prostych problemów chemicznych przez uczniów na początkowym etapie edukacji chemicznej. *Acta Facultatis Paedagogicae Universitatis Tyrnaviensis, Séria D, Vedy o výchove a vzdelávaní, Suplementum 1*, Trnava : Trnavská univerzita.

Paśko J. R., Jyż D., 2011. *Interaktywny program do nauki pisania równań reakcji chemicznych*. Kraków : Pracownia Technologii Nauczania AP, 2007.

Paśko J. R, Kamisiński A., 2011. Program komputerowy pozwalający na badanie wyobrażenia ucznia o strukturze danej substancji chemicznej. In *Technologie informacyjne w warsztacie nauczyciela: nowe wyzwania*. Kraków, Wydawnictwo Naukowe Uniwersytetu Pedagogicznego.

iViewX software, 2014. [online] Available at http://lyrawww.uvt.nl/~cenv/dci-lab/smi/iViewX.pdf [Accessed 28 June 2014]

EYE TRACKING AS A DIAGNOSTIC METHOD OF A DIGITALIZED CHEMICAL EXPERIMENT ON THE BACKGROUND OF THE GIFTED STUDENTS‘ WORK RESEARCH

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Abstract

The technology of Eyetracking was originally used in the army. Later it was used as a research method in advertising and now it is getting into the area of education and evaluation. The Eyetracker is a costly device that is used for monitoring the movements of a human eye. In this paper we are trying to demonstrate a completely new and hitherto unexplored possibility of using the eyetracker as a scientific device to research students that excel in science. This paper focuses on the presentation of digitalized chemical experiment and its evaluation.

Keywords

Eye tracking, digitalized chemical experiment, visualization, research, eye movement.

INTRODUCTION

The quality and efficiency of education are nowadays coming to the fore of interest in relation to the evaluation processes. The key role of evaluation processes is not only in evaluating the education systems, schools, teachers but especially individual pupils (Průcha, 2009). Evaluation of student can not be understood only in terms of quantity (the volume of their knowledge and skills) but also from a qualitative point of view, i.e. how students approach the task.

The qualitative view of the issue can be solved by means of various qualitative methods of educational research, such as observation or interview with the student, but in accordance with the plans of the Ministry of Education, Youth and Sport (MoEYS) ICT technologies can also be used. Ministry of Education does not specify the form in which ICT should be applied and it can therefore be assumed that a trend of NIQES project (the

National System of inspection and evaluation of the education system) can be applied.

To assess the quality of education and evaluation eyetracking can also be used.

EYE TRACKING

To apply the eyetracking method for research purposes the Faculty of Education, University of Ostrava purchased an eyetracker which has the ability of optical scanning without direct contact by using optical methods that follow the movements of eyes. Movements of eyes are monitored by infrared light that is reflected into them and detected by the camcorder. For sensing the movement of an eye it is not only the light reflection from the cornea that is used, but also that from the lens and retina. The advantage of the optical eyetracker is in its non-invasiveness and a lower cost compared to the other two types.

The key thing for proper functioning of the eyetracker is its calibration, which adjusts the focus of a pupil to each observer separately. For research purposes there are currently used optical eyetrackers based on light or dark irises. The diagnostics work of the eyetracker can be spoilt by sub-optimal lighting conditions (too much light, dark). Its sensitivity can also be affected by pigmentation of the iris, longer lashes or light refraction environment (the use of optical glasses).

Eye movement can be divided into two basic parts:

- fixation
- SAKADA (Duchowski, 2007).

While at fixation we look at an object, SAKADAs are used to show the movement between the objects observed. The result of fixations and SAKADAs is referred to as the scan path. When focusing on something the optical beam is transferred to the macula of an eye. The macula is the place of the sharpest vision where the range that we are able to perceive is only 1 – 2°. The fixation usually lasts for about 200 ms. Scan paths are crucial for the assessment of cognitive purposes, for identifying places of interest and the assessment of the need based on visual communication. The scanning path may be influenced by different factors. The most common one is a gender of the examined individual.

The advantage of the eyetracking is that it has the ability to track the place where the person is focusing their attention. The outputs can be displayed e.g. in the form of an animated presentation which can directly present or show the specific way of the problem solving of the examined person, i.e. fixations and SAKADAs.

(Why did the content of the test tube turn blue? a) Because of copper nitrate; b) Because of sulphate; c) Because of cupric chloride; d) Because of sulphite copper)

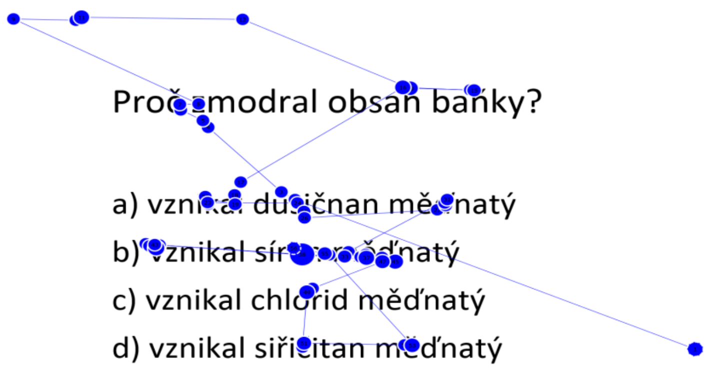


Figure 1: Fixations and SAKADAs

The device records large amounts of statistical data which we may obtain and then use the specific information that is relevant to the research project. The third option of the output are so-called heat maps which accumulate the focus of attention and according to the length and orientation the colour of the field changes (the higher the frequency of fixation, the more the colour of the area is closer to red).

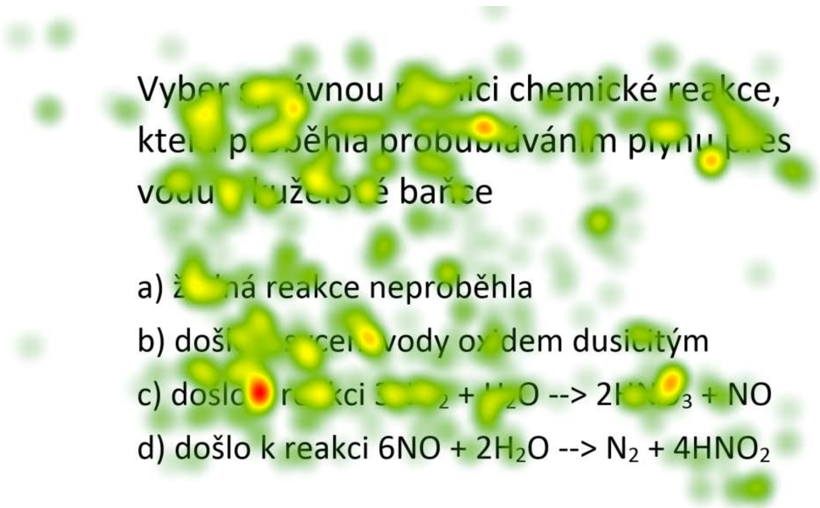


Figure 2: Example of display by using heat maps

The last of the visual outputs are so called dead zones where, from the original black screens, are visible only those areas that the user focuses their attention on.

GIFTED PUPILS

There are many different definitions for the word talent or gift. An example might be the definition of S.P. Marland Jr., who performed a broad survey at American schools in 1972. From his exploratory investigation arose the following definition: "... there are children who are identified by professionally qualified persons as children with the benefits of outstanding ability for high performance. These children require differentiated educational programs and services beyond those commonly provided by conventional training programs to enable them to contribute to their own benefit and the benefit of the society. Children capable of high performance are those that demonstrate the potential benefit in any one or more of the following:

- General intellectual ability,
- Specific/individual academic eligibility
- Creative and productive thinking,
- Leadership skills,
- Art,
- Psychomotor skills. (Sejvalová, 2012, Škrabánková, 2012).

Gifted children have their own characteristics in the positive as well as negative sense of the word. The positive aspects include the extreme maturity in learning and performance, asynchronous development, rich vocabulary, ability to deal with complex intellectual operations compared to their peers, ability to solve complex and challenging tasks, extreme sensitivity or irritability. The negative side of these individuals are usually protest against routine and predictable work, unwillingness to do their work and obey commands, certain domination and rejection of submission and cooperative learning, etc. (Sejvalová, 2004).

The development of talented children, pupils and students is also defined in the Education Act. The schools are obliged to create optimal conditions for the development of these students. The possibility of developing a talent is very broad e.g. the further or enriched teaching of particular subjects and also modifying the plan or organization of the pupil's learning program e.g. the pupil is moved to the higher grade or creating individual education plan (Education Act, 2012).

PRACTICAL USE OF EYE TRACKING AS A DIAGNOSTIC METHOD OF A DIGITALIZED CHEMICAL EXPERIMENT

Eyetracking as a diagnostic method is used in the research activities by the Research Centre of educational and evaluation processes at the Pedagogical Faculty, University of Ostrava. The laboratory is equipped with a static eyetracking device Tobii TX 300, one master computer and two monitors. For a deeper analysis there is also a measuring device EdLaB with attached galvanic skin response sensor – the skin conductivity. It is a programmable sensor with a noise filter and it is used as a gauge of emotions (Jedlička, 2014).

For the diagnosis we selected a digitized experiment - chemical reaction of copper with concentrated nitric acid which was downloaded from YouTube. The experiment was edited for the research purposes. We subsequently defined five questions related to the experiment.

Test questions:

a) What is the chemical formula of the gas produced during the chemical reaction?

b) What compound was being formed while the gas was bubbling through the water in the conical flask?

c) Choose the correct equation of a chemical reaction that took place during the development of the gas.

d) Choose the correct equation of a chemical reaction that took place while the gas was bubbling through the water in a conical flask.

e) Why did the content of the flask turn blue?

The research was carried on eight students of a secondary school in Ostrava. The pupils were selected by their teachers who work with the students on regular basis. Among the respondents there were four boys and four girls aged 15-19 years of age.

A DISCUSSION RELATED TO THE DIAGNOSTICS OF USING THE EYE TRACKING METHOD

The students were originally chosen not only on the basis of sex, but also according to their participation or non-participation in the chemical competitions. Another criterion was the rating of "excellent" in the subject of chemistry. However, the original assumption of a different view on the visualizations and responses in terms of the category of participation or non-participation in competitions was not confirmed. The visual perception was similar in both categories.

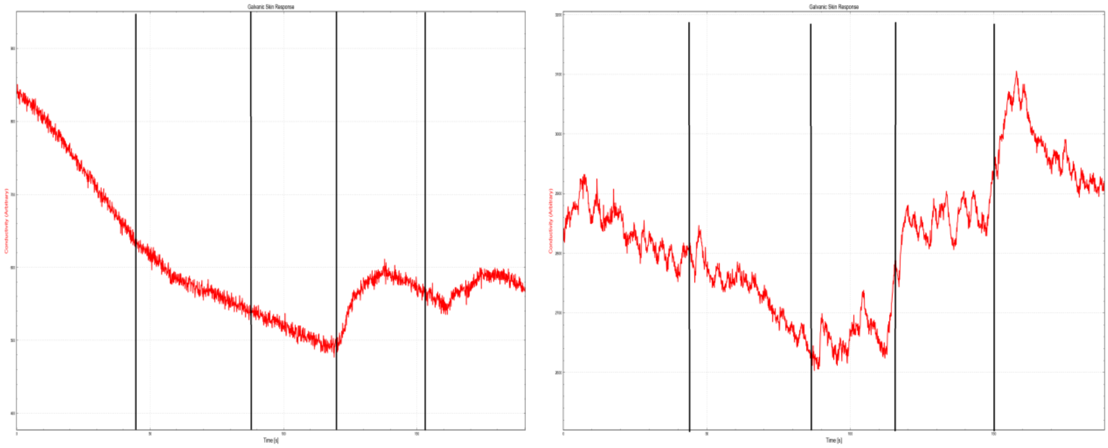
However, with all questions the views were different from the point of view of boys and girls – so in terms of gender. While the girls focused on reading questions and selecting a correct response, the boys, for the same time period, recorded greater dispersion of observations of all elements. Below is an example of response by using "heat maps". The longer and more often the student directed his/her attention to a specific part on the screen, the more the area turned yellow or even red. Areas that weren't observed at all remained white.

Figures 3 and 4 are model answers. The results of the other four questions were similar.

(Why did the content of the test tube turn blue? a) Because of copper nitrate; b) Because of sulphate; c) Because of cupric chloride; d) Because of sulphite copper)

Figure 3 and Figure 4: Heat maps (illustration 3 – a summary of girls‘ heat maps, illustration 4 - heat maps of boys)

Apart from the research in the field of visual perception the students were also tested for their reaction to the stressful situation, i.e. they were asked questions previously unknown. From the Figures 5 and 6 below it is apparent that each individual responds to stress differently. It is not possible to say whether there is a connection between a gender and the situation – the graphs below are only examples of possible responses. Vertical lines are there to separate individual questions. Illustration 1 on the left is a record of the girl’s reaction to the stress which occurred at the initial stage. She gradually calmed down until the questions 4 and 5 when she again "energized" – it may have been the type question or she did not know the answer or she became stressed because the time was running out. As for the boy whose emotional curve is shown on the right – he also shows gradual reduction of emotions but there is a larger fluctuation of emotions compared that of the girl.



Figures 5 and 6: the outputs of the sensor ("skin conductivity", "lie detector"), Chart 1: girl’s skin conductance, Chart 2: boy’s skin conductance

It can be concluded that while girls focus their attention only on certain parts of a question and at the same time try to find the right answer, the boys, for the same period of time, try to capture as much information as they can and only after that subsequently derive the answer to the task.

CONCLUSION

Eyetracking shows as a suitable method of diagnosis of visual perception of information. The above assessment of the digitized image gives us information that there are differences in access to the information between the genders. The testing based on the the digitized image was carried out on eight respondents.

In future it is be possible to use the method of eyetracking as an objective method for the research in the diagnosis of learning styles.

REFERENCES

Duchowski, A. T., 2007. *Eye tracking methodology: theory and practice*. 2nd ed. London: Springer.

Eye tracking. 2001. In: Wikipedia: the free encyclopedia [online]. San Francisco (CA): Wikimedia Foundation. Available at: http://en.wikipedia.org/wiki/Eye_tracking. [Accessed 2014-07-05]

Jedlička, L. 2014. *Vybavení laboratoře VCEEP. Web Výzkumného centra edukačních a evaluačních procesů* [online]. Available at: http://vceep.osu.cz/ET.html. [Accessed 2014-07-04].

Průcha, J. (ed.). 2009. *Pedagogická encyklopedie*. Praha: Portál, 2009.

Sejvalová, J. 2004. *Definice a projevy nadaných žáků*. Metodický portál: Články [online]. Available at: http://clanky.rvp.cz/clanek/c/z/17/DEFINICE-A-PROJEVY-NADANYCH-ZAKU.html. [Accessed 2014-07-04].

Škrabánková, J. 2012. *Žijeme s nadáním*. Ostrava: Ostravská univerzita v Ostravě, Pedagogická fakulta.

Act on pre-primary, primary, secondary, tertiary professional and other education (Education Act), 2012.. In: *Collection of Laws*. Roč. 2012, 139.

ATTITUDE OF CHEMISTRY TEACHERS TO GRADE OF CHEMICAL OR NATURAL SCIENCE LITERACY

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Abstract
The results of the last testing of the 15-year-old students' literacy in OECD PISA (2012) study were vastly unsatisfactory for our country. We tried to determine whether teachers are satisfied with students' understanding of subject or they try to use the students' gained knowledge in common life situations. We were interested if there are created preconditions for better score of scientific literacy in OECD PISA study in 2015.

Key words

Chemistry teaching, natural science literacy, problem solving tasks, reading comprehension, laboratory exercises

INTRODUCTION

We could see in several previous months the comparison of sportsmen from different countries at Olympic Games or at FIFA World Cup. Millions of people were interested in these comparisons and they were interested, together with sportsmen and their couches, in improving the performance. But this common interest decreased over time.

We can see the similar situation in education process. We saw the public discussion in the media about the reasons of the unflattering results of comparison of the 15-year-old students between countries (2012) after it was published by Ministry of Education, Science, Research and Sport of Slovak Republic and National Institute for Certified Educational Measurements (NÚCEM)[1] (December 2013). The most known study (due to the public media) is OECD PISA international study, which started in year 2000 and tests 15-year-old students in three years cycles the mathematical, reading and natural scientific literacy. The last study in 2012 tested students in 65 countries all over the world. But now, nearly one year before the next test round, there is no publicity about this topic, not only in the media, neither in schools. This state is worrying, because from year 2003, when the Slovak students were tested for the first time, the results were always below the average level in studied literacy. In the last comparison in year 2012 only students from Chile and Mexico were worse than ours from all OECD countries. The students from Czech Republic were above the average of OECD countries – and we have had the same education development for 68 years with Czech Republic.

We were curious if there are active similar measures in improving our students, as they are made after sports failures (exchanges of couches, conditions, style of preparation). The next question was about the attitude of the chemistry teaches of the lower secondary education.

METHODS, RESULTS AND DISCUSSION

The Slovak students acquired in OECD PISA study in year 2009 the little improvements in results, but in year 2012 there were large decrease in all measured literacy. We tried to determine whether teachers are satisfied with students' understanding of the subject matter, or they improve the critical thinking of students, so they can review the reliability of information and use it in problem solving of common everyday life. The main goal was to find out if there are preconditions to present higher level of scientific literacy of our students than in previous tests. We made a questionnaire for grammar school chemistry teachers. We sent it to 118 grammar schools by e-mail (table 1). We focused primary to the schools from the middle parts of Slovakia (regions Banská Bystrica and Žilina), but we sent it also to schools in distant parts of Slovakia (regions Bratislava and Košice). We dominantly selected schools with more than 100 students in 5th to 9th year.

We wanted to make an idea about chemistry teaching methods in particular schools, what prefers the chemistry teachers and if they try to intentionally improve the science literacy.

We asked the chemistry teachers what are, by their options, the main reasons for low level of scientific resp. chemical literacy (table 2). The responses indicate there are several deficiencies and they result in below average literacy. The teachers agree that the test results are influenced not only by amount of knowledge, but mostly by ability in reading comprehension (25.56 %) and use the gained knowledge in a problem solving situations (21.1 %). This correlates with published results from Monitoring 2014, in which the main shortage was in reading comprehension. The Slovak language teachers demand to use also other school subjects to improve reading literacy.

Table 1 Number of addressed and participated grammar schools in research

Region	Number of addressed schools	Number of participated schools
Banská Bystrica (BB)	36	23
Bratislava (BA)	16	9
Košice (KE)	23	18
Žilina (ZA)	43	40
Total	118	90

Table 2 The respondent's opinion on our students' low level of scientific literacy

Missing abilities of students	Number of answers from respondents in			
	BB	BA	KE	ZA
Lack of practical skills		1		1
Missing laboratory exercises	1	2	1	3
Logical thinking	3		6	5
Reading comprehension	6	3	4	10
Interconnection of knowledge from different subjects	2	1	1	
Lack of interest to discover the essence of phenomenon		2	4	
Application in the practice	6		2	11
Ability of watching the nature				5
Lack of interest in subject matter	3			2
Communication skills	2			3

We wanted to know the opinion of chemistry teachers about the possibility of supporting the reading literacy, which they consider to be important factor in increase of scientific literacy (table 3).

Table 3 Activities that support the increase of reading literacy in chemistry teaching

Activities	BB	BA	KE	ZA
Reading text from the text book	14	4	6	12
Support of the data mining from literature	6		3	7
Self-education		2		
Work with text		3	9	21
Introduce students to interesting popular science articles, texts	3	1		1

All respondents agree that the chemistry allows also the increase of reading comprehension. But the presented opinion does not totally correspond with reality as presented activities are not sufficiently or regularly implemented in chemistry teaching. We can analyse from responses that students usually do not use the chemistry textbook in school or at home. According to this, the reading comprehension is limited. The teacher usually presents new information and students only occasionally make some exercises from their textbooks or workbooks. There is usually no time for such activities. The respondents states that in general students learn and repeat new information only from their notes in notebooks and not by reading the text in chemistry textbook. This is probably the main reason for the situation presented in PISA 2012 study. In this study the 26.8 % of Slovak students were in the lowest – the risk group.2 Ability of students to investigate the problem task is limited, only if they previously meet such type of challenge. They are able to solve only easy problems with one condition composed of one or two steps. They do not know to plan sequence of steps or to propose partial goals, which are necessary to solve the whole problem.

The respondents stated, when the students should solve some project, they use thematically sorted information from internet. They do not need to sort out basic and substantial data. But the respondents did not tell, whether they provide any literature list or scholarly articles to their students. Even those respondents, who prepare yearly 1 to 10 students for chemistry Olympiad, didn't state this.

Another problem, which significantly influences the level of science or chemical literacy, is the mutual connection of learning and practice. The teachers recommended making this connection much stronger than it is currently done in a teaching process. This argument is based on responses to the question about dealing with common life problems in chemistry classes as these problems are presented in the media (press, television, radio, advertisements, movies) from point of view of chemistry or other science. The problem on the grammar schools, which were involved in this research, is also the differential teaching based on students intellectual abilities and interests. None of the respondents stated to present extra challenges to individual or talented students. If they make some problem solving exercises on chemistry lesson, they are solved by a whole class under teacher's supervision, or in several students groups. Only occasionally is the challenge solving assigned for homework. Surprisingly, this is done also in 6th and 7th year, but not in later years. We cannot decide if the reason is that there are only few hours assigned to chemistry or it is because the students in these years are more creative and they are able to solve those challenges at home.

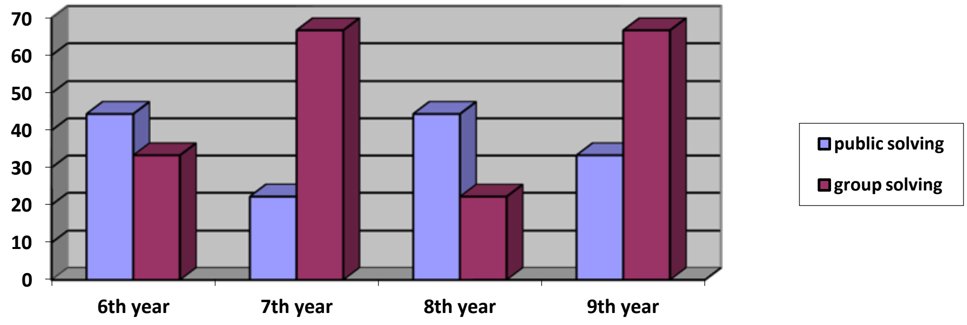

Fig. 1 Public and group challenge solving in each year

As it is presented on figure 1, the public solving during chemistry lessons is present in different amount in each year. The challenges appropriate for work in groups in 7th year are based on lessons "Exploring chemical reactions in our environment" and "Changes in chemical reactions". We were interested weather the challenges are based on common life, because the PISA study contains this type of problems (fig. 2).

Common life situations are not only parts of solving the challenges, but they are often parts of topic motivations. The respondents use for motivation purposes, besides the talk, also the experiment. Although we are aware of that the real experiment is more authentic, but we were surprised that teachers do not use projected experiments. Schools have guaranteed access to the internet network. They also have access to the project "Planéta Vedomostí" (Universal Curriculum), where are the experiments collected for each topic during the year. They are using also many kinds of animation, with visual and sound perceptions, to help understanding of the presented information.

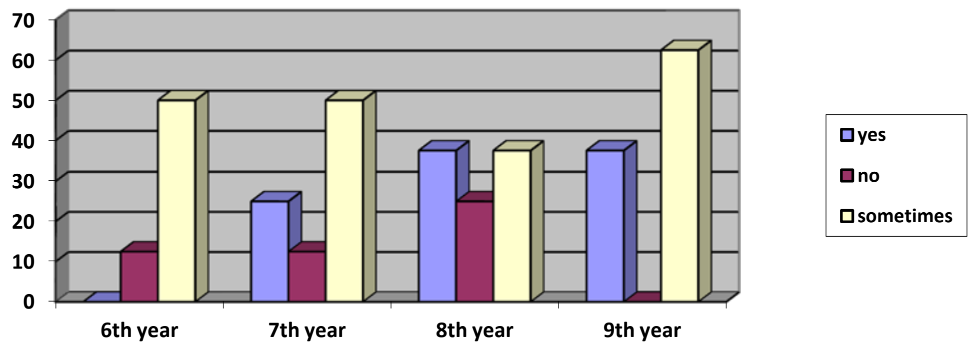

Fig. 2 Solving the common life challenges in separate years

The chemistry teachers stated that probably one of responsible reasons of low level of literacy is lack of laboratory exercises (fig. 2). We think the laboratory exercises based on exact steps can only negligible improve logical thinking and solving of problems. We would say the teachers' statement about lack of experiments more represents the fact that the schools are not prepared for making such demonstrations. This was presented also by evaluation of previous PISA studies.3 Example about dealing with this experiment shortage is chemistry teacher from Badín. She with her students' parents build chemical laboratory. Her activities are presented in Dnešná škola magazine.4 But to increase literacy, students should discover the proper way to make the laboratory experiment, to find out chain of steps to solve the problem, discuss them and argument their correctness. This way is not applied in schools yet or even not supported. The investigative teaching methods of chemistry are applied in minimal level in grammar schools, as it is showed by respondents. However if teachers tried to implement some investigative method in chemistry teaching, they did it mostly in 7th or 8th year. But the students of the 9th year have the best assumption to gain some new knowledge, understand and apply them. In these classes teachers do not uses the investigative methods. The presumed reasons are the class spirit, the students' effort to get the best assessment or their disinterest on extended teaching. In many foreign schools there are used such investigative methods. And also the international project ESTABLISH is focused on using them in natural science education.[5]

CONCLUSION

According to responses from the questionnaire filled up by chemistry teacher, there won't be any significant increase of scientific literacy in the next PISA study in 2015. But the Ministry of education made some activities to get better results. They published information on their web site that the Ministry started cooperation with schools chosen for PISA 2015 testing after publishing the PISA 2012 results. The Ministry made training of coordinators for next testing PISA 2015. The results of this training were not published yet. Also none of the respondents mentioned the pilot testing or that they used previously published tasks for natural science from PISA 2006 study.[6]

We can say on the base of the presented data, the teachers are focused on teaching the facts. They do not have time to intensive training of these knowledge in different problem solving situations, to complete knowledge with information from different subjects (biology, physics), to the development of critical thinking comparing the positive and negative influences on living organisms, nature and to evaluation the information presented in the media and advertisements. Teaches stated to exchange their experiences on internet portal “Zborovňa” (Teachers staff room) and they do not mention any professional journal nor internet magazine “Dnešná škola” (Present school), which is focused on natural science teaching at grammar schools.

The chemistry teachers would like to participate on activities to get real experiences how to increase the natural scientific literacy, about proceeding in each year and they would also welcome the possibility of open lessons. They miss some collection of problems they can use on corresponding lessons to increase the quality of teaching i. e. not only to memorize the data, but to get the ability to use them in school and common life situations.

Even if there are organized such actions, they are individually organized and not coordinated for all teachers with similar orientation. There remains the question, who should be the one to organize such activities for teachers. Should they be the Methodological and Pedagogical Centers, the National Institute for Education, Universities, NÚCEM or the Association of chemistry teachers? Who should coordinate these activities to focus them to all teaches to increase the education of whole population, not only for teachers involved in PISA testing. The educational level of the population is directly linked with prosperity of a state. This correlation is supported by the leading positions of students from Korea, Japan and China in the PISA testing. The recent changes in educational process did not brought satisfactory results.

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LITERATURE

Ministerstvo školstva, vedy, výskumu a športu SR, 2013. Výsledky sledovaných 15-ročných žiakov sa podľa medzinárodnej štúdie OECD PISA 2012 zhoršili. [Online], [cit. 3.12.2013]. Dostupné na: https://www.minedu.sk/vysledky-slovenskych-15-rocnych-ziakov-sa-podla-medzinarodnej -studie-oecd-pisa-2012-zhorsili/

NÚCEM : PISA. 2012 Prvé výsledky medzinárodného výskumu 15-ročných žiakov z pohľadu Slovenska. [Online], [cit. 4. 6. 2014]. Dostupné na: http://www.nucem.sk/documents/27/medzinarodne_merania/pisa/publikacie_a_diseminacie/4_ine/PISA_2012.pdf

Holec, S., Kmeťová, J., Spodniaková-Pfefferová, M., Raganová, J., Hruška, M. 2010. *Testovanie prírodovednej gramotnosti PISA 2006*. Bratislava : ŠPÚ, s. 1-11.

Dovalová, L. 2014. Ako na to... . *Dnešná škola*, 1, 7, s. 14-15.

Ganajová, M., Kristofová, M. 2013. Bádateľské aktivity vo výučbe chémie. In *Zborník z 1. národnej konferencie učiteľov chémie „Prezentácia inovatívnych trendov a koncepčných zámerov vo vyučovaní, hlavne v predmete chémia na všetkých typoch škôl.* Bratislava : ZUCH, s. 98-103.

Koršňáková, P. 2008. *Úlohy PISA – prírodné vedy 2006.* Bratislava : ŠPÚ.

THE ROLE OF STUDENTS' INDIVIDUAL WORK IN TEACHING AND LEARNING CHEMISTRY

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Abstract

Homework is an important element of the teaching and learning process. Unfortunately, it is not always used effectively in chemical education. The aim of the current study was to see whether and to what extent modify the way students' chemistry homework is planned, implemented, checked and assessed would have an impact on their school results, interest in chemistry, engagement in learning and autonomy. We used selected assumptions of constructivism as a basis for improving the effectiveness of homework in chemistry education. The study involved 110 students of the third grade of junior high school and their teachers. The students were divided into parallel groups. The control group was made up of classes in which students had a higher level of chemical education at the end of the second grade. The teacher in the experimental group organized the lessons so as to allow the students to work independently both during the lessons and at home, according to the tips received earlier. The following instruments were used in the study: a questionnaire for the teachers and students, sheets for assessing independent work and tests. The study found that introduction of modified version of students' individual work help them to achieve better results in the test and make them engaged more actively in classroom activities and in learning chemistry in general. It also increased their autonomy, motivation to work independently and interest in chemistry.

Keywords

Chemistry homework, constructivism, information technology, individualizing education.

INTRODUCTION

Education conceived as the process proceeding according to changing realities must be addressed to pupils. It should satisfy their expectations, needs and take into consideration their psychophysical possibilities. School, where this process is mainly realized, to be effective should ensure the best possible effects achieved by each pupil as far as his or her abilities, possibilities or talents allow for. To achieve this aim it is indispensable for teachers to use individualization. It consists in such organization of the teaching and learning processes that there will be taken into consideration on one hand individual possibilities of the pupil and on the other hand, cooperation and collaboration of all pupils in the class. The objective of work individualization of the pupil is to improve learning outcomes owing to the exploitation of his or her individual abilities. Thus the teacher's main task is reconstruction of the educational process structure in such a way that it would be possible to make use of different contents for individual pupils or at least for the three main groups: the most gifted, average, the poorest within the same contents.

Homework also called the independent or the individual work is one of the important educational elements in the Polish educational system and it can constitute the means of individualization rule realization. Unfortunately, in modern times it is not valued by both pupils and teachers. Disinclination to individual work and difficulties connected with it were confirmed by the studies on a group of junior secondary school pupils and teachers. In the school year 2006/2007 the investigations were made in 6 junior secondary schools in three cities in Poland. The obtained data show how and in which form the homework is done in Polish schools and the difficulties which both pupils and teachers encounter. The investigation results confirm that the independent work is not used in the chemical education process in accordance to the potential and abilities. It does not realize all didactic and educational functions which could make it an attractive, effective and independent activity of the learners. This suggests necessity of more detailed and profound analysis of the function and role of homework in chemical education (Kamińska-Ostęp, 2009).

LITERATURE REVIEW

The problem of homework appears in only few researches of the chemical education process. Some of them deal with determination of the factors improving teaching methods and enhancing understanding students' physical chemistry. This stream of studies determines the relations between the pupils knowledge and doing homework by them. The investigation results show that homework and general knowledge of chemistry positively affect pupils' achievements in physical chemistry. The conclusions drawn from the investigations suggest the need of homework as it improves learning (Hahn and Polik, 2003). The other researchers report how different learning opportunities affect achievement in a large college chemistry class that makes use of authentic problem-solving activities supported by scenarios and virtual laboratories. Their study reveals that: (a) a significant portion of the learning takes place in the self-directed study the last few days before the exams; (b) authentic problem-solving activities have an important mediating effect in learning; (c) self-directed study and homework are the most relevant learning opportunities, explaining 48% of achievement in this course; (d) study and carefully planned homework activities can overcome the initial differences in prior knowledge (Leinhardt, Cuadros and Yaron, 2007).

The traditional homework is often replaced by the independent online work. This is natural consequence of information technology development and large accessibility of the IT tools and means. Definitely more researches deal with using the independent form of work and its effect on education efficacy on different levels of education. In one paper based on the studies the author states that, homework with the use of the Internet can contribute to pupils larger interactions and engagement in chemical problems solving (Shepherd and Tricia, 2009).

In the paper "Gendered responses to online homework use in general chemistry" the authors show positive effects of online homework on students. There were investigated the differences between the responses of girls and boys to the internet homework during the general chemistry course. Replacement of class quizzes by the internet homework significantly improved the general results in chemistry for both genders, however, the average results was twice larger for the girls. Using the online homework diminished the gap in girls' achievement compared to that of boys. Therefore, females might benefit from online homework positive impact on their confidence in understanding the material. In addition to improving students' performance, online homework also appeared to enhance student retention in the course. Overall, online homework provides a time and cost effective means to enhance pedagogy in large classes for both male and female students. The other authors have developed a series of Web-based homework and tutorial programs implemented through WebCT that are designed to help students gain a better understanding of chemistry. This project has two major instructional goals: to encourage students to take responsibility for their own learning and to provide a resource to help students focus their study efforts. The system is designed to structure students' studying and make the student responsible for doing the work necessary for success. Researchers analysed the students' performance in the course as well as the results from the students' interviews concerning their responses the online material. The study showed no significant quantitative difference in student performance, but positive outcomes in terms of reported students' attitudes were observed (Cole and Todd, 2003). The next tasks concern pupils' approach to the possibility of doing homework several times. The special feature of the protocol is the option of a "second chance". When a student gives a wrong answer in the weekly homework assignment, a second version of the same question is posed to that student within 48 hours. Both the original and the second versions of the homework are Web-based and automatically graded. More than 90% of the students used the second chance at least once during the semester. More than 60% used this feature for every homework assignment. The second-chance option motivates students to study the feedback associated with a missed answer (Hall, Butler, McGuire, McGlynn, Lyon, Reese and Limbach, 2001).

Literature review in the area of homework shows the researchers' interest trend. The research trend determining the effect of pupils' independent work on better chemical education efficacy is common. Based on the contemporary theories of teaching, mainly the main constructivist trend, the attempt was made to determine the conditions under which there can depend the issue that the independent work in chemistry learning and teaching would give educational benefits and possibility of education individualization. It seems to be the way leading to the increase in the teaching and learning efficiency. Another factor of significant importance is rapid development of information technology. Due to its general accessibility, attractive form and contents as well as a variety of communication ways, there is a chance of polysensory action to learners which, in turn, should affect pupils' interests in the work and stimulate the desire to do it independently. It would play a supportive role and would make homework more attractive.

METHODOLOGY OF RESEARCH

Constructivism, due to its assumptions, can positively affect efficacy in individual work in chemistry teaching which can change the attitude of pupils and teachers about the reason for its application. Pedagogical constructivism is the theory of learning, getting to know and acquiring knowledge. Its foundation is the assumption that this is the pupil who controls learning and knowledge constructing. Acquiring it is a process and the knowledge is discovered and formed by the learner independently and in an active way based on various sources of information. In the learning process there is selection, processing of information and making decisions (Spivey, 1997; DeVries, 2000). Pupils play a significant role in evaluation of their own educational progress so they control learning and are co-responsible for it. Self-evaluation has a motivational character. Constructivism forces out the change of role not only of a pupil but also of a teacher in the educational process. According to this theory the teacher should be responsible for creation of learning environment, motivating pupils to discovering new knowledge assisting their learning process. Thus the teacher is not a source of knowledge but a guide imposing cognitive tasks and steering pupils various activities. The constructivist theory demands from the teacher skills of organizing pupils' learning based on his individual knowledge and determination whether the pupil broadened his knowledge and developed suitable skills in meaningful, creative way consistent with his experiences and useful in everyday situations (Fosnot, 1996; Glasersfeld, 1996).

Individual learning understood in this way should be additionally assisted by information technology. Contemporary achievements of IT create conditions for quick acquisitions of information, arouse curiosity are attractive and above all common so they are indispensable as the means-method to be applied in the independent work. A large number of computer thematic programs, multimedia handbooks including interactive communication of chemical contents, tasks, films, and experiments are a new area to be used in the homework by pupils. Basing the individual work system on using information technology ensures desired feedback during the whole learning process.

If we take into account the assumption of constructivism and contemporary achievements of IT, then the properly planned and done homework should develop creative cognitive activity owing to the application of methods and forms of work attractive for the pupil and adequate for the topic. This can make pupils aware of purposefulness and reason for the activities proposed by the teacher and attractive ways of their realization. This will affect the ability of acquiring new knowledge based on that already possessed. It will also enhance independent actions revealed in planning, organizing and performing tasks and then in their summing up combined with evaluation. In turn, self-evaluation is the reversible information about achievements, acquired knowledge and individual development. As a result, it will make pupils aware of usefulness and applicability of knowledge in everyday life.

In order to verify the above hypothesis in the chosen junior secondary schools in Lublin there were carried out studies introducing the constructivism assumptions to enhance the function and efficacy of the pupils' independent work in chemical education. The research group had 110 pupils from the third grade of junior secondary schools. The investigations were carried out during the organic chemistry lessons. Two classes were the experimental group and two others the control one. The control groups were the classes whose pupils obtained better marks in chemistry after the second grade compared to those in the parallel class so they presented higher level of education. The investigations were carried out in two schools realizing the same curriculum. The differences between the control group and the experimental one consist in introducing strong individualization of the teaching-learning process in the form of pupils' independent work during the lessons and at home in the experimental group. In the control group individualization was not realized to such an extent. In this group the independent work is treated traditionally i.e. without paying a special attention.

The investigations included among the following problems:

1. Will the pupils' independent work in the constructivism formulation be an effective tool of individualisation of the teaching and learning processes?
2. Will individualisation in the form of the independent work during the lessons and at home affect broadening of pupils' knowledge, increase in chemistry interest, effectiveness and independence in doing homework?

In order to collect the data from the investigations, there was elaborate the research tool for the teacher and pupil in the form of questionnaire. There was also worked out the procedure of actions and recommendations for teachers enabling preparation and reorganization of the lessons according to the assumptions of constructivism and the evaluation sheets of the independent work for pupils and teachers.

The tips for the teachers taking part in the investigations are as follow. The independent work done during the lessons and at home must include three areas of knowledge: cognition, development and consolidation and the whole is to influence on interest in chemistry and arouse motivation for learning. It seems necessary to use obligatory and additional individualised independent work taking into account the pupils' intellectual level: poor, average and gifted as well as range of educational contents (in accordance with curriculum and beyond it). Forms of work should correspond to differentiated activities which pupils must do – written, oral, manual etc. Pupils should propose the tasks connected with their interests whom they can do individually or in groups using various sources of information including IT. The independent work during the lessons could cover the whole lesson unit or only its part and constitute a link introducing or summing up the lessons. It is necessary to evidence the activities and presents the works which should be subjected to regular control and evaluation by both the teacher and the pupil (self-evaluation). To this end there was prepared the sheet of the independent work evaluation for the pupil and the teacher.

The investigation results were quantitatively and qualitatively analysed. The quantitative analysis was made based on the results obtained from among the evaluation of teachers and pupils included in the sheets of independent work. The qualitative analysis was made based on the documents such as the questionnaire for the teachers and pupils from the experimental and control groups. This paper will present only part of results of qualitative analysis.

The questionnaire for the pupil covered 24 questions, 8 open and 16 closed. The questions referred to the individual work of the pupils during the lessons and at home, its types, frequency and its effect on pupil's engagement during the lesson approach to learning, interest and motivation to learn chemistry. Some questions were about difficulties in doing the independent work and assistance by the teacher.

The questionnaire for the teacher included 24 questions, 10 open and 14 closed. They were about the ways of organization of pupils' own work, types of proposed tasks and their influence on education effectiveness and difficulties in task accomplishment.

RESULTS: A QUALITATIVE ANALYSIS OF THE QUESTIONNAIRES

Applying selected principles of constructivism to organising students' independent work encouraged chemistry teachers to:

- reorganise classroom activities,
- individualise classroom activities,
- plan and prepare diverse homework tasks,
- explain the goals of homework tasks and discuss them in more detail,
- set homework at an appropriate time during the lesson,
- check students' homework more systematically and assess it more thoroughly,
- make use of the results of students' independent work in the classroom,
- get to know the students better by becoming more familiar with their interests.

It caused the following changes in students' behaviour and attitude towards learning:

1. a stronger interest in chemistry – 67%
2. independence in doing homework tasks – 64%
3. involvement in working in the classroom – 60%
4. a stronger motivation to do homework tasks – 60%
5. an increase in in-class activity – 53%
6. involvement in studying in general – 34%
7. more openness and improvement in communicating both with the teacher and other students – 27%
8. healthy competition among students – 27%
9. development of general study skills such as managing one's own learning – 22%

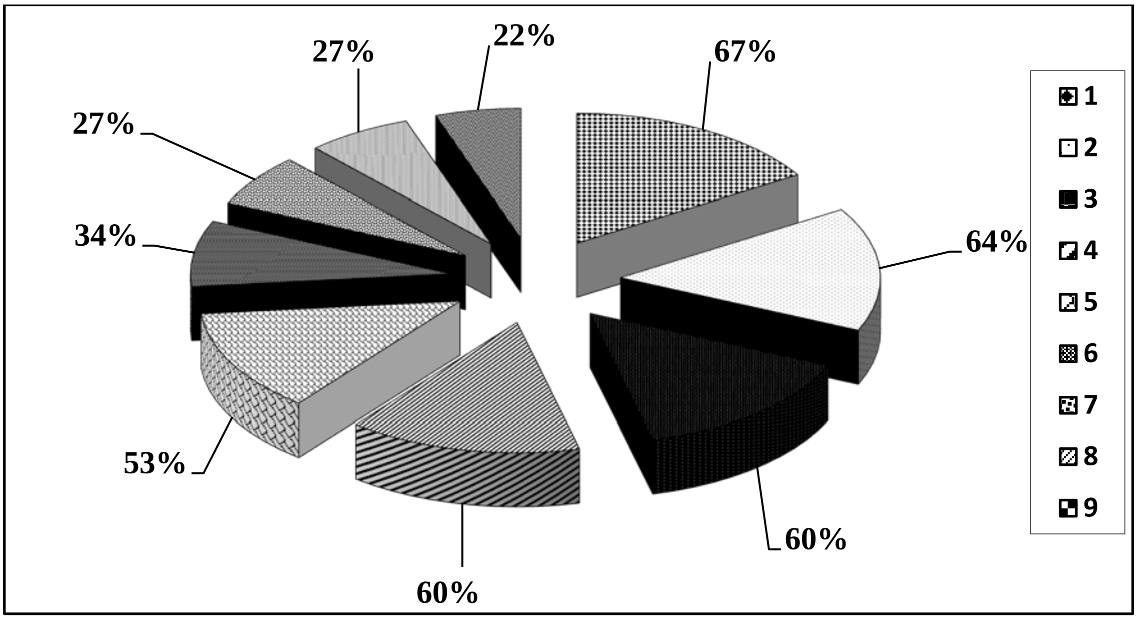

Figure 1. The changes in students' behaviour and attitude towards learning after applying selected principles of constructivism to organising students' independent work. (The percent of pupils responses)

According to the students, the tasks with the following goals were the most helpful in learning chemistry:

- developing creativity – 56%
- revising the material covered in class – 51%
- checking students' grasp of the material covered in class – 40%
- supplementing the material covered in class – 25%
- preparing students to develop materials independently – 20%
- developing skills – 15%

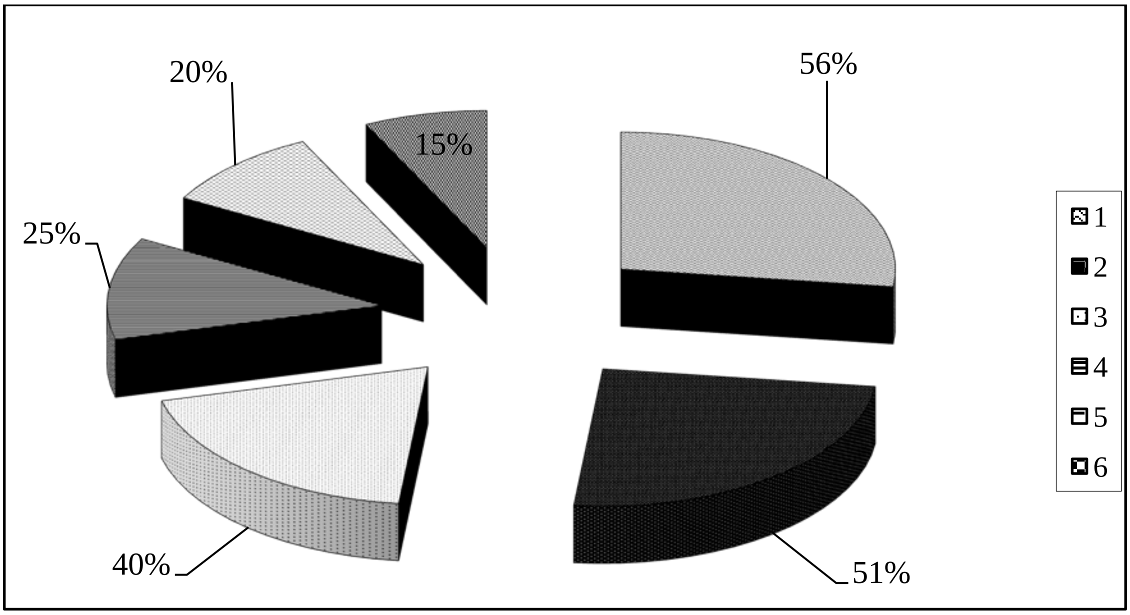

Figure 2. The tasks with the following goals were the most helpful in learning chemistry.

Exemplary proposals of pupils' tasks to be done as homework:

- Performing experiments e.g. examination of substance reaction
- Making observations of changes in everyday life e.g. combustion processes
- Making technical works e.g. plasticine models
- Preparation of multimedia presentations e.g. carboxylic acids around us
- Recording films e.g. hydrocarbons in nature
- Preparation of posters e.g. sugar obtaining process
- Searching contents beyond the curriculum, e.g. interesting pieces of information, popular articles, educational program, www websites
- Elaboration of tasks, puzzles, crosswords etc.

CONCLUSIONS

When carried out according to the principles of the constructivist theory, independent work makes it possible to achieve all the aims of modern education, which include: individualising education, developing key skills, discovering and developing students' natural abilities, developing the ability to work in a team and using IT. It is assumed that the proposed reorganization of independent work will cause that the pupil will acquire knowledge in an independent and active way using up-to-date didactic means. As a result, it will be useful in practical situations which, in turn, will enhance the feeling of purposefulness and rational arguments for doing the homework.

This is one of the ways to ensure the equilibrium between effective and up-to-date teaching and between effective and conscious learning.

REFERENCES

Cole, R., Todd, J., 2003. Effects of Web-Based Multimedia Homework with Immediate Rich Feedback on Student Learning in General Chemistry, J. Chem. Educ., 80 (11), p 1338

DeVries, R., 2000. Vygotsky, Piaget, and education: a reciprocal assimilation of theories and educational practices, New Ideas in Psychology, 18, Issues 2-3, August, p.187

Fosnot, T. C., 1996. Constructivism, Theory, Perspectives, and Practice, Teachers College Press, New York

Glasersfeld, E., 1996. Radical Constructivism, A Way of Knowing and Learning, Falmer Press, London

Hahn, K., Polik, W., 2003. Factors Influencing Success in Physical Chemistry,. J. Chem. Educ., 81 (4), p 567

Hall, R., Butler, L., McGuire, S., McGlynn, S., Lyon, G., Reese, R., Limbach, P., 2001. Automated, Web-Based, Second-Chance Homework, , Department of Chemistry, Louisiana State University, Baton Rouge, LA 70803 J. Chem. Educ., 78 (12), p 1704

Kamińska-Ostęp, A., 2009. Teoria i praktyka w świetle badań dotyczących pracy domowej, Materiały XIV Szkoły Problemów Dydaktyki Chemii "Chemia bliżej życia-Dydaktyka chemii w dobie reformy edukacji", Poznań

Leinhardt, G., Cuadros, J., Yaron, D., 2007. One Firm Spot: The Role of Homework as Lever in Acquiring Conceptual and Performance Competence in College Chemistry, J. Chem. Educ., 84 (6), p 1047

Shepherd, J., Tricia, D., 2009. Mastering Chemistry. Chem. Educ., 86 (6), p 694

Spivey, N. N, 1997. Reading, writing and the making of meaning. The constructist metaphor, San Diego CA Academic Press.

MATHEMATICAL CONTENT OF THE OLYMPIAD AND ENTRANCE EXAMINATION PROBLEMS IN CHEMISTRY

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Abstract

The article is devoted to the evaluation of the mathematical competences of Chemistry Department applicants in the absence of the entrance examination on mathematics at Moscow State University. The results of the study of the mathematical content of about 2000 chemical entrance examination and Olympiad tasks, as well as results of the textual analysis of the written works of Olympiad "Lomonosov" participants in 2013 are presented. On the base of the analysis of large number of the examination and Olympiad tasks in chemistry, the set of mathematical skills necessary to solve chemical problems was identified. The control of the degree of saturation of entrance examination tasks in chemistry by mathematical content is proposed in order to indirectly evaluate mathematical training of applicants. In present situation in Russian educational system, we consider that it is necessary to continuously monitor the level of mathematical training of university entrants.

Keywords

Chemistry education. Unified State Exam. Selection of applicants. Chemistry Olympiads. Entrance examination. Mathematical content of chemical problems.

INTRODUCTION

Until recently, according to the admission rules to Moscow State University (MSU), the applicants had to pass through the set of competitive examinations. For example, at Chemistry Department there were four written entrance examinations: on mathematics, physics, Russian language and literature, and chemistry. At all MSU natural-science departments (Biology, Physics, Soil, Geology, and some others) written examination on mathematics was the very first, so-called profiling examination, and it was a difficult test, which only 50 % of entrants were able to overcome successfully. So, to avoid failure, future entrants were to prepare thoroughly.

Over the last ten years, the position of mathematics at University entrance examinations has significantly changed. Now, in accordance to the Education Law of Russian Federation, the selection of entrants in all Russian higher-education institutions is conducted basing on the sum of Unified State Exam (USE) scores, and only Moscow State University and St. Petersburg State University have the right to conduct one written entrance exam in addition to USE. Now the Chemistry Department applicants must submit their USE scores in mathematics, chemistry, physics, and Russian language, and pass through written exam in chemistry. Thus, at the enrollment to university, additional test on mathematics is not provided.

In Russia, the USE on mathematics is one of the two compulsory secondary school leaving examinations, but the level of knowledge required to fulfill this test is significantly lower than that required to successfully pass through classic University entrance examination. Also it should be noted that the decrease of interest to science and technical professions leads to significant reduction of competition on the corresponding specialties in university. Therefore, secondary-school graduates with rather low USE scores could be enrolled to the Chemistry Department; besides, the shortage of their scores in mathematics could be compensated by other subjects.

The problem would not be so important, if the significance of mathematics in studying chemistry was not so great. Meanwhile, the initial mathematical qualification of first-year University students declines year by year and they meet many difficulties while studying the mathematical analysis, analytical geometry, and others mathematical disciplines (Kuz'menko, Lunin, and Ryzhova, 2006). Thus, the need to evaluate the real level of mathematical knowledge of applicant under condition of the absence of entrance examination in mathematics arose. With this in mind, we decide to evaluate the mathematical content of chemical tasks of University Olympiads for schoolchildren (for example, popular in Russia "Lomonosov" Olympiad) and entrance examinations in chemistry.

MATHEMATICAL CONTENT OF CHEMICAL TASK

First of all, let us determine, what we mean under the term "the mathematical content of chemical task".

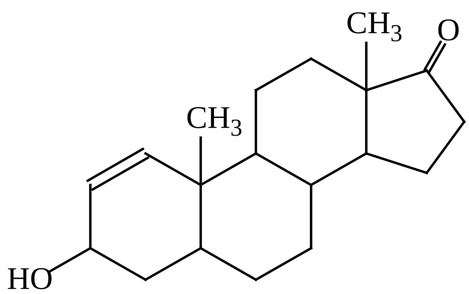
It is well-known, that the authors of examination cards in chemistry often incorporate into the tasks some content elements belonging to other disciplines, emphasizing thus the existing interdisciplinary connections.

The examples of such tasks are given below (Kuz'menko, Ryzhova, Terenin, 2012).

Examination in chemistry at MSU Department of Bioengineering and Bioinformatics in 2002: "One of neurotoxins of the scorpion poison is a protein containing 64 amino acid residues. After complete hydrolysis of 50.00 g of the protein, 1.448 g of serine, 6.676 g of cysteine, and 1.841 g of alanine were isolated. Determine the molar mass of neurotoxin and calculate mass fraction of sulphur in it."

Department of Basic Medicine (2003): "3-Pyridinecarboxilic acid (vitamin PP) is used as an antiscorbutic drag. Draw the structure of vitamin PP and write two reactions characterizing its properties. Calculate the number of nitrogen atoms consumed by human organism with daily doze of the medicine (20 mg)."

"Lomonosov" Olympiad in chemistry (2007): "International Olympic Committee forbade anabolic steroid boldenone. The usage of boldenone by athlete is determined by the presence in urine of the following compound with molecular mass of 288, which is the product of biotransformation of boldenone in human organism.



Write molecular formula corresponding to the above compound and calculate its elemental composition (in %)."

In all the above examples, the biological or biomedical elements do not affect the solution of chemical task, and inclusion of such problems in the entrance examination cards in chemistry does not imply testing the biological competences of the entrants. So, the applicants of any chemistry-oriented Department can easily solve these problems without the involvement of knowledge from other fields of science. The main aim here is to decorate the task and make it more attractive for entrants, despite the fact that the task may seem a little too bulky in a result. The interdisciplinary connections, reflected in the tasks, emphasize the importance of chemistry for further professional activity of biologist or doctor.

Concerning a mathematical component of chemical tasks, situation is absolutely different. As a rule, there aren't any mathematical terms within the formulation of the task; however, its solution requires a good mathematical qualification. Thus, actually mathematical content of chemical tasks is a set of mathematical operations required for successful solution of a chemical task. It turns out, that offering an applicant (or Olympiad participant) the chemical task with high mathematical content, we can indirectly verify his/her mathematical training.

After analysing of a large number of the examination and Olympiad tasks in chemistry, we have identified the following mathematical skills necessary to solve chemical problems.

In the area of arithmetic:

- the ability to write and solve proportions;
- fluency skills with percents and fractions (for example, mass fraction);
- the ability to manipulate with numbers in standard form (for example, $6.02 \cdot 10^{23}$);
- competent handling with units of measure.

In the area of algebra:

- the ability to solve linear and quadratic equations;
- the ability to solve inequalities;
- the ability to solve systems of linear equations;
- possession of logarithmic, exponential, and trigonometric functions;
- the ability to solve equations with parameters.

In plane geometry and solid geometry:

- the ability to calculate the area of shapes (rectangle, circle);
- the ability to solve geometrical tasks (for example, calculating the length of the sides and angles of a triangle);
- the ability to calculate the volumes of the bodies (box, sphere, cylinder).

ANALYSIS OF ENTRANCE EXAMINATION AND OLYMPIAD TASKS

Also we have analysed a large number of written entrance examination and Olympiad tasks in chemistry (since 1990 until now, about 2000 published tasks, for example, see Kuz'menko, Ryzhova and Terenin (2012) in order to reveal the dynamics of saturation of the tasks with mathematical content. All tasks were divided into two groups: purely chemical problems without mathematical elements (represented mainly with so-called chains of chemical transformations and theoretical questions) and the tasks, which include mathematical component. The second group was classified according to the type of mathematical operations needed to solve the tasks. It was found, that during the above period, the saturation of the examination cards with the tasks with mathematical content continually increased. So, in the early 1990s, an examination card consisting of seven tasks usually included two tasks with mathematical content. But now, the number of such problems within the examination card increased to five of ten, and also the diversity of needed mathematical operations had grown. The revealed changes are a kind of adaptation of the applicant selection system to the modern educational reforms in our country. Moreover, these changes reflect a global trend of implementation of mathematical methods in chemistry.

We also tried to identify the specifics of calculation chemical tasks by direct analysis of the written works of the participants (in 2013, the "Lomonosov" Olympiad involved 1128 secondary-school students, and 3280 in 2014). We revealed that in 2013, only 5 from 15 tasks of correspondence round were of purely chemical nature, and others incorporated the mathematical content. As an example of such problems, we present below three tasks.

Problem 4: "Fungus *Aspergillus* is sensitive to metal ions on the level of $5 \cdot 10^{-10}$ mol/L and is used for determination of inorganic cations and anions. Determine, whether this method is suitable for finding iron ions in the probe of water with mass fraction of iron (III) sulfate of 10^{-7} % in it."

Problem 5: "Old coin with diameter of 2.5 cm and 1.8 mm thick, made of copper alloy with density of 8.92 g/cm^3, was placed in dilute hydrochloric acid. The coin was partially dissolved, after that the obtained residue was completely dissolved in concentrated sulphuric acid, and 2.48 L of a gas was evolved. The volume of gas was measured under normal pressure and 30 ºC. Determine the mass fraction of copper in the coin alloy."

Problem 12: "The compound of element X and chlorine contains 66.20 % of Cl. The investigation of molecular structure revealed that X–Cl and Cl–Cl distances are equal to $2.113 \cdot 10^{-10}$ m and $3.450 \cdot 10^{-10}$ m correspondingly. Determine the molecule composition and propose its spatial configuration. Specify the hybridization type of X atom in the compound."

From a mathematical viewpoint, the solution of Problem 4 requires a possession of operations with percents as well as of arithmetic operations with numbers in standard form. Chemical aspect of the problem requires knowledge of different expressions of the concentration of the solution, and also an understanding that the molar concentration of Fe^{3+} ions in the solution is twice more than that of salt $Fe_2(SO_4)_3$.

The task appeared to be rather difficult for the participants of the Olympiad; its solvability (the ratio between the calculated mean score of the task and its maximum score) was 61.29 %. It should be noted that strong participants with high total score are inclined to make mistakes connected with mathematical component of the task (most of all, wrong actions with numbers in standard form, resulting in incorrect order of value). The lower was total score of participant, the more often the mistakes in chemistry occurred, and chemical errors were combined with the math ones. The frequencies of chemical and math errors in this task were approximately equal for students having total score below 50.

Problem 5 (62.44 % solvability) requires the calculation of the following values: the volume of cylindrical coin (thus it is necessary to use correct units of measurement for diameter and thickness), mass of coin, amount of released sulphur (IV) oxide, and copper mass fraction in the alloy.

Analysis of the written works revealed that this task was solved practically without errors by students, having total score about 50 or higher. Less successful applicants made a significant part of errors in the chemical aspect of task (they took into account the non-existent reactions of copper with dilute hydrochloric acid, or hydrogen evolution in the reaction of copper with concentrated sulphuric acid; in addition, they considered the specified volume of gas as given under normal condition – the most frequent error).

As a rule, mathematical errors in the works of weak participants were connected with misuse of units of measurement and using of wrong formula of the cylinder volume, also the participants made arithmetic errors (at rounding, at calculating copper percentage, etc.).

Problem 12 (49.71 % solvability) was the most difficult one. The solution required identification of an unknown element by known mass fraction of chlorine in the molecule (actually, this is the task with a parameter, where unknown part is a valence of element). Then, interatomic distances allowed us to find a bond angle and determine the spatial configuration of the molecule. The participants had to consider the triangle and to apply the cosine theorem to find the angle. The chemical part of the problem required basic knowledge of atomic weights and valences of the elements, and hybridization of atomic orbitals.

Participants with a total score lower than 50 failed to solve this task. On the other hand, those with the highest scores (above 80) solved it almost completely and correctly. Many participants lost some points, because they did not confirm their findings by calculation of the bond angle through cosine theorem.

Most errors were related to the inappropriate choice of the element (participants chose sulphur, chlorine, fluorine, manganese, copper, or others elements instead of germanium). This may be the result of arithmetic errors in atomic weight calculation, and the result of ignorance of element valences.

The most difficult part of the task was the geometric component; only few were able to apply the cosine theorem correctly.

It should be noted that school students had nearly three months on the solution of the tasks of the Olympiad correspondence round, and they could use teacher's assistance and reference materials in any way without limit. Nevertheless, the numerous mistakes were revealed while checking the works.

Within the card of internal final round of "Lomonosov" Olympiad, six tasks of ten possessed mathematical content. As an example, we present the following problem.

"The portion of dry ammonium chloride (3 g) was placed into glass tube, after that the tube was fixed in the inclined position and heated. The gases evolved from lower and upper ends of the tube were passed through 250 mL and 1 L of distilled water, correspondingly. Calculate pH values for both obtained solutions, the basicity constant of NH_4OH is given $K_b(NH_4OH) = 2{\cdot}10^{-5}$."

To solve this problem, participant should handle with logarithms, the numbers in standard form, and solve quadratic equations.

Annually more than two hundred pretenders are enrolled to the MSU Chemistry Department, but not all of them are ready for the fact that modern higher chemical education is linked with the study of various mathematical disciplines (about 15 % of university curriculum). Education process at the University takes place so rapidly that the student does not have time for elimination of gaps in school knowledge. Similar problems with school mathematical background are characteristic for junior-course students of different natural science departments. In agreement with this are the results of our study conducted among second-year students of MSU Biology Department. For these students small-scale tests (only one task) are held to control the intermediate knowledge while studying the Physical Chemistry course. We analysed the solutions of such task from mathematical viewpoint.

"Calculate the enthalpy of combustion of pentane at 850 K, the enthalpies of formation of substances at 298 K are given: $\Delta_f H(C_5H_{12}(g))$ = –146.44 kJ/mol, $\Delta_f H(CO_2(g))$ = –393.51 kJ/mol, $\Delta_f H(H_2O(g))$ = –241.82 kJ/mol. Heat capacities of gases (J/(mol·K)) within 298–1000 K temperature interval are as follows: $C_p(C_5H_{12}) = 120.20 + 0.368{\cdot}T$, $C_p(O_2) = 29.36 + 0.033{\cdot}T$, $C_p(CO_2) = 37.11 + 0.102{\cdot}T$, $C_p(H_2O(г)) = 33.58 + + 0.0144{\cdot}T$."

To calculate the reaction enthalpy at 298 K, only the arithmetic operations are needed. Then Kirchhoff's law is used to calculate the enthalpy of combustion at 850 K, for this purpose it is necessary to integrate a simple polynomial. It was found that only a one third of students (33 students from 98) coped with the task without failing. The others made arithmetic errors (30 % of students), calculated the integral incorrectly (23 %), and made mistakes in converting units of measurement (14 %). We have found that only 28 % of students have gaps in their knowledge of physical chemistry (their errors were associated with misunderstanding of physical chemistry's concepts). The above listed mathematical errors of students revealed significant gaps in their secondary school mathematics.

One of the ways to solve the problem is to include revision of the secondary school mathematics into the first year studies in university (Konecna and Habiballa, 2012).

CONCLUSION

The problem of evaluation the real mathematical competences of applicants under condition of the absence of entrance examination in mathematics could be solved through control of the mathematical content of chemical tasks of entrance examinations and Olympiads.

Except control function, mathematical content of the tasks of chemical Olympiads and entrance examinations performs another function. It prepares the school students to the fact that serious employment of chemical science often implies good mathematics knowledge. Mathematics is useful and often necessary for solution of many chemical problems (Eremin, 2014). Moreover, rapidly developing computer chemistry applies mathematical methods to modelling molecular structures or to simulation of the reactions, enabling us to investigate complex biochemical processes.

In present situation in Russian educational system, we consider that it is necessary to continuously monitor the level of mathematical training of university entrants.

REFERENCES

Eremin, V. V., 2014. *Theoretical and Mathematical Chemistry for School Students. Preparation for Chemistry Olympiads.* Moscow: Moscow Center of Continuous Mathematical Education.

Konečná, P., Habiballa, H., 2012. Student's Auto-evaluation in the First Year of Science Study Fields Especially in Mathematics Phase 2. *Journal of Applied Mathematics*. V. 5, p. 247-252.

Kuz'menko, N. E., Lunin, V. V., Ryzhova, O. N., 2006. On Modernization of Education in Russia. *Russian Education and Society*, V. 48, No. 5, p. 5-22.

Kuz'menko, N. E., Ryzhova, O. N., Terenin, V. I., 2012. *Entrance Examinations and Olympiads in Chemistry: Experience of Moscow University*. Moscow: Moscow University Press.

Moscow State University, 2014. *Lomonosov Olympiad.* [online] Available at <http://www.msu.ru/entrance/olimp.html> [Accessed 10 July 2014]

CHEMICAL ENGLISH KNOWLEDGE AMONG CZECH ENGLISH LANGUAGE LEARNERS

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Abstract

The authors of this paper tested the level of selected skills of different groups of respondents (with respect to specialization of the respondents: chemistry, translator or teacher of English or university student of English, absolvent of a course English for Chemists or similar study) connected with work with chemical texts written in English. Although professional English translators, interpreters or teachers often refuse to work with chemical texts (arguing that they do not understand the problem that should be translated), the result of this research is different. University students preparing themselves for a career of English translators, interpreters or teachers who supplemented a course of English for Chemists and some basic course of chemistry have achieved better results in testing than university students of chemistry who supplemented the course of English for Chemists.

The second result is the finding that university students of English without any training in chemistry or English chemical terminology mastered the test significantly better than university students of chemistry after a course in "normal" English but also without training in English chemical terminology although all of them did go through the English chemical terminology passively. Following these findings the authors received a grant. Its aim is to increase the level of chemical English among students of chemistry teaching at Faculty of Education, Masaryk University, Brno by means of newly established subject Compendium of Chemistry.

Keywords

Chemistry. English. English for Chemists. Education. Test.

INTRODUCTION

In many European countries the teaching at university is divided into two languages - the national language and English. It is not usual in the Czech Republic, but in many countries it is a quite normal situation that the language of a lecture can switch from the national language to English in the presence of even single exchange student (Airey and Linder, 2006).

The reasons for the widespread use of English at universities can be traced to many more factors than the presence of students who do not speak the national language. Other important factors influencing language choice in favour of English are for instance availability of good course texts, lecturing by foreign academics, needs of the job market or preparation of students for the academic world dominated by English (Airey and Linder, 2006).

Unfortunately, knowledge of scientific discipline English language is in the Czech Republic, despite more than 20 years of post-communist regime, still at a very low level. Students coming from high schools and universities know general basics of English grammar, but schools do not prepare students adequately to be able to get continuously involved in international cooperation (Breznen, 2013). English of any scientific discipline must be studied in the context of given discipline. It is for instance not possible to master the chemical English well if we do not understand chemistry.

Surprisingly, in research literature much attention has been paid to teaching science for English language learners (ELLs) - persons who speak a language other than English in their home. The majority of the researches is focused on the elementary school level (Buxton, 1999; Hampton & Rodriguez, 2001; Stoddart et. al, 2002; Lee et. al, 2004; Stoddart et al., 2010). A lot was written about bilingual reading (McBrice-Chang, 2004, Deacon and Cain, 2011 and many others), again at the level of elementary school (Flores and Smith, 2013).

Much less attention is paid to older English language learners (for instance Dixon, 1995, Clark et. al, 2012). Little work has been focused on science education for older ELL students who may face more challenges in acquiring the English language (Short and Fitzsimmons, 2007). This study focuses on the beliefs and perceptions of teachers, and the academic science achievement of the ELL students, but gives little insight into the experiences of the students learning science and the English language together (Flores and Smith, 2013). A completely different work was done by Flores and Smith (2013). Their research question was: What are the experiences of ELL students learning both chemistry and English in high school (Spanish - speaking high school students in the USA)? This research indicated that for learning chemistry in the English language for ELL students is the process called code switching very important (listening to the problem in English, thinking about it in the mother tongue and translating the answer again into English). The results indicated that the environment that allowed the students to use their mother language as well hindered the development of their English language skills but was a benefit to their learning chemistry in

English. It is stated in the article that ELL students could benefit from a structured note-taking strategy, such as using Cornell notes (Donohoo, 2010). In the case of ELL students in the chemistry classroom, their notes could be both in English and the mother tongue with a gradual shift towards more English. Another important result of the research is the information given by the majority of students that study of chemistry in English is difficult for ELL students, especially for the usually problematic parts of the curriculum (chemical calculations, abstraction needed for switch from macro-world to micro-world).

The fact that very little research has been done with aspect to the relationship between students` performance and the lecturing language at university level is stated also in Airey and Linder (2006). This work is very similar to that of (Flores and Smith, 2013), but it is focused on physics education in English at 2 universities in Sweden.

Unlike many developed countries, it follows from interviews previously carried out with Czech university students of chemistry teaching (Cídlová, 2014) that many of them believe that their general knowledge of the English language used in everyday life is sufficient and that if they needed professional chemical English, they would ask some translation company for this. Maybe this is the reason why the level of chemical English knowledge is not very good among Czech graduates from chemistry teaching study.

However, professional Czech-English translators, interpreters or teachers often refuse to work with chemical texts (arguing that they do not understand the problem that should be translated). This is why chemists usually translate chemical texts on their own.

THE AIM OF THE RESEARCH

The authors of this research decided to compare the level of selected skills of different groups of respondents (with respect to specialization of the respondents: chemistry, translator or teacher or university student of English, absolvent of a course English for Chemists or similar study) connected with work with a chemical texts written in English. The aim of the research was to find out:

- whether passive contact with English chemical terminology can significantly improve knowledge of chemical English,

- whether one-semester course of English for Chemists is enough to improve significantly the skills of working with English chemical text,

- whether professional English translators, interpreters or teachers after completing a course of English for Chemists and some basic course of chemistry might be better in translating chemical texts then professional chemists after completing a course English for Chemists.

The next aim was to try to find the answer for the question, what is the best way to teach Czech students the "chemical English".

METHODS

The main method of this research was a test consisting of four parts. The first of them involved English-Czech translation of 12 single words or of two-word phrases. The second part required Czech - English translation of 12 single words or of two-word phrases. The third part was based on making pairs between 6 English chemical terms and their explanations written in English sentences. In the last part the respondents had to assign 6 pictures of chemical laboratory equipment and correct English words.

The test was prepared on the bases of glossary of textbook Complete Chemistry for Cambridge IGCSE (Gallagher and Ingram, 2011).

Solving the test, no dictionary was allowed. The respondents had no information about the test in advance. The total time for solving depended on the respondents themselves and was approximately 20 minutes.

RESPONDENTS

In the research, 5 groups of respondents (in this text labelled I – V) solved the test.

Group I included 19 university students of chemistry teaching. All of them had passed the courses General Chemistry and Computers in Chemistry successfully. Within General chemistry lessons, the students got acquainted with some English terms (e.g. for phase states). Within the course of Computers in Chemistry the students worked with ChemSketch, which required from them to understand terms like density, formula weight, etc. Using ChemSketch, the students had also the opportunity to become familiar with English names of various pieces of laboratory equipment. The study of English terms, however, was not required from them.

Group II included also university students of chemistry teaching that had passed the courses General Chemistry and Computers in Chemistry successfully. Moreover, they completed a one-semester course of English for Chemists. The time between the end of the course and the test was 3-5 semesters. There were 8 students in this group.

Group III included students of English and professional translators, interpreters or teachers of English that had supplemented a course of English for Chemists and some basic course of chemistry. There were just only 3 respondents in this grout as it is extremely difficult to find people with this education.

Group IV contained 9 students of English without any course of English for Chemists.

Group V contained 21 university students and graduates neither specialized in English nor in chemistry.

RESULTS

The results can be seen in Figure 1 and Figure 2.

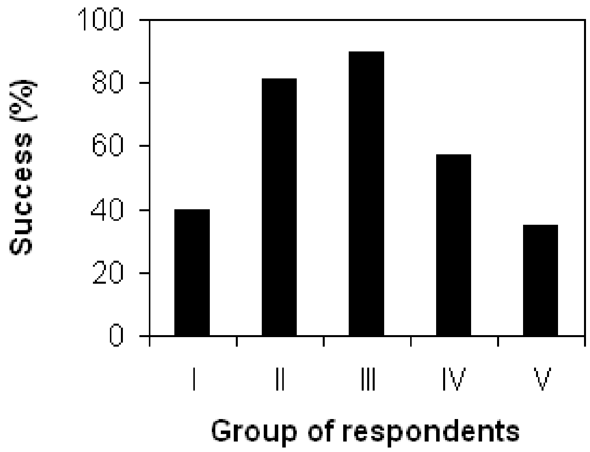

Figure 1: Success in solving the test for different groups of respondents.

It can be seen from Figure 1, that Group I of respondents was not significantly more successful in solving the test than group V. That means passive contact with English chemical terminology did not improve knowledge of chemical English very much.

As for the second question (whether one-semester course of English for Chemists is enough to improve significantly the skills connected with work with English chemical texts), the answer is given by comparison of success in solving the test of Group I and Group II (students of chemistry) and by comparison of success in solving the test of Group III and Group IV (students of English). In both cases, when the students took the course one-semester course of English for Chemists, they were much more successful in solving the test.

The last question was whether professional English translators, interpreters or teachers after completing a course of English for Chemists might be better in translating chemical texts then professional chemists after completing a course of English for Chemists and some basic course of chemistry. It is obvious from Figure 1 (Group II and Group III) that professional English translators, interpreters or teachers after completing a course of English for Chemists and some basic course of chemistry had better results in the test than chemists. But this difference is not very big and, on the other hand, only few professional English translators, interpreters or teachers are willing to complete a course of English for Chemists and to study the necessary basics of chemistry.

The most interesting fact that can be seen from Figure 2 is that all the respondents (with the exception of Group III) had problems with the 3rd part of questions which required work with sentences and not only with 1-2 words.

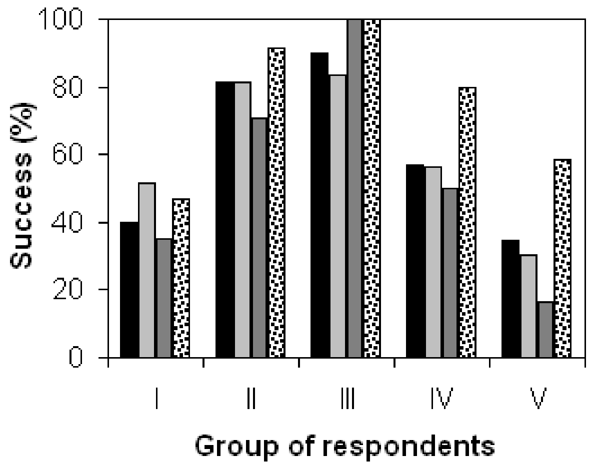

Figure 2: Success in solving test items

Meaning of colours: Black ... 1st part of questions. Light grey ... 2nd part of questions. Dark grey ... 3rd part of questions. Dots ... 4th part of questions.

DISCUSSION AND IMPLICATIONS

The research clearly shows that it is necessary and meaningful to lead chemistry students to master the basics of professional chemical English. It is true that translations of chemical texts might translators-specialists do better than chemists who completed basic chemical English. However, this is accomplished only under the condition that the translator understands the chemical issue as well. Such workers are not many.

Another reason for the necessity to study chemical English is the fact that expressed for instance Breznen (2013): knowledge of scientific discipline English language is in the Czech Republic, despite more than 20 years of post-communist regime, still at a very low level. Students coming from high schools and universities know general basics of English grammar, but schools do not prepare students adequately to be able to get continuously involved in international cooperation.

The third reason for the need to improve the knowledge of professional English (and especially work with English text) is the fact that while many children in the developed countries learns to read in two languages (Deacon and Cain, 2011, with reference to the McBride-Chang , 2004), the results of our research showed that all groups of respondents, including English-language specialists (with the exception of those who studied also chemistry in addition to English language), had the worst test results in the part of the test that required work with whole English sentences in a chemical context.

Among large projects aimed at raising the level of chemical English that have been carried out in our country in recent years belong the project *English for Chemists focused on plastics and remedies production*. This project was solved in 2009-2012 by Masaryk Secondary School of Agriculture and the College of Opava (Kunčarová, 2009). While this project was primarily directed at teaching technical English for courses Chemist Operator - Industrial Chemistry and Science Lyceum in companies producing plastics and remedies, but subsequently lessons of professional chemical English were offered to various other schools (including universities) that teach their pupils/students chemistry. The project met with positive responses, but its level including created study materials was appropriate for higher secondary school. For university chemistry students its level was not sufficient.

Based on the facts mentioned above, the authors of this text have asked for a grant project which aims to increase knowledge of professional chemical English among students of chemistry teaching at the Faculty of Education, Masaryk University. Unlike the course English for Chemists (it is offered to students as optional already at the bachelor undergraduate level, the project aims to enable students to study chemical English in two stages. The first (preparatory) level would be the subject English for Chemists which should introduce basic vocabulary (especially names of laboratory equipment, names of elements and bases of chemical nomenclature) to the students. In the last year of study, the second level (a newly created subject Compendium of Chemistry) should follow up.

In this course, students of chemistry teaching will be shown a series of international textbooks published by Oxford University Press (this series is used for teaching science in the United Kingdom and at the same time it is designed to be used around the world at schools using English instead of national language) and some textbooks of chemistry aimed for preparation for the exam General Certificate of Secondary Education (this exam is usually taken by students aged 14-16 during their secondary education in the United Kingdom). Chemistry Made Clear (Gallagher and Ingram, 1987) was chosen as the best textbook (for both teaching chemical English and repetition of chemistry). The students will work with this book throughout the whole semester.

The grant project team believe that the project should use some of the experiences stated by Flores and Smith (2013) or Airey and Linder (2006). The students should not do "two things at the same time", because the lack of knowledge of the language results in slower understanding of chemistry and vice versa (additional explanation chemical problems in the native language slows the acquisition of English language skills). Therefore, the subject Compendium of Chemistry will be taught in the end of university study, when the students should already master chemistry. Within Compendium of Chemistry, the students should only refresh their chemistry knowledge and they should focus on the English language.

CONCLUSION

The authors have found that the knowledge of chemical English is nearly as low with students of chemistry as with non-chemists. After taking one-semester course of English for Chemists, their knowledge improves significantly for at least 3-5 semesters of no exposure to this subject. Chemistry students after completing the course English for Chemists achieve even better test scores than students of English without English for Chemists course.

The authors of this text received a financial support of grant project. The aim of this project is to purchase a set of Cambridge textbooks of Science and Chemistry and to prepare a new compulsory English-spoken subject Compendium of Chemistry for students of chemistry teaching at Faculty of Education at Masaryk University.

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REFERENCES

Airey, J. and Linder, C., 2006. Language and the Experience of Learning University Physics in Sweden. *European Journal of Physics*. 27(3) pp. 553-560.

Breznen, M., 2013. Naše reference: Ing. Marek Breznen. *Open Learning.* [online] Available at: <http://www.openagency.cz/reference/reference.html> [Accessed 05 August 2014].

Buxton, C., 1999. Designing a Model-based Methodology for Science Instruction: Lessons from a Bilingual Classroom. *Bilingual Research Journal*. 23(2-3), pp. 147-177.

Cídlová, H., 2014. *Unpublished results* (Personal data, 3 August 2014).

Clark, D. B., Touchman, S., Martinez-Garza, M., Ramirez-Marin, F. and Drews, T. S., 2012. Bilingual language supports in online science inquiry environments. *Computers & Education*. 58(4), pp. 1207-1224.

Deacon, H. and Cain, K., 2011. What we have learned from 'learning to read in more than one language'. *Journal of Research in Reading*. 34(1), pp. 1-5.

Dixon, J. K., 1995. Limited English Proficiency and Spatial Visualization in Middle School Students' Construction of the Concepts of Reflection and Rotation. *Bilingual Research Journal*. 19(2), pp. 221-247.

Donohoo, J., 2010. Real-Time Teaching. *Journal of Adolescent & Adult Literacy*. 54(3), pp. 224-227.

Flores, A. and Smith, K. Ch., 2013. Spanish-Speaking English Language Learners` Experiences in High School Chemistry Education. *Journal of Chemical Education.* 90(2), pp. 152-158.

Gallagher, R. and Ingram, P., 1987. *Chemistry Made Clear*. GCSE ed. Oxford: Oxford University Press.

Gallagher, R. and Ingram, P., 2011. *Complete chemistry for Cambridge IGCSE*. 2nd ed. Cambridge: Oxford University Press.

Hampton, E. and Rodriguez, R., 2001. Inquiry Science in Bilingual Classrooms. *Bilingual Research Journal*. 25(4), pp. 461-478.

Kunčarová, J., 2009. Angličtina pro chemiky ve výrobě plastů a léčivých přípravků. *Open Learning.* [online] Available at: <http://www.anglictinaprochemiky.cz/> [Accessed 05 August 2014].

Lee, O., Hart, J., Cuevas, P. and Enders, C., 2004. Professional development in inquiry-based science for elementary teachers of diverse student groups. *Journal of Research in Science Teaching*. 41(10), pp. 1021-1043.

McBridge-Chang, C., 2004. *Children's Literacy Development (International Texts in Developmental Psychology)*. London: Oxford University Press.

Short, D. and Fitzsimmons, S., 2007. *Double the Work: Challenges and Solutions to Acquiring languiage and Academic Literacy for Adolescent English Language Learners - A Report fo Carnegie Corporation of New York.* Alliance for Excellent Education: Washington, DC.

Stoddart T., Pinal, A., Latzke, M. and Canaday, D., 2002. Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching*. 39(8), pp. 664-687.

Stoddart, T., Solis, J., Tolbert, S. and Bravo, M., 2010. A Framework for the Effective Science teaching of English Language Learners in Elementary Schools. In *Teaching Science with Hispanic ELLs in K-16 Classrooms*. Sunal, D., Sunal, S and Wroght, W. (Eds.); Information Age Publishing: Charlotte, NC, 2010, pp. 151-181.

HOW TO TEACH ABOUT ENERGY THROUGH INQUIRY OR PREPARING SCIENTIFIC CORRECTLY WORKSHEETS

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Abstract

Energy is one of the most important concepts in science and also in science education. It is not possible to understand science without scientific correctly understanding energy. For better knowing cognitive structure of energy we used triangulation – concept mapping, free word association and interview about instance. Using energy misconceptions, information about energy and principles of inquiry based education, we prepared series of worksheet. We also defined some aspects which are essential in the process of preparing worksheets.

Keywords:

Energy education, concept, energy, misconception, work sheets, inquiry.

ENERGY – KEY CONCEPT IN SCEINCE EDUCATION

Energy can take different definitions depending on its using different disciplines. Scientists from different disciplines have different point of views on energy concept. It is hard to find concrete and universal definition of the energy concept, Sefton (2004) notes. It is central concept in science and also in science education. Without scientifically understanding of energy is not possible to correct other important concepts like force, work, photosynthesis, chemical reaction, etc...

RESEARCH

Our participants included students attended five regional schools (two city and three village areas) in Slovak republic. We investigated cognitive structure related to energy concept. Data were collected (through applying a triangulation) - by free word association, concept mapping and interview about instance.

Free word association was used in many studies (Duit 1981, 1984, Goldring, Trumper 1990, 1991, 1993, 1996a, 1997, Trumper a Gorsky 1993, Osborne 1994, Bahar et al., 1999, Trumper, Raviolo, Shnersch 2000, Nakiboglu 2008, Kuhnová, 2010, 2011, 2012, Ozatli, Bahar 2010, Kurt 2013).

According to (Atasoy 2004, Atasoy et al. 2007) the aim of free word association is to present the word as stimuli to the participants one by one in each time. It determines a cognitive structure and also the relationship between the concepts. In is based on the process in which an answer is suggested to a word that is used as a stimulus without limiting the mind to any specific response (Bahar et al. 1999, Sato, James 1999, Kurt 2013).

Concept mapping is method useful in research of cognitive structures and also evaluation tool in science education. Concept map could visualize relationship between concepts. According to Novak and Cañas (2006) concept maps usually reflect ideas, concepts and information in boxes or circles with labelled arrows or lines in a hierarchical structure. The relationship between concepts can be articulated in linking phrases such as causes, requires or contributes to.

Concept mapping method was used in many studies (Edwards, Fraser 1983, Peterson, Tregust, Garnett 1986, Heinze-Fry, Novak, 1990, Novak 1990, 2005, Brody 1993,Hazel, Markham et al. 1994, Prosser 1994, Taber 1994, Ruiz-Primo, Shavelson 1996, Markow, Lonning 1998, Guastello et al. 2000, Kinchin 2000, Blake 2001, Tekkaya 2003, Ross, Munby 2007).

Concept mapping is appropriate representation of cognitive structure (Jonassen, Beissner, Yacci 1993, Acton, Johnson, Goldsmith 1994,), we decided to amplify it by using interview for achieving more relevant research results (Brody 1991, Novak, Musonda 1991, Rye 1995, Rye Rubba 1998).

Interview about instance was developed by Osborne, Gilbert (1979) and later used in many other researchers and studies, f.e. Osborne, Gilbert 1980, Watts 1981, Gilbert et al. 1982, Osborne 1983, Watts 1983, Watts, Gilbert 1983, Brook, Briggs 1984, Gilbert, Watts, Osborne 1985, Osborne, Freyberg 1985, Salyachivin et al. 1985, Novak, Gowin 1986, Driver 1989, Hewson, Hewson 1989, Kruger, Summers 1989, Kruger 1990a, 1990b, Brown 1993, Fleer, Hardy 1993, Fleer 1999, Shepardson 2002, Taylor, Coll 2002, Papadouris et al. 2004, Kuhnová 2010, 2012, Awan et al. 2012, Awan 2013). Mentioned method involves clinical interview with each pupil.

According to Osborne and Gilbert (1979) the interview-about-instance method depended on the choice of an appropriate set of examples and counterexamples of the concept, so that the critical aspects of students' understandings could be explored. The examples are usually graphics such as line picture, drawings, or diagrams. We used drawings which contained clear cut examples and some "borderline cases" – unusual applications of the world from the physical point of view. Mentioned drawing involving the energy concepts were used in many studies (Bliss, Ogborn 1985, Gilbert, Pope 1986, Trumper 1993, Kuhnová 2011).

Pupils were interviewed in small groups and they were asked to discuss their answers. We analysed students answers and identified some typical misconceptions and classified them according official list of misconceptions (Watts 1983, Gilbert, Pope 1986, Trumper 1990, 1991, 1993, 1996a, 1997a, 1998, Trumper, Gorsky 1993, Trumper, Raviolo, Shnersch 2000).

ALTERNATIVE CONCEPTIONS

Every child brings to the science lessons his own conception which could cause teaching problems. Determination of alternative conceptions is important in terms of choosing suitable teaching methods as well as preparing effective teaching documents f.e. work sheets (Kuhnová, 2012).

Main aspects of the scientific concept of energy strongly contrast with everyday uses of the term and it is one of reasons why so many researchers have identified alternative conceptions of energy (Duit, 1981, Solomon 1983, Driver et al. 1994, Watts 1983, etc...). Energy is abstract idea, not observable and measurable quantity.

Many researchers (Clement 1978, Gilbert 1979, Osborne, Gilbert 1979, Viennot 1979, Watts, Gilbert 1983, Duit 1984, Kemp 1984, Driver, Warrington 1985, Solomon 1985, Kruger 1990, Kruger et al. 1992, Kesidou, Duit 1993, Summers, Kruger 1993, Goldring, Osborne 1994, Trumper 1993, 1997, 1998, Leget 2003, Papadouris et al. 2008, Kuhnová, Held 2010, Kuhnová 2010, 2011, 2012) have noted students' lack of differentiation between energy and other physical concepts especially force and also work. According to Osborne, Gilbert (1979), Watts, Gilbert (1983), Solomon (1985) and Kruger et al. (1992) in everyday language energy is not clearly distinguished from force, momentum, movement and power.

Energy can be interpreted different ways in various contexts both in and out of the school (Bauman, 1992). During last thirty years there was presented a list of students' misconceptions about energy (Watts 1983), which was later substantiated (Gilbert, Pope 1986):

- Anthropocentric framework: energy is associated with human beings.

- Depository framework: some objects have energy and expend it. The depository framework became: the original depository framework, which is of a passive agent and the active one – the energy as "causing things to happen." (Trumper 1990). For Clement (1978) this model of energy if source of force. Pupils see some objects as having energy, some as needing energy and others just as neutral.
- Ingredient framework: energy is a dormant ingredient within objects, released by a trigger.
- Activity framework: energy is an obvious activity.
- Product framework: energy is by-product of a situation.
- Functional framework: energy is seen as a very general kind of fuel associated with making life comfortable.
- Flow-transfer framework: energy is seen a type of fluid transferred in some processes.
- Transformation framework: when two system interact (i.e., when a process takes place), something that we name energy, is transferred from one system to another. (Curriculum Development Center 1992).

Despite of many initiatives (Novick, Nussbaum 1981, Schmid 1982, van Huis, van den Berg 1993, Boohan, Ogborn 1996, Stylianidou, Boohan 1998, William, Reeves 2003, Ametler, Pintó 2002, Hammer et al. 2012) just a few students scientifically correctly use and understand ideas about energy at every educational level (Watts 1983, Brook, Driver 1984, Duit 1984, Brook, Solomon 1985, Wells 1988, Finegold, Trumper 1989, Liu, McKeough 2005). Driver, Warrington (1985), Duit (1984), Kuhnová (2010, 2012) found out that students defined energy with daily life meaning rather that its scientific meaning.

Not only student but also teachers at every educational level have many alternative conceptions (Kruger, Summers, 1989, Kruger 1990, Bransky, Hadass, Lubecky 1992, Kruger et al. 1992, Wubbels 1992, Kerr, Beggs, Murphy 2006, Tobin et al. 2012, Trumper 1997a, 1997b). Their understanding of energy as scientific concept is strongly limited.

INQUIRY AS A PART OF SCIENCE EDUCATION

Inquiry has a very important role in generating knowledge in science education. According to Crawford (200) popular terms in the world of practicing teachers, including "doing science", hands-on science, and real-world science are frequent in reducing the complexity of teaching to simplistic algorithms. There is a danger in equating inquiry-based instruction with the currently accepted notion of “hands-on-science” which teachers provide students with a series of hands on activities that often are unconnected to substantive science content.

Inquiry-based teaching strategies need to align with theories how children learn science which include students revising their understanding through teachers building on students´ experiences (Driver et al. 1994).

Many researchers (Gibson, Chase 2002, Hodson 1998, Lunetta 1999) suggest using inquiry based method in the field of science education especially laboratory work.

For understanding nature of science is very important curiosity, willingness to suspect judgment, open mindedness and also scepticism. Inquiry based education of focused on developing all mentioned attitudes. According to Carey, Smith 1993, Freuzeig, Roberts 1999, Lehrer, Schauble 2000, Schwartz, White 2005 inquiry based education strongly support scientific understanding of the nature of science.

The main goal of using inquiry based strategies in education is to teach students think like scientists (more scientifically than usual).

WORKSHEETS IN ENERGY EDUCATION

Very important part of teachers work is preparing appropriate materials for their students. As support for using inquiry based education is creation of inquiry based worksheets which strongly influence students´ and teachers´ activities. There are many aspects which are very important during their preparation as: closely connection with national curriculum, supporting creativity and motivation...

We investigated cognitive structure related to energy concept. Data were collected (through applying a triangulation) - by free word association, concept mapping and interview about instance. As we reported above, we distributed prepared worksheets attended five regional schools (two city and three village areas) in Slovak republic. We acquired much information about cognitive structure which is closely connected with the energy concept. It was the base for preparing worksheets. We consider very important to know cognitive structure and misconceptions of children before preparing either of teaching materials.

We prepared series of worksheets focused on many aspects of energy concept. The main themes of worksheet were: heat comes from sun, energy in plants, wind mill, water mill, warming of earth´s surface, moving of particles, solar panel, heat and chemical reaction, temperature and chemical reaction, heat of reaction, ignition temperature, organisms and environment, breathing and energy, light and photosynthesis, plants and breathing,

The fundamentals of worksheet structure were models of lectures used in FAST project with respect to construstivistic approach, inquiry based education and way of work in real science. We also used model of scientific inquiry which was created by Harwood (2004). He divided the process of scientific inquiry into ten parts: asking questions, defining the problem, forming the questions, investigating the known, articulating an expectation, carrying out the study, examining the results, reflecting of the findings, communicating with others, making observation.

How to prepare appropriate inquiry based worksheet? What is the most important during their preparation?

During the preparation teachers have to be really sophisticated, patient, and creative, etc... There are some very important aspects which are essential in the process of preparing worksheets. They have to:

- offer students possibility to work in small groups and investigate scientific phenomena together;
- incorporate suitable types of question;
- solve problems;
- interpret data (numbers, schemas, tables, graphs);
- use many types of tasks and questions;
- respect crosscurricular themes (concepts) and also obligatory content of education;
- help think and observe scientifically correctly and etc...

FINDINGS

Without using appropriate materials it is not possible to be successful teacher. Using inquiry based worksheets teacher could develop very important skills such as: observing, classifying, time management, measuring, using numbers and graphs, predicting, formulating hypothesis, experimenting, modelling, interpreting data, exploring. It is necessary to understand energy scientifically and be able to apply energy ideas in real-world contexts and in everyday language because it is one of the main concepts of science, economy, environmental studies and sometimes everyday language.

Our worksheets were tested at schools, we planned continue in testing. Later we would like to process results in another paper.

REFERENCES

Acton, W., Johnson, P., Goldsmith, T. 1994. Structural knowledge assessment: comparison of referent structures. *Journal of Educational Psychology*, 86, 303-311.

Ametler, J., Pintó, J. 2002. Students´ reading of innovative images of energy at secondary school level. International Journal of Science Education, 24(3), 285-312.

Awan, A. S. 2013. Comparison between Traditional Text-book method and Constructivist Approach in Teaching the Concept Solution. *Journal of Research and Reflections in Education,* 7(1), 41-51.

Awan, A. S., Iqbal, M. Z., Khan T.M., Mahmood, R., Mohsin, M. N. 2012. Pupils´ Ideas in Learning Concept of the Chemical Bonding among Pakistani Students. International Journal of Applied Science and Technology, 2(6), 139-146.

Bahar, M., Ozatli, N. S., 2003. Investigating high school freshman students´ cognitive structure about the basic components of living things through word association test method. *Journal of the Institute of Science and Technology of Balikesir University*, 5(1), 75-85.

Bauman, R. P., 1992. Physics textbook writers usually get wrong: Heat and energy. *Physics Teacher*, 30(6), 353-356.

Blake, A. 2001. Developing Young Children´s understanding an example from earth science. Evaluation and Research in Education, 15(3), 154-161.

Bliss, J., Ogborn, J. 1985. Children´s choice of uses of energy. European Journal of Science Education, 7, 139-148.

Bransky, J., Hadass, R., Lubezky, A. 1992. Reasoning fallancies in preservice elementary school teachers. *Research in Science and Technological Education,* 10, 83-91.

Brody, M. 1991. Understanding of pollution among 4^{th}, 8^{th}, and 11^{th} grade students. *Journal of Environmental Education,* 22, 24-33.

Brook, A., Driver, R., 1984. Aspects of secondary student understanding of energy: Children´s Learning in Science Project, Leeds: University of Leeds.

Brook, A., Wells, P. 1988. Conserving the circus? An alternative approach to teaching and learning about energy. *Physics Education,* 23, 80-85.

Boohan, R., Ogborn, J. 1996. Energy and change. A set of booklets. Hatfield. Association of Science Education.

Carey, S., Smith, C. 1993. On understanding the nature of scientific knowledge. *Educational Psychologist,* 28(3), 235-251.

Caton, E., Brewer, C., Brown, F. 2000. Building Teacher-Scientist Partnership: Teaching About Energy Through Inquiry. *School Science and Mathematics,* 100(1), 7-15.

Crawford, B.A. 2000. Embracing the Essence of Inquiry: New Roles for Science Teachers. *Journal of Research in Science Teaching.* 37(9), 916-937.

Curriculum Development Center 1992. Energz and Its Transformations. Ministry of Education, Jerusalem, 1992. In Trumper, R. 1993. Children´s energy concepts: a cross age study. *International Journal of Science Education,* 15, 139-148.

Driver, R., Asoko, H., Leach, J., Mortimer, E., Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23, 4.

Driver, R., Warrington, L. 1985. Students´ use of the principle of energy conservation in problem situations. *Physics Education,* 29, 171-176.

Duit, R. 1981. Students´ notions about the energy concept – before and after instruction. Paper presented at conference, *Problems concerning students´ representation of physics and chemistry knowledge,* Ludwigsburg, W. Germany, 14-16 September.

Duit, R. 1984. Learning the energy concept in school – empirical results from the Philippines and West Germany. *Physics Education*, 19, 59-66.

Edwards, J., Fraser, K. 1983. Concept maps as reflectors of conceptual understanding. *Research in Science Education,* 13, 19-26.

Fleer, M. 1999. Children´s alternative views: alternative to what? *International Journal of Science Education.* 21(2), 119-135.

Fleer, M., Hardy, T. 1993. How can we find out what 3 and 4 year olds think? New approaches to eliciting very young children´s understanding in science. *Research in Science Education,* 23, 68-76.

Feurzeig, W., Roberts, N. 1999. Computer modelling and simulation in science education. New York: Springer-Verlag.

Gibson, H.L., Chase, C. 2002. Longitudinal impact of an inquiry-based science program on middle school students´ attitudes toward science. *Science Education,* 86, 693-705.

Gilbert J.K et al. 1982. Students´ Conceptions of Ideas in Mechanics. *Physics Education,* 17(2), 62-66.

Gilbert, J., Pope, J. 1986. Small group discussion about conception in science: a case study. *Research in Science and Technological Education.* 4, 61-76.

Gilbert, J., Watts, D.M., Osborne, R. 1985. Eliciting students´ views about an interview-about-instance technique. *Cognitive Structure and Conceptual Change.* Ed. L. West and A. Pines (London: Academic Press) 11-29.

Goldrong, H., Osborne, J. 1994. Students´ difficulties with energy and related concepts. *Physics Education,* 29(1), 26-32.

Guastello, E.F., Beasley, T. M., Sinatra, R.C. 2000. Concept mapping effects on science content comprehension of low-achieving inner-city seventh grades. *Remedial and Species Education*, 21, 356-366.

Hammer, D., Goldberg, F., Fargason, S. 2012. Responsive teaching and the beginnings of energy in a third grade classroom. *Review of Science, Mathematics and ICT Education*, 6(1), 51-72, 2012.

Harwood, W. 2004. A new model of inquiry. *Journal of College Science Teaching*, 33(7), 29-33.

Hazel, E., Prosses, M. 1994. First year university students´ understanding of photosynthesis, their study strategies and learning context. *The American Biology Teacher,* 56(5), 274-279.

Heinze-Fry, J. A., Novak, J. D. 1990. Concept mapping bring long-term movement toward meaning learning. Science Education, 74(4), 461-472.

Hewson, P.W., Hewson, M.G. 1989. Analysis and Use of a Task for Identifying Conceptions of Teaching Science. *Journal of Education for Teaching*. 15(3), 191-209.

Hodson, D. 1998. Is this really what scientists do? Seeking a more authentic science in and beyond the school laboratory. In Wellington, J. Practical work in school science: Which way now? London: Routhledge.

van Huis, C., van den Berg, E. 1993. Teaching energy – a system approach. Physics Education, 28, 146-153.

Jonassen, D. H., Beissner, K., Yacci, M. 1993. *Strucutal knowledge techniques for representing, converting and acquiring structural knowledge.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Kemp, H.R. 1984. The concept of energy without heat and work. *Physics Education*, 19, 234-240.

Kerr, K., Beggs, J., Murphy C. Comparing children´s and student teachers´ ideas about science concept. *Irish Educational Studies,* 25(3), 298-302.

Kesidou, S., Duit, R: 1993. Students´ conceptions of the second law of thermodynamics – an interpretive study. *Journal of Research in Science Teaching,* 30(1), 85-106.

Kinchin, I.M. 2000. Using concept maps to reveal understanding: a two analysis. *School Science Review,* 8, 41-46.

Kruger, C. 1990a. Some Primary Teachers´ Ideas about Energy. *Physics Education,* 25(2), 86-91.

Kruger, C: 1990b. An Investigation of Some English Primary School Teachers´ Understanding of the Concepts Fore and Gravity. *British Educational Research Journal,* 16(4), 383-397.

Kruger, C. Summers, M., 1989. Some primary teachers'´ understanding of changes in materials. *School Science Review,* 71(255), 17-21.

Kuhnová, M. 2010. Možnosti implementácie konštruktivizmu a využitie modelu didaktickej rekonštrukcie vo vzdelávaní o energii. Dizertačná práca. Trnavská univerzita.

Kuhnová, M. 2011. Is model of educational reconstruction suitable for creating educational materials in the field of energy education?. In Biologie. Chemie. Zemepis, 20. Chemické vzdelávaní v teorii a praxi. Materiály z medzinárodné conference o výuce chemie.

Kuhnová, M. 2012. Students´ misconceptions about energy. In. *Research in didactics of physics.* Pedagogical University of Krakow. Department of chemistry and chemistry education. ISBN 978-83-77271-765-8.

Kuhnová, M., Held, Ľ. 2010. K aktuálnemu stavu vedeckého pojmu energia u slovenských školopovinných žiakov. In. Škoda, J., Doulík, P. Prekoncepce a miskoncepce v odborových didaktikách, 45-67. Univerzita J. E. Purkyně: Ústí nad Labem.

Kurt, H., 2013. Determining biology teacher candidates´ conceptual structures about energy and attitudes towards energy. Journal of Baltic Science Education, 12, 4, 399-423.

Lehrer, R., Schauble, L. 2000. Modelling in mathematics and science. In Glaser, R. Advances in instructional psychology. Volume 5: Educational design and cognitive science. 101-159. Mahwah, NJ: Erlbaum.

Leggett, M. 2003. Lessons that non-scientist can teach about concept of energy a human centred approach, *Physics Education,* 38(2), 130-134.

Liu, X., McKeough, A. 2005. Developmental growth in students' concept of energy: analysis of selected items from TIMMS database. *Journal of Research in Science Teaching*, 42(5), 493-517.

Lunetta, V. N 1999 The school science laboratory: Historical perspectives and contexts for contemporary teaching. In. Fraser, B.J., Tobin, K.G. International handbook of science education. Dordrecht: Kluwer Academic.

Markham, K. M., Mintzes, J.J., Jones, M.G. 1994. The concept map as a research and evaluation tool: further evience of validity. *Journal of Research in Science Teaching*, 31, 91-101.

Markow, P.G., Lonning, R.A. 1998. Usefulness of concept maps in college chemistry laboratories students´ perceptions and effects on achievement. *Journal of research in Science Teaching,* 35(9), 1015-1029.

Nakiboglu, C., 2008. Using word association for assessing nonmajor science students´ knowledge structure before and after general chemistry instruction: The case of atomic structure. *Chemical Educational Research Practice,* 9, 309-322.

Novak, J. D. 1990. Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching*, 27(10), 937-949.

Novak, J. D. 2005. Results and implications of a 12-year longitudinal study of science concept learning. Research in Science Education, 35, 23-40.

Novak, J. D., Cañas, A. J. 2006. The theory of underlying concept maps and how to construct nad use them. Institute for Human and Machine Cognition. Available online: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm [2.5.2014]

Novak, J. D., Musonda, D. 1991. A twelve-year longitudinal study of science concept learning. *American Educational Research Journal,* 28, 117-153.

Novick, S., Nussbaum, J. 1981. Pupil´s understanding of the particulate nature of matter: a cross-age study. Science Education 65(2), 187-196.

Osborne, R.J., Gilbert, J.K., 1979. Investigating student understanding of basic physics concepts using an interview-about-instance technique. *Research in Science Education,* 9, 85-93.

Osborne, R.J., Gilbert, J.K. 1980. A Method for Investigating Concept Understanding in Science. *European Journal of Science Education.* 2(3), 311-321.

Osborne, R.J. 1983. Towards Modifying Children´s Ideas about Electric Current. *Research in Science and Technological Education.* 1(1), 73-82.

Ozatli, N.S., Bahar, M., 2010. Revealing students´ cognitive structures regarding excretory system by new techniques. *The Journal of Abant Izzet Baysal University,* 10(2), 9-26.

Papadouris, N. et al. 2004. Student understanding of energy as a model that accounts for Changes in Physical Systems. *Paper presented at the GIREP Conference: Teaching and Learning Physics in new Contexts,* Ostrava, Czech republic.

Papadouris, N. et al. 2008. Students´ use of the energy model to account for changes in physical systems. *Journal of research in science teaching.* 45(4), 444-469.

Peterson, R., Treagust, D., Garnett P. 1986. Identification of Secondary Students´ Misconceptions of Covalent Bonding and Strucutre Concepts using a Diagnostic Instrument. Research in Science Eduation, 16, 40-48

Ross, B., Munby H. 2007. Concept mapping and misconceptions: a study of highschool students´ understanding of acid and bases. *International Journal of Science Education.* 13(1). 11-23.

Ruiz-Primo. M. A., Shavelson, R.J. 1996. Problems and issues in the use of concept maps in science assessment. Journal of Research in Science Teaching, 33(6), 569-600.

Rye, J. A., Rubba, P. A. 1998. An exploration of the concept maps as an interview tool to facilitate the externalization of students´ understanding about global atmospheric change. *Journal of Research in Science Teaching*, 35, 521-546.

Salyachivin, S. et al. 1985. Students´ Conceptions on Force. Journal of Science and *Mathematics Education in Southeast Asia,* 8(1), 28-31.

Sato, M., James, P. 1999. "Nature" and "environment" as perceived by university students and their supervisors. *International Journal of Environmental Education and Information,* 18 (2), 165-172.

Schmid, G.B. 1982. Energy and its carries. *Physics Education.* 17, 212-218.

Schwarz, C., White, B. 2005. Meta-modelling knowledge: Developing students´ understanding of scientific modelling. *Cognition and Instruction*, 23(2), 165-205.

Shepardson, D.P., 2002. Bugs, Butterflies, and Spiders: Children´s Understanding about Insects. *International Journal of Science Education,* 24(6), 627-643.

Solomon, J. 1983. Learning about Energy: how pupil think in two domains. *European Journal of Science Education,* 5, 49-59.

Solomon, J. 1985. Teaching the conservation of energy. *Physics Education*, 20, 165-170.

Stylianidou, F., Boohan, R. 1996. Understanding why things happen. Case studies of pupils using an abstract picture language to represent the nature of change. *Research in Science Education,* 28(4), 447-462.

Summers, M., Kruger, C. 1993. Long term impact of a new approach to teacher education for primary science. *Paper presented at the Annual Meeting of the British Educational Research Association,* Liverpool, United Kingdom.

Taber, K.S. 1994. Student reaction on being introduced to concept mapping. *Physics Education*, 29, 276-281.

Taylor, N., Coll, R.K., 2002. Accessing students´ prior concepts of physical change by the use of a purpose-designed survey instrument. *Journal of Science and Mathematics Education in S.E. Asia*, 25, 1, 25-40.

Tekkaya, C. 2003. Remediating High School Students´ Misconceptions Concerning Diffusion and Osmosis through Concept Mapping and Conceptual Change Text. *Research in Science and Technological Education*, 21(1), 5-16.

Tobin, R. G., Crissman, S., Doubler, S., Gallagher, H., Goldstein, G., Lacy, S., Rogers, C.B., Schwartz, J., Wagoner, P., 2012. Teaching about Energy: Lessons from an Inquiry-Based Workshop for K-8 Teachers. *Journal of Science Education and Technology,* 21, 631-639.

Trefil, J., Hanzen, R. M., 2004. *Physics matters: an introduction to conceptual physics.* New York: Wiley.

Trumper, R. 1990. Being constructive: An alternative approach to the teaching of the energy concept – Part one. *International Journal of Science Education,* 12, 343-354.

Trumper, R. 1991. Being constructive: An alternative approach to the teaching of the energy concept – part two. *International Journal of Science Education.* 13:1-10.

Trumper, R. 1993. Children´s energy concepts: a cross age study. International *Journal of Science Education,* 15(2), 139-148.

Trumper, R. 1996a. Teaching about energy through spiral curriculum: guiding principles. *Journal of Curriculum and Supervision*, 12(1), 66-75.

Trumper, R., 1997a. The need for change in elementary school teacher training: the case of the energy concept as an example. *Educational Research,* 39(2), 157-174.

Trumper, R. 1998. A longitudinal study of physical students´ conceptions of energy in preservice training for high school teachers*. Journal of Science Education and Technology,* 7(4), 311-318.

Trumper, R., Gorsky, P. 1993. Learning about energy: the influence of alternative frameworks, cognitive levels and closed mindedness. *Journal of Research in Science Teaching.* 30(7), 637-648.

Trumper, R. Raviolo, A., Shnersch, A. M. 2000. A cross-cultural survey of conceptions of energy among elementary school teachers in training – empirical results from Israeli and Argentina. *Teaching and Teacher Education,* 16(7). 667-714.

Viennot, L. 1979. Spontaneous learning in elementary dynamics. *European Journal of Science Education,* 1, 205-221.

Watts, D. M., 1981. Exploring Pupils´ Alternative Frameworks Using the Interview-about-Instances Method. Paper presented at the Annual Meeting of the Padag.

Watts, D. M., 1983. Some Alternative Views of Energy. *Physics Education.* 18(5), 213-217.

Watts, D. M., 1983. Enigmas in School Science: Students´ Conceptions for Scientifically Associated Words. *Research in Science and Technological Education,* 1(2), 161-171.

Williams, G., Reeves, T. 2003. Another go at energy. Special feature: energy at the environment. *Physics Education,* 38(2), 150-155.

Wubbels, T. 1992. Taking account of students' teachers´ perceptions. *Teaching and Teacher Education,* 8, 137-149.

STRUCTURE OF MATTER AT SECONDARY SCHOOL – RESULTS OF THE RESEARCH

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Abstract

Presented in many textbooks models of the atom proposed by N. Bohr is outdated however widely used. In school practice this model should be replaced with the model which is based on quantum chemistry. The paper presents the way of teaching pupils of lower secondary school about the structure of electron cloud and writing the electron configuration with use of orbitals. In order to check if the presented way of teaching is effective the research was carried out. The studies were conducted among pupils of the first class of lower secondary school. The research revealed that thirteen years old pupils are able to understand the structure of electron cloud, of course in a simplified way, without any complicated mathematical equations and they can write electron configuration in atoms and ions. Introduced model of atom, based on the assumptions of quantum mechanics, is an introduction to rational discovering chemistry in further education.

Keywords

Structure of atom. Electron configuration. Lower secondary school.

INTRODUCTION

Studying in the fields of natural sciences at the present time is becoming less popular. There could be various reasons for this trend. One reason may be the demographic, Other reason can be the interest in such branches of studies that require less mental effort from a student and enable him to easily obtain a professional degree.

Moreover, reasons for the lack of motivation to study natural sciences should be looking at the stage of primary school and secondary school.

At the stages of early childhood education and in the first years of primary school there are already some natural contents, but often they are introduced incorrectly and often with colloquial language. Nevertheless, at this stage, children are curious and interested in learning about the world, in particular the reality that can be explored by their senses.

In further education, natural contents are distributed on various subjects, including chemistry and physics. Most of the older pupils (13 years old) is already reluctant to learning chemistry because they think it's difficult and incomprehensible. This is due to the fact that learning chemistry requires the student to move within the 3 areas.

One area is chemical symbolism – the chemical language – the level of chemical symbols, formulas, structures, models of chemical compounds, chemical equations.

Second area is the level of the observable world (ie, macro world, the world in which we move, which is perceived with senses, and where the symptoms of chemical reactions are observed).

The third area is an invisible micro-world (ie the level of individual chemical species - atoms, ions and molecules), a world in which the changes and interactions actually take place. The key to understanding chemistry so understands the structure of the microworld.

The basic chemical entity in microworld is the atom. In most lower secondary schools atomic structure is taught based on the shell model proposed by N. Bohr, which is significantly different from the current scientific model, based on the achievements of quantum mechanics. Moreover, presented in many textbooks graphical models of the atom include factual errors (Nodzynska, Cieśla, Paśko, 2012).

Undoubtedly, the use of the Bohr model has certain advantages, but carries the risk of creating misconceptions and negative transfer in the later stages of education (Paśko, 2004).

For this reason, one should give up teaching both chemistry and physics based on the Bohr model of the atom and replace it with a contemporary model in which the internal structure of the electron cloud will be described by quantum numbers, and hence with the use of the concept of orbital. An exemplary method of introducing the concept of atom in the gymnasium has been described in the literature (Cieśla, 2012).

RESEARCH

The study aimed to verify whether among students of the first class of lower secondary school (13 years old), the structure of the atom and the electron distribution in the cloud based on assumptions of quantum mechanics can be discussed. The research involved students of the Ist class of lower secondary school.

Prior to the study it was assumed that students know only the definition of the concept of atom and that it is built from the nucleus and the surrounding electron cloud. No pretest was performed, since previously conducted classes did not contain the content related to the research. Moreover, the studies are carried out at the beginning of teaching chemistry and the tested approach to learning about the structure of the atom is not included in the curriculum to the earlier stages of education, and this knowledge is not widely used in everyday life.

In the next step the construction of the atomic nucleus and possible transformations taking place in the nucleus of an atom, including radioactive decays were introduced. This topic is not the subject of the paper so it will not be discussed.

In order to discuss the construction of electron cloud analogy to a hotel have been used (Table 1.). The construction of the electron cloud was compared to the construction of appropriately designed hotel. The term "orbital" was defined as the part of a space with a certain shape around the nucleus of an atom, in which the electrons can occupy.

Table 1: Analogy of the atom to the hotel (text in the table is adapted from the textbook "Duch chemii" by M. Nodzyńska, P. Cieśla, in press)

Hotel	**Atom**
Suppose that our hotel is multi-story. On the ground floor there is a reception.	In the space around the nucleus one can distinguish areas of a certain energy called energy levels.
Floors are numbered. The lowest floor is number 1, and further assume the values of consecutive natural numbers, ie 2, 3, 4, etc.	The energy of the energy level is dependent on the so-called principal quantum number (**n**). This number can take the values of consecutive natural numbers from 1 to infinity, but in practice ranges from 1 to 7.
On each floor rooms are available.	Within a given energy level, we can distinguish smaller pieces of space - orbitals.
All rooms in our hotel are double.	A single orbital can hold a maximum of two electrons.
The rooms in our hotel are of different shapes and different standards.	The type (shape) of orbitals and how many of these orbitals are, is determined by the azimuthal quantum number (l), which takes values from 0 to n-1.
Standard (Type) of a room denote the corresponding letters **s, p, d, f.**	- If it takes the value 0 (l = 0) - the orbital is called **s**, - If it has a value of 1 (l = 1) - the orbitals are called **p**, - If it has a value of 2 (l = 2) - we are talking about orbitals of type **d**, - If the value is 3 (l = 3) - they are called **f**.
Number of types of rooms on each floor is dependent on the number of the floor.	The value of n determines also how many types of orbitals will be available at each energy level.
Number of rooms of a given type depends on what is the type of room.	The number of orbitals of each type depends on the number of l, that is, of what is the type of orbital.

The room of s type is available on each floor. There is only one s room on each floor.	s orbital is always one and is available on each energy level
p rooms are always 3 on each floor, starting from the second floor up;	p orbitals are always 3 on each energy level, starting from the second energy level;
d rooms are always 5 on each floor, starting from the third floor up;	d orbitals are always 5 on each energy level, starting from the third energy level;
f rooms are always 7 on each floor, starting from the fourth floor up;	f orbitals are always 7 on each energy level, starting from the fourth energy level;
Number m_l determines the arrangement of the rooms on the floor with respect to the directions of the world and how many such rooms will be available. Number of rooms with a given standard depends on what is the type of room.	The magnetic quantum number ml determines the position of the orbitals surrounding the nucleus in relation to other orbitals. It takes integer values in the range -l to l, including 0.
The rooms in our hotel are numbered according to the following code: the first digit indicates the floor number and the letter behind it - the type of room.	Orbitals in an atom are indicated by the following code: digit indicates the consecutive number of the energy level and the letter – type of the orbital.
In conclusion, on the first four floors of our hotel rooms will be as follows:	In summary, at the first four energy levels each atom will have the following orbitals available:

4s □ 4p□□□ 4d□□□□□ 4f□□□□□□□

3s □ 3p□□□ 3d□□□□□

2s □ 2p□□□

1s □

After introducing the quantum numbers and the orbitals examples of their shape was shown. In order to do that the Dynamic Periodic Table was used (http://www.ptable.com/#Orbital). In the next step the way and the order of filling the orbitals with electrons was introduced, according to Hund's Rule and Pauli exclusion principle. Now pupils were able to draw electron configuration of any element.

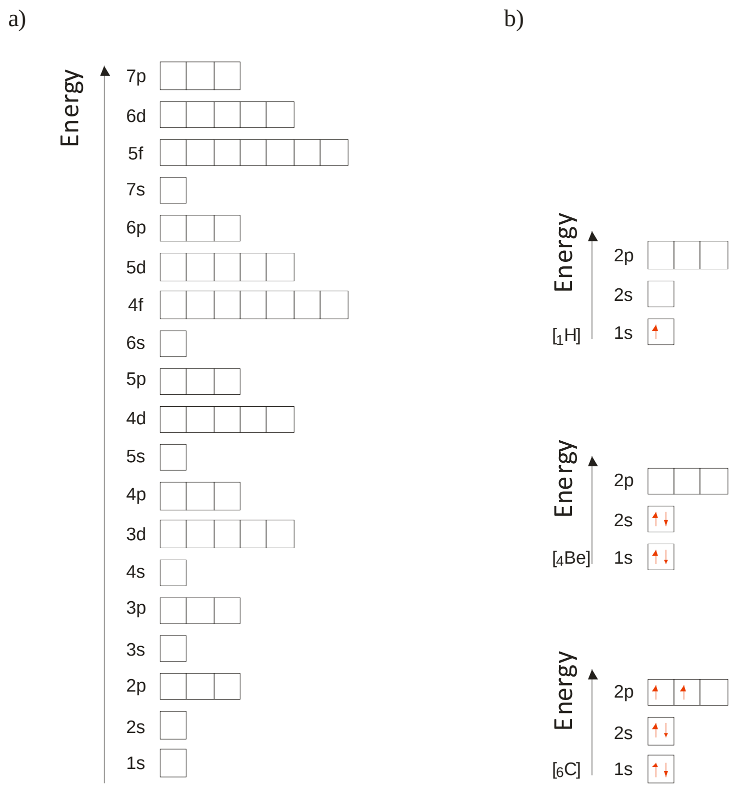

Figure 1: a) Scheme used for practicing of filling the orbitals with electrons; b) examples of filling the orbitals with electrons.

Next lesson was devoted to practical exercises of drawing electron configuration of elements. Students also learned how to convert the electron configuration presented graphically into electron configuration written symbolically.

During practicing pupils were drawing and writing the electron configuration of elements from the same groups of periodic table in order to discover similarity of the configuration of the elements from the same group.

Finally the shape of periodic table of elements was explained.

In order to verify if students gained the skills of writing the electron configuration the test was carried out. The pupils' task was to draw electron configuration of given three elements: sodium, iron and phosphorus - in a graphical way as well as in symbolic way. During the test pupils could use the periodic table of the elements and empty scheme with orbitals (Figure 1a). The test involved 140 students. The results are presented in the Figure 2.

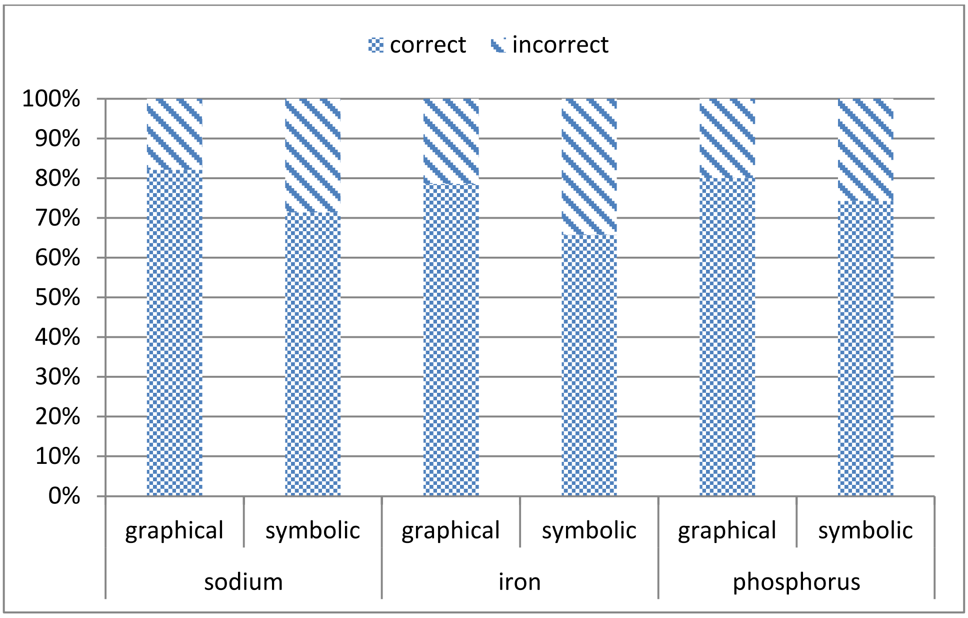

Figure 2: Percent of correct answers of electron configuration of atoms.

The results revealed that most of pupils wrote the electron configuration of atoms correctly. A smaller number of correct answers was obtained in symbolic notation. This is understandable, since the students created symbolic notation based on the graphic one. In the erroneous responses of students appeared the following errors: incorrect number of electrons were distributed; improper draw the electrons at particular orbitals omission of Hund's rule. In addition, while writing the symbolic notation the following errors occurred: incorrect sequence of orbitals; wrong number of electrons; improper form of writing.

In the consecutive lessons, based on the electron configuration, also the concept of ion and electron configuration of simple ions were introduced. Mastering of writing electronic configuration of the ions also was checked by a test in which students were asked to draw the electron configuration of atoms or ions indicated by the teacher. The results are presented in Figure 3.

Writing the electron configuration of ions revealed to be more difficult, however more than 60 % of pupils solved the task correctly in a graphical way and more than 50 % of pupils in a symbolic way. The errors in incorrect answers were similar as mentioned above, however the most repeating error was the wrong number of electrons. Some pupils forgot to add electrons in negative ions and subtract in positive ones.

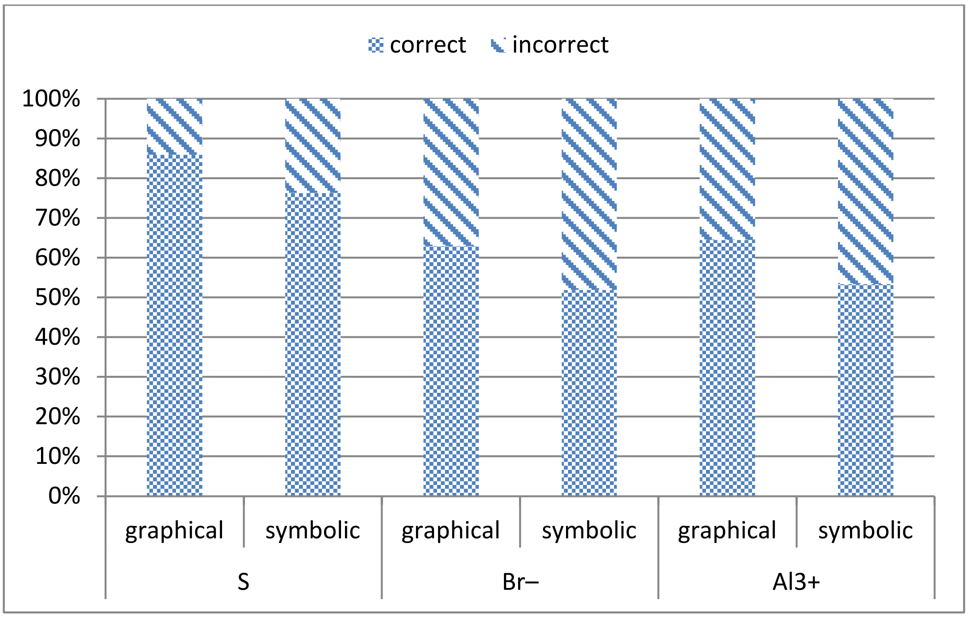

Figure 3: Percent of correct answers to the question: write down the electron configuration of S atom, Br^{-} and Al^{3+} ions – graphically and symbolically.

After realization of the whole part of the school curriculum, ie. after about two months, the test was performed. In the test the skills of writing electron configuration were checked once more. The test involved 140 students. The results are presented in the figure nr 4.

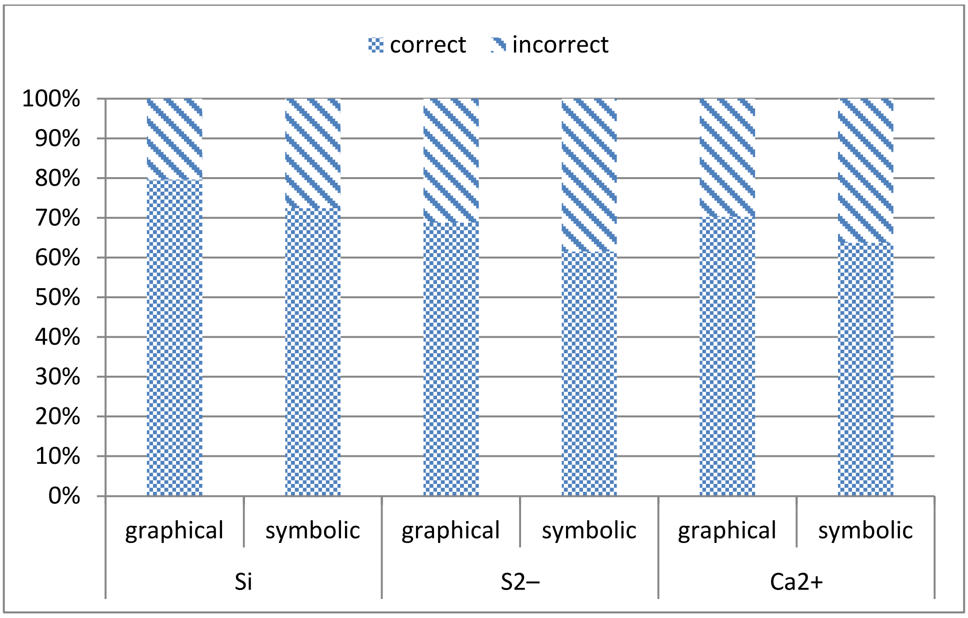

Figure 4: Percent of correct answers to the question: write down the electron configuration of Si atom, S^{2-} and Ca^{2+} ions – graphically and symbolically.

CONCLUSION

Introduced model of atom, based on the assumptions of quantum mechanics, is an introduction to rational discovering chemistry in further education, and therefore it should be implemented at the beginning of chemical education, instead of the widely used model - Bohr model of the atom.

The advantages of this model include: compliance with current views on the constitution of matter; opportunity to explain the shape of the periodic table; the possibility of rational learning of chemistry.

The results of the research show that the students cope with writing of the electron configuration very well, in graphical form as well as in symbolic one, both atoms and ions.

In addition, the results of test performed after the implementation of the entire unit of the curriculum, carried out after about 2 months since the introduction of the electron configuration indicate the understanding of atomic structure, with particular emphasis on the construction of electron cloud.

REFERENCES

Cieśla P., 2012 Jak uczyć o strukturze atomu w gimnazjum, bazując na podstawach mechaniki kwantowej in: *Badania w dydaktyce chemii* ed. Cieśla P., Nodzyńska M., Stawoska I., Pedagogical University of Cracow, Poland.

Nodzyńska, M., Paśko J. R. Cieśla P. 2012: Variety of Textbooks and its Influence on Quality of Chemistry Education in Poland - *Journal Of Science Education,* Vol. 13, pp. 1, s 28 – 33

Paśko J. R., 2004 Wpływ transferu na kształtowanie pojęć na wyższych etapach edukacji, p. 58, XIII ogólnopolska Konferencja Psychologii Rozwojowej Człowiek w świecie - świat w człowieku, Trans Humana, Białystok.

THE CURRENT PARADIGMS OF CHEMISTRY EDUCATION AND THEIR IMPACT ON LEARNING/TEACHING TECHNOLOGY AND TEACHER EDUCATION

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Abstract

Chemistry education as a part of science education has become more important because of economic, environmental, and social challenges. It is necessary to prepare students for their jobs and everyday life. Society needs a workforce with generally higher levels of science and technology literacy for all students and support for highly gifted individuals. Therefore educators should change their attitude to the importance of acquired skills and knowledge. They should involve not only science knowledge and skills but especially knowledge and skills which are necessary for everyday life. Therefore it is necessary to establish a new paradigm of science (chemistry) education. Since the beginning of the twentieth century, experts have defined several major paradigms of science education, which influenced and some of them are still affecting education. Due to the development of science and society they are all outdate and unsatisfactory, and experts try to find some theoretical and empirical support for the creation of a new paradigm, that would meet the requirements of all stakeholders. The change of paradigm in order to be successful has to be accepted by all participants in the educational process - students, their parents, politicians and especially by teachers and educators, who implement these changes into practice. Using the PROFILES-project curricular Delphi study on science education, we focused on the identification of the views on chemistry education, what opinions of current chemistry (science) education are held by stakeholders and what priority should be preferred in their opinion as a base of a new paradigm.

Keywords

Delphi study, Chemistry education, Paradigms, Teacher education.

INTRODUCTION

Chemistry education as a part of science education is undergoing changes in the Czech Republic, similarly to other European countries and the USA (Osborne, Dillon, 2008). The reason of these changes is the fact that science and technology education has become even more important today, facing economic, environmental, and social challenges. It is necessary to prepare today's children for their adult roles as citizens, employees, managers, parents, and entrepreneurs (Pellegrino, Hilton, 2012; Rocard et al, 2007). There is agreement that society needs workforce with generally higher levels of science and technology literacy for all students, as well as a sufficient number of highly gifted individuals entering scientific and engineering careers (Bybee, Fuchs, 2006). Therefore educators change their mind about the importance of needed acquired skills and knowledge. This new attitude to science education involves not only science knowledge and skills but especially knowledge and skills which are necessary for everyday life. Knowledge and skills in the area of chemistry education belong indisputably to this objectives and contents. Czech educators try to focus on this way of chemistry education but there is inertia of the old way of science education.

According to the expert commission of the EU "Science Education Now" (Rocard et al, 2007) the new attitude to science education could increase the interest of young people in science and thus also chemistry. Curricular changes in order to be successful have to be accepted by all of the participants in the educational process - students, their parents, politicians and especially by teachers and educators, who implement these changes into practice. Research findings show that teachers refuse to accept the changes of teaching activities, practices, and curricula which are forced upon them by administrators, policy-makers, etc. (Pajares, 1992; Raymond, 1997; Richardson, 1998; Lederman, 1999; Powers et al, 2006). In our research, we focused on the identification of the views on chemistry education, what opinions of current chemistry (science) education are held by stakeholders and what priority should be preferred in their opinion. We are presenting the findings of the PROFILES-project curricular Delphi study on science education which involved important conclusions about current paradigms of chemistry education. These research results could provide incentives for innovation in chemistry (science) education towards new requirements of society (constructivism, IBSE, etc.). In experts´ opinion, principles of teaching / learning innovations have to be implemented into teacher education (Coufalova et al, 2003; Darling-Hammond, 2000; Duffy, Roehler, 1986; Fullan, 1991; Hanushek et al, 2005; Osborne and Dillon, 2008). Our research results can support development of the new chemistry paradigm.

RATIONALES

In this study, we understand the term paradigm of chemistry education as a set of basic assumptions, approaches, contents, objectives and means which influence the transformation of scientific knowledge into chemistry education. According to experts (Herron, Nurrenbern, 1999) there is a gap between chemistry and chemistry education with differing theoretical bases and research paradigms. It is also necessary to consider the impact of society. It is understandable that education is always closely linked with the development of science disciplines and the development of society, or rather, society's demands for science and technology education.

If we look back in time, firstly we cannot speak about chemistry education separately, but about science education. It used to be focused much more practically, especially on agricultural work, crafts and military applications. Science courses were taught only in a descriptive way to use knowledge primarily for pupils for their future work (for example merchants or artisans, etc.). Students were not encouraged to explore natural phenomena and their connections or to inquire using scientific methods. This approach began to change in about the second half of the 19th century with the rapid development of science. Lives of people were strongly influenced by the technological applications of knowledge from the area of natural sciences (e.g. steam engines, the development of railways, electrification, and telephone). The rapid development of scientific theoretical knowledge was reflected into science and technology education. The paradigm aimed at practice was replaced by more modern approaches. Teaching was still descriptive and practically oriented but there were significant changes in the content of education and increase in appearance of theoretical knowledge (Doulík, 2009).

Since the beginning of the twentieth century experts have defined several major science paradigms (pragmatic, polytechnic, humanistic, scientific paradigm, etc.) which influenced and some of them are still affecting science (chemistry) education (Doulík, 2009). But they are all outdated and unsatisfactory, and experts try to find some theoretical and empirical support for the creation of a new paradigm, that would meet the requirements of all stakeholders.

The search for a new paradigm of science education is an essential task of current research. This problem has become a global problem, as it is based on global social changes. In the search of a new paradigm of science (chemistry) education it is necessary to consider the social conditions. These include in particular the sharp increase in scientific knowledge and its application in daily life (the Internet, etc.) and in functioning of the whole society (rapid and open information boom, etc.). An equally important factor is the growth of human population and its demand on resources. It is not too bold to say, that finding a paradigm of science education for the future has become a strategic social issue.

The fact, that no new paradigm in science education has been found so far, is connected with the high complexity of this issue, which has got many variables. The basis of these variables is relatively new areas such as politics, economy, safety, etc. The second factor is a relatively wide range of topics and approaches that should be covered by science education. This includes e.g. environmental issues, relationship between science and society, criteria for selecting curriculum, support of interdisciplinarity, individualization of education, specialization of science education (in relation to professional needs of people), acceptance of specific educational needs etc.

From the range of issues creating a new paradigm of science (chemistry) education, we selected the following educational issues (content) for our study:

- Global ecology and the theory of sustainable development
- Key concepts and theories
- Content connected with everyday life
- Competences
- Interdisciplinarity

In our study based on a Delphi study, we decided to determine the position of these issues in the opinions and ideas of significant stakeholders who participate in the process of science (chemistry) education. These are: students, teachers, educators and scientists. The summary of these views can help to complete data for finding the appropriate paradigm.

In the implementation of the educational process, a paradigm fulfils the role of a "plan", how to proceed in order to achieve desired outcomes. However, this “plan” must be accepted by all stakeholders. That's why our DELPHI study focused on identifying major stakeholders´ views on above mentioned aspects of chemistry education.

The effort to create a new paradigm comes out from needs to change science education. But the quality of education is closely related to the quality of teachers (Darling-Hammond, 2000; Hanushek et al, 2005), which is one of the most important factors influencing the student educational outcomes. To accept changes teachers need to be familiar with them and accept them. Findings of many studies substantiate the close relationship between teachers' beliefs and their classroom practices. Findings indicate that teachers' beliefs and practice were not wholly consistent. But it is not easy to change teachers' beliefs. According to Raymond (1997), there is inertia in teachers' beliefs. Therefore we try to identify their beliefs using results of Delphi study.

RESEARCH QUESTIONS AND METHODS

We tried to investigate roles of science education from different points of view and to take into account the opinions of experts on a new paradigm in science education. In our study we are presenting findings related to chemistry education.

The main research questions are:

1. *Which characteristics of a desirable chemistry education do the participants consider as being important?*
2. *Which conceptual frameworks are considered as being necessary and important for chemistry education?*

Our research questions are examined in the total sample and in the individual groups of the participants of the Delphi Study (students, teachers, educators and scientists) as well.

The main research method we used is a curricular Delphi study (Osborne et al, 2001; Bolte, 2008). We applied the curricular Delphi study on science education that was specifically developed within the PROFILES project (2013). The main objective of this curricular Delphi study was to find out views of different groups of respondents to contents and aims of science education in general as well as to engage them to outline aspects and approaches of innovative science education (inquiry-based science education etc.). This study is also focused on those aspects of science education that are considered relevant and pedagogically desirable for the individual in the society of today and in the near future.

According to previous curricular Delphi studies (Bolte, 2008; Osborne et al, 2003), the PROFILES curricular Delphi study on science education was carried out in three rounds between the years 2011-2013. The first round offered the participants a possibility to express their ideas about aspects of contemporary and pedagogically desired science education in three open questions regarding motives, situations and contexts as well as fields, aspects and qualifications. In the second round, the participants were informed about the allocated categories of the first round and asked both to assess to what extent the aspects expressed by the categories are realized in practice and to prioritize the given categories (see Table 1). In order to identify concepts that are considered important regarding science education, the participants were also asked to combine categories from the given set of categories. In the third round, those concepts identified by cluster analysis were feed back to the participants for a weighted assessment in the same way as in the second round.

According to (Bolte, 2008) we selected four different groups of participants: students (age 14-16), science teachers (lower and upper secondary schools), science educators (didactics, university teachers involved in pre-service and in-service teacher training) and scientists (see Table 2) - main stakeholders of science education.

Table 1: Categories in questionnaire.

Categories	***Number of items***
Part I: Situations, contexts and motives	18
Part II a: Basic concepts and topics	20
Part II b: Scientific disciplines and perspectives	24
Part III: Qualifications	18
Part IV: Methodical Aspects	8

Table 2: Structure and number of participants.

	students	teachers	educators	scientists	total
Number of participants	56	30	28	25	139

Stakeholders (research participants) answered the same questions from two points of view – wishes and *reality (written in italics)*. They wrote answer to questions according to their opinion about reality in Czech schools and they also wrote their wishes - opinion how it should be. The sample of questionnaire item ("Students' interest") is presented in Table 3.

Table 3: The sample of questionnaire item.

Part I: **Situations, contexts and motives:** Please assess the following categories according to the two questions stated.	Which **priority** should the respective aspects have in science education? 1 = to a very low extent 2 = to a low extent 3 = to a rather low extent 4 = to a rather high extent 5 = to a high extent 6 = to a very high extent	*To what **extent** are the respective aspects realized in current science education?* *1 = very low priority* *2 = low priority* *3 = rather low priority* *4 = rather high priority* *5 = high priority* *6 = very high priority*
Students' interests	[1] [2] [3] [4] [5] [6]	*[1] [2] [3] [4] [5] [6]*

RESULTS AND DISCUSSION

To answer the question number one "*Which characteristics of a desirable chemistry education do the participants consider as being important?*", we are presenting findings of the PROFILES curricular Delphi study on science education. The first and second round of the PROFILES curricular Delphi study on science education yielded a number of interesting findings from which we select the most important part concerning chemistry education. We focus on above mentioned issues related to creating a new paradigm of chemistry (science) education. The main findings of the part aimed to situations, contexts and motives connected with global ecology and the theory of sustainable development, key concepts and theories, content connected with everyday life, competences and interdisciplinarity are presented in Table 4. To better comparison of opinions of participants (on reality at schools and what they want to be priority - their wishes) we are presenting findings together ("reality" data - in italics).

Table 4: Opinions of participants on the importance of situations, contexts and motives

Part I: Situations, contexts and motives:	Which priority should the respective aspects have in science education? (Wish)						*To what extent are the respective aspects realized in current science education?(Reality)*					
	Students S		Teachers T		Educators E		Scientists Sc		Adult T + E + Sc		Total S + T + E + Sc	
	Mean standard deviation		mean standard deviation		mean standard deviation		mean standard deviation		mean standard deviation		mean standard deviation	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Students' interests	5,1 0,9	*3,2 1,1*	5,1 0,9	*3,2 0,9*	5,3 0,7	*3,1 0,9*	4,6 1,5	*2,6 1,4*	5,0 1,1	*3,0 1,1*	5,1 1,0	*3,1 1,0*
Education / general pers. development	5,0 0,8	*3,7 0,7*	4,7 1,0	*3,5 0,9*	5,5 0,7	*3,5 0,9*	4,9 1,2	*3,0 1,0*	5,0 1,0	*3,3 1,0*	5,0 0,9	*3,5 0,9*
Media/ current issues	4,6 1,0	*3,7 1,3*	4,5 1,0	*3,6 1,1*	4,2 1,0	*2,7 1,0*	4,4 0,8	*2,8 0,9*	4,3 0,9	*3,0 1,1*	4,4 1,0	*3,3 1,2*
Medicine / health	4,9 1,1	*4,0 1,0*	5,1 0,9	*3,7 1,3*	4,9 0,8	*3,2 0,8*	5,3 0,7	*3,5 0,9*	5,1 0,8	*3,5 1,0*	5,0 0,9	*3,7 1,0*
Nature / natural phenomena	4,6 1,0	*4,0 1,0*	5,1 1,0	*3,8 1,0*	5,0 0,9	*3,6 0,7*	5,1 1,0	*3,8 0,9*	5,1 1,0	*3,7 0,9*	4,9 1,0	*3,8 0,9*
Everyday life	4,5 1,1	*3,4 1,0*	5,2 1,0	*3,4 1,0*	4,9 1,5	*2,9 1,1*	5,2 0,8	*3,0 0,9*	5,1 1,1	*3,1 1,1*	4,9 1,1	*3,2 1,1*
Global references	5,0 1,1	*3,8 1,3*	4,9 1,0	*3,7 1,3*	4,3 0,8	*2,9 1,0*	4,5 1,2	*3,2 1,3*	4,6 1,0	*3,3 1,2*	4,7 1,1	*3,5 1,3*

Part I: Situations, contexts and motives:	Which priority should the respective aspects have in science education? (Wish)						*To what extent are the respective aspects realized in current science education?(Reality)*					
	Students S		Teachers T		Educators E		Scientists Sc		Adult T + E + Sc		Total S + T + E + Sc	
	Mean standard deviation		mean standard deviation		mean standard deviation		mean standard deviation		mean standard deviation		mean standard deviation	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Society/public concern	4,6 1,0	*3,8* *1,2*	4,1 0,8	*3,3* *1,1*	4,2 0,8	*2,8* *1,2*	4,2 1,2	*2,8* *1,1*	4,2 0,9	*3,0* *1,2*	4,4 1,0	*3,3* *1,2*
Curriculum framework	3,9 1,1	*3,8* *0,9*	3,6 1,4	*3,7* *0,9*	3,9 1,1	*3,8* *1,2*	4,2 1,2	*3,6* *1,2*	3,9 1,2	*3,7* *1,1*	3,9 1,2	*3,7* *1,1*

According to findings presented in the table 4 participants would like to change the priorities in Czech schools. They think that especially students' interests, issues related to health and general personal development are not priority in Czech schools. Participants express their opinions, that other issues that are recommended by experts as important for creating a new paradigm of science education are not considered as priorities in Czech schools as well. We are presenting opinions of all groups of participants because there are some differences among them.

In our opinion participants´ views on the importance of individual science subjects and science interdisciplinarity are very interesting. According to findings presented in Table 5 science interdisciplinarity is underestimated. Participants would like to more support science interdisciplinarity and chemistry and physics as well. Biology has got approximately priority as participants think that it should have.

Table 5: Opinions of participants on the importance of subjects and science interdisciplinarity.

Part I: Situations, contexts and motives:	Which **priority** should the respective aspects have in science education? (Wish)						*To what **extent** are the respective aspects realized in current science education?(Reality)*					
	Students S		**Teachers T**		**Educators E**		**Scientists Sc**		**Adult T+E+Sc**		**Total S+T+E+Sc**	
	mean standard deviation		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Science - biology	4,6 1,1	*4,1* *0,9*	4,7 1,1	*4,2* *1,0*	4,9 0,7	*4,1* *0,9*	4,6 1,0	*4,0* *1,0*	4,7 0,9	*4,1* *0,9*	4,7 1,0	*4,1* *0,9*
Science - chemistry	4,2 1,2	*4,0* *1,1*	4,7 1,0	*4,0* *1,1*	4,8 0,6	*3,1* *1,0*	4,8 0,8	*3,1* *1,1*	4,8 0,8	*3,4* *1,1*	4,6 1,1	*3,6* *1,1*

Science - physics	4,0 1,3	*4,1* *1,1*	4,9 1,0	*4,0* *1,2*	5,0 0,5	*3,3* *1,2*	5,0 0,8	*3,0* *1,2*	4,9 0,8	*3,5* *1,3*	4,6 1,1	*3,7* *1,2*
Science - interdisciplinarity	4,5 1,0	*3,5* *1,0*	5,1 0,9	*3,0* *1,3*	5,3 0,8	*2,7* *1,1*	4,8 0,9	*2,8* *1,2*	5,1 0,9	*2,8* *1,2*	4,8 0,9	*3,1* *1,2*

Basic concepts and topics are very important for creating a new paradigm of science education. Findings related to this issue we are presenting in Table 6.

Table 6: Opinions of participants on the importance of basic concepts and topics.

Part IIa: Basic concepts and topics:	Which **priority** should the respective aspects have in science education? (Wish)						*To what* ***extent*** *are the respective aspects realized in current science education?(Reality)*					
	Students S		**Teachers T**		**Educators E**		**Scientists Sc**		**Adult T+E+Sc**		**Total S+T+E+ +Sc**	
	Mean standard deviation		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Matter / particle concept	3,8 1,1	*3,5* *1,1*	4,0 0,9	*3,8* *0,8*	4,2 0,9	*3,8* *1,0*	4,3 0,9	*3,1* *1,3*	4,2 0,9	*3,6* *1,0*	4,0 1,0	*3,6* *1,1*
Structure / function / properties	4,3 1,1	*3,9* *1,0*	4,4 0,7	*3,9* *0,8*	4,4 1,0	*3,4* *1,0*	4,4 0,9	*3,3* *1,1*	4,4 0,9	*3,6* *1,0*	4,4 1,0	*3,7* *1,0*
Chemical reactions	3,8 1,1	*4,0* *1,1*	4,0 0,9	*3,9* *0,9*	4,0 0,7	*3,3* *1,0*	4,3 0,9	*3,4* *1,0*	4,1 0,8	*3,5* *1,0*	4,0 1,0	*3,7* *1,0*
Energy	4,4 1,2	*3,7* *1,1*	4,4 0,7	*3,8* *0,6*	4,8 0,8	*3,7* *0,9*	5,2 0,8	*3,2* *1,2*	4,7 0,8	*3,6* *0,9*	4,6 1,0	*3,6* *1,0*
Terminology	3,8 1,2	*3,9* *1,2*	4,3 0,8	*4,0* *0,9*	4,1 0,9	*3,9* *1,6*	4,0 0,8	*3,7* *1,2*	4,1 0,9	*3,9* *1,3*	4,0 1,0	*3,9* *1,2*
Scientific inquiry	4,7 1,2	*3,1* *1,2*	4,5 1,0	*2,9* *0,9*	4,6 0,9	*2,8* *1,1*	4,4 1,2	*2,8* *1,3*	4,5 1,0	*2,9* *1,1*	4,6 1,1	*3,0* *1,1*
Food / nutrition	4,6 1,0	*3,6* *0,9*	5,1 0,9	*3,7* *0,8*	4,8 0,7	*3,6* *0,8*	4,6 1,3	*3,8* *1,4*	4,9 1,0	*3,7* *1,0*	4,8 1,0	*3,6* *1,0*
Health / medicine	5,0 1,1	*3,9* *1,1*	5,1 0,7	*3,6* *0,9*	4,7 0,8	*3,3* *0,7*	4,8 0,9	*3,2* *1,0*	4,9 0,8	*3,4* *0,9*	4,9 0,9	*3,6* *1,0*
Matter in everyday life	4,8 1,2	*3,5* *1,0*	5,4 1,0	*3,4* *1,0*	5,3 0,7	*3,5* *1,1*	4,7 1,1	*3,0* *1,1*	5,2 1,0	*3,3* *1,1*	5,0 1,1	*3,4* *1,0*
Safety and risk	4,8 1,1	*3,9* *1,2*	5,2 0,8	*3,5* *1,2*	4,8 1,0	*3,0* *1,0*	4,4 0,8	*3,4* *1,5*	4,8 0,9	*3,3* *1,2*	4,8 1,0	*3,5* *1,3*
Environment	3,8 1,1	*3,4* *1,2*	5,1 0,8	*3,9* *0,9*	4,9 1,0	*3,6* *1,1*	4,9 1,0	*4,4* *1,3*	5,0 0,9	*4,0* *1,1*	4,9 1,0	*3,7* *1,2*

According to findings presented in Table 6 all topics connected with issue of everyday life are underestimated in Czech schools. Participants would like to more support them similarly like scientific inquiry and environmental issue. In participants´ opinion chemical reactions and terminology have got adequate priority.

In terms of creating of a new paradigm of chemistry education participants´ opinions on representation of various chemical disciplines are important. According to our findings presented in Table 7 it is necessary to support biochemistry and ecology. We are also presenting data about mathematics, because mathematics received the higher priority of all scientific disciplines. The lowest priority is given to history of science.

Table 7: Opinions of participants on the importance of chemistry disciplines.

Part IIb: Scientific disciplines and perspectives:	Which **priority** should the respective aspects have in science education? (Wish)						*To what **extent** are the respective aspects realized in current science education?(Reality)*					
	Students S		**Teachers T**		**Educators E**		**Scientists Sc**		**Adult T+E+Sc**		**Total S+T+E+ Sc**	
	mean standard deviation		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Inorganic chemistry	3,9 1,2	*3,9* *1,1*	4,1 1,0	*3,9* *0,6*	4,0 1,4	*3,6* *1,3*	3,8 1,0	*3,5* *1,0*	3,9 1,2	*3,7* *1,0*	3,9 1,2	*3,8* *1,0*
Organic chemistry	4,1 1,3	*4,1* *1,0*	4,3 0,9	*3,8* *0,9*	3,9 1,1	*3,5* *1,0*	3,7 1,1	*3,5* *1,0*	4,0 1,1	*3,6* *0,9*	4,0 1,2	*3,8* *1,0*
Analytical Chemistry	3,9 1,1	*3,5* *1,1*	3,3 1,1	*2,9* *1,3*	3,3 1,0	*2,8* *1,1*	3,6 1,0	*2,8* *1,1*	3,4 1,0	*2,8* *1,1*	3,6 1,1	*3,1* *1,2*
Biochemistry	4,2 1,2	*3,8* *1,1*	3,8 1,2	*3,2* *1,1*	3,7 1,4	*2,7* *1,0*	2,9 1,2	*2,9* *1,2*	3,9 1,3	*2,9* *1,1*	4,0 1,2	*3,3* *1,2*
Ecology	4,7 1,1	*3,4* *1,1*	4,9 1,0	*3,9* *0,9*	4,3 1,3	*3,8* *1,3*	4,6 1,1	*4,3* *0,8*	4,6 1,1	*4,0* *1,1*	4,6 1,1	*3,8* *1,1*
History of the sciences	2,9 1,1	*3,0* *1,1*	3,3 1,1	*2,7* *0,8*	3,4 0,9	*2,4* *0,7*	2,9 1,3	*2,9* *1,3*	3,3 1,0	*2,6* *1,0*	3,2 1,0	*2,8* *1,0*
Mathematics	4,5 1,0	*4,3* *1,0*	5,1 0,8	*4,2* *1,1*	5,3 1,0	*3,9* *1,0*	3,5 0,9	*3,5* *0,9*	5,2 0,9	*3,9* *1,0*	5,0 1,0	*4,0* *1,1*

Findings presented in Table 8 are related to competences. All Participants support skills which form the basis of key competencies listed in the Czech curriculum. They state that these skills have low priority a recommend to increase their priority in Czech schools. For chemistry education participants´ support of experimentation is very positive. But we are afraid of proclamative statements. According to our experience teachers know that mentioned skills are important but they do not develop them.

Table 8: Opinions of participants connected with competences.

Part III: Qualifications:	Which **priority** should the respective aspects have in science education? (Wish)						*To what **extent** are the respective aspects realized in current science education?(Reality)*					
	Students S		**Teachers T**		**Educators E**		**Scientists Sc**		**Adult T+E+Sc**		**Total S+T+E+Sc**	
	mean standard deviation		**Mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**Mean standard deviation**	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Motivation and interest	5,3 0,8	*3,6* *0,9*	5,8 0,6	*3,8* *1,0*	5,3 1,0	*3,0* *0,7*	4,9 0,9	*3,2* *1,0*	5,4 0,9	*3,3* *1,0*	5,3 0,9	*3,4* *0,9*
Critical questioning	4,5 0,9	*3,3* *1,0*	4,8 0,9	*3,0* *1,0*	4,5 1,4	*2,5* *0,8*	4,6 0,9	*2,8* *1,0*	4,7 1,1	*2,8* *1,0*	4,6 1,0	*3,0* *1,0*
Acting reflectedly and responsibly	4,9 0,9	*3,3* *1,2*	5,0 1,0	*3,1* *1,1*	4,9 0,9	*2,9* *0,9*	4,7 0,9	*2,7* *0,9*	4,9 0,9	*2,9* *1,0*	4,9 0,9	*3,1* *1,1*
Comprehension /understanding	5,3 0,9	*3,6* *1,0*	5,3 0,7	*3,5* *0,9*	5,2 1,3	*3* *1,1*	5,2 0,8	*2,8* *1*	5,2 1,0	*3,1* *1,0*	5,2 1,0	*3,3* *1,1*
Applying knowledge, thinking creatively / abstractly	4,9 1,1	*3,5* *1,1*	5,3 0,7	*3,0* *1,0*	5,1 0,9	*2,8* *0,9*	5,1 1,0	*2,6* *1,0*	5,2 0,9	*2,8* *1,0*	5,1 1,0	*3,1* *1,1*
Judgement /opinion-forming / reflection	5,0 0,8	*3,6* *1,0*	5,4 0,8	*2,9* *1,0*	5,0 1,2	*2,5* *0,6*	5,1 1,0	*2,6* *1,0*	5,2 1,0	*2,7* *0,9*	5,1 0,9	*3,0* *1,0*
Finding information	4,9 0,9	*4,0* *1,0*	5,6 0,6	*3,8* *1,0*	5,0 0,6	*3,5* *1,0*	4,7 1,1	*3,6* *1,3*	5,1 0,9	*3,7* *1,1*	5,0 0,9	*3,8* *1,1*
Communication skills	4,9 1,3	*3,8* *1,0*	5,1 0,8	*3,5* *0,9*	5 0,9	*3,1* *0,9*	3,9 1,3	*2,9* *1,2*	4,7 1,1	*3,2* *1,0*	4,8 1,2	*3,4* *1,1*
Social skills / teamwork	5,0 0,9	*3,6* *1,1*	5,1 0,7	*3,5* *0,9*	4,8 1	*2,8* *0,9*	4,3 1,2	*2,8* *0,9*	4,7 1	*3,0* *0,9*	4,9 1,0	*3,3* *1,0*
Formulating scientific questions / hypotheses	4,1 1,2	*3,2* *1,1*	4,1 1,0	*2,5* *1,1*	4,7 1,0	*2,5* *0,9*	4,0 1,3	*2,5* *1,0*	4,3 1,1	*2,5* *1,0*	4,2 1,2	*3,1* *1,2*
Experimenting	4,8 1,1	*3,4* *1,3*	5,2 0,7	*3,3* *1,1*	5,0 1,4	*2,7* *1,2*	5,1 1,0	*2,8* *1,1*	5,1 1,0	*3,0* *1,1*	5,0 1,1	*3,0* *1,1*
Rational thinking / analysing / drawing conclusions	4,8 0,8	*3,6* *1,0*	5,3 0,7	*2,7* *1,1*	5,1 1,0	*2,7* *0,8*	5,2 1,0	*2,6* *1,0*	5,2 0,9	*2,7* *1,0*	5,1 0,9	*3,0* *1,1*

According to educators innovative methods are suitable for acquiring the desired knowledge and skills, so therefore we have also examined participants´ opinions on methodical aspects. All participants (especially adults) want to support priority of interdisciplinary learning. Inquiry-based science learning recommended by experts is supported by all participants as well. Interesting findings is that difference between reality and wish connected with Inquiry-based science education at students´ group is the lowest. Students believe that they have in instruction more IBSE than teachers report (see Table 9).

Table 9: Opinions of participants connected with methodical aspects.

Part IV: Methodical aspects:	Which **priority** should the respective aspects have in science education? (Wish)						*To what **extent** are the respective aspects realized in current science education?(Reality)*					
	Students S		**Teachers T**		**Educators E**		**Scientists Sc**		**Adult T+E+Sc**		**Total S+T+E+Sc**	
	mean standard deviation		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**		**mean standard deviation**	
N	**56**		**30**		**28**		**25**		**83**		**139**	
Cooperative Learning	4,1 1,1	*3,5* *0,8*	4,3 0,9	*2,9* *0,8*	4,4 0,8	*2,6* *0,9*	3,8 1,0	*2,9* *0,9*	4,2 0,9	*2,8* *0,9*	4,2 1,0	*3,1* *0,9*
Learning in mixed-aged classes	2,9 1,4	*2,2* *1,1*	2,7 1,2	*1,7* *0,9*	2,5 1,1	*1,7* *1,1*	2,5 1,0	*2,2* *1,2*	2,6 1,1	*1,8* *1,1*	2,7 1,2	*2,0* *1,1*
Interdisciplinar y learning	3,8 1,1	*3,2* *1,1*	4,6 1,1	*2,6* *0,9*	4,4 1,3	*2,5* *0,8*	4,1 1,1	*2,8* *1,2*	4,4 1,2	*2,6* *0,9*	4,2 1,2	*2,8* *1,1*
Inquiry-based science education	4,3 1,3	*3,0* *1,0*	4,9 0,9	*2,6* *1,2*	4,4 1,2	*2,0* *0,8*	4,0 1,2	*2,0* *1,1*	4,5 1,2	*2,2* *1,1*	4,4 1,2	*2,5* *1,1*
Discussion / debate	4,7 1,1	*3,1* *1,0*	5 0,9	*3,4* *1,1*	4,8 0,8	*3,3* *1,2*	4,4 1,3	*2,8* *1,2*	4,7 1,0	*3,2* *1,2*	4,7 1,0	*3,2* *1,1*
Using new media	4,6 1,2	*3,4* *1,1*	5 0,7	*4,1* *1,0*	4,2 1,0	*3,4* *1,2*	4,2 1,1	*3,6* *1,0*	4,5 1,0	*3,7* *1,1*	4,5 1,1	*3,6* *1,1*

To answer the question number two “*Which conceptual frameworks are considered as being necessary and important for chemistry education?”* we are presenting findings of the third round of the PROFILES curricular Delphi study on science education. This round has also interesting conclusions from which we select common results. The main output is a set of concepts in science education. Here is a brief description of these concepts A, B, and C:

(A) Awareness of the sciences in current, social, globally relevant and occupational contexts in both educational and out-of-school settings refers to an engagement with the sciences within the frame of current, social, globally relevant, occupational and both educational and out-of-school contexts, enhancing emotional personality development and basic skills.

(B) Intellectual education in interdisciplinary scientific contexts refers to an engagement with the sciences, their terminology, their methods, their basic concepts, their interdisciplinary relations, their findings and their perspectives, which enhance individual intellectual personality development.

(C) General science-related education and facilitation of interest in contexts of nature, everyday life and living environment refers to a science-related engagement with everyday life and living environment issues that takes up and promotes students' interests, enhancing general personality development and education. Dealing with topics from the natural and technological living environment shows how scientific research, scientific applications and scientific phenomena influence both public and personal life.

The third round PROFILES curricular Delphi study on science education is to determine priorities and opinion of realization of these concepts in science education with different groups of participants. Issues important for new attitude to chemistry education are in all the three concepts, but there is serious representation of recommended topics in the third concept (C). The research result shows that the priority and opinion of realization of different groups of participants are very different. All these concepts gained their supporters. Slight predominance had a concept C, which is preferred especially by students and teachers. Scientists slightly preferred concept B. On the contrary, as the concept of science education, which is established in Czech schools, participants determined concept B. Since the views about the concept of education are very important (above mentioned reasons), we have investigated in larger group of teachers, what concept they prefer. We are presenting priorities and opinion of realization in the group of 145 science teachers (see Figure 1 and 2).

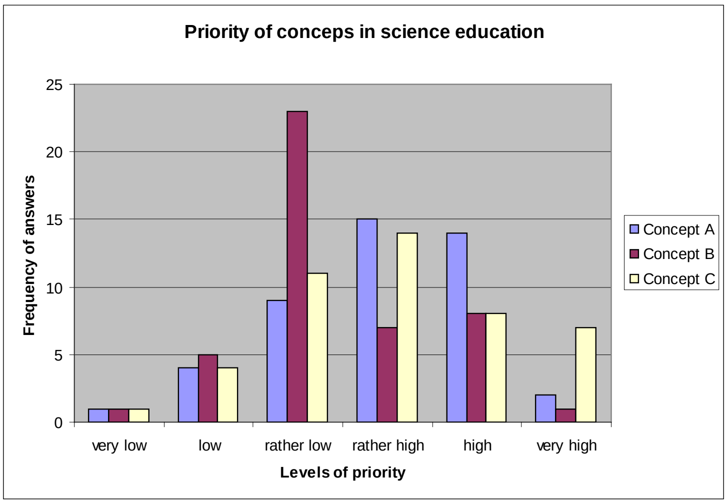

Figure 1: Priority of concepts.

Czech teachers tended towards a slight predominance for option C. Option A was chosen as the second option and option B was supported the least. These results confirm a change in the way Czech teachers thinking about the teaching of science. Earlier research has shown that Czech teachers preferred the view that school science subjects need to copy the structure of science and students should be "little natural scientists." This earlier view of teaching science is related to option B and is also related to the classical way of teaching, which preferred an 'active teacher' to an 'active student.' With the change in the concept of science education comes the need to change the way of teaching and 'energize' students in the new vision. This demands greater teacher competence and this in turn is dependent on teacher creativity.

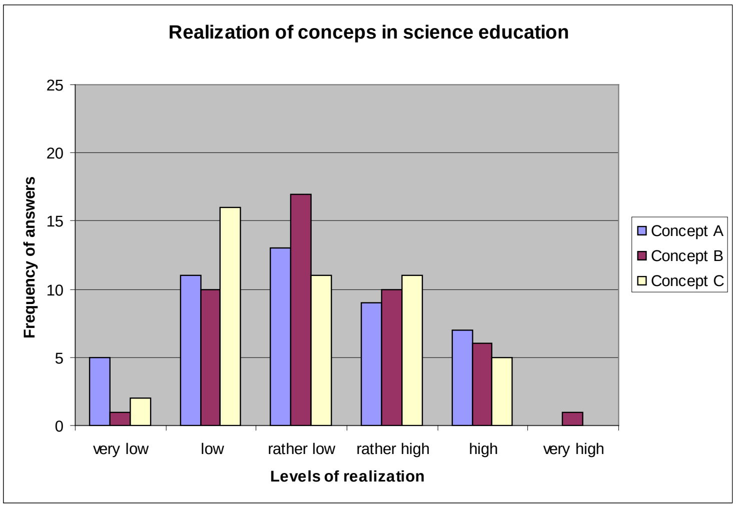

Figure 2: Realization of concepts.

The graphs show that teachers wish the concept C involving recommended issues for a new paradigm would have a higher priority (see the number of responses with the highest priority), but reality is different. The positive finding is that teachers prefer concepts, where these issues are more contained. But negative finding is that teachers who can influence concepts in science education declare that in practice these concepts are not implemented. The reason may be inertia of the old way of science education.

CONCLUSION

According to experts a new paradigm of chemistry (science) education is needed. To create high quality paradigm it is necessary to know the views of all stakeholders on the basic issues connected with creating a new paradigm of chemistry (science) education. Using the PROFILES curricular Delphi study on science education we have determined their priorities and opinion on global ecology and the theory of sustainable development, key concepts and theories, content connected with everyday life, competences and interdisciplinarity as recommended issues (Doulík, 2009).

The main result of our research is a set of concepts (A, B and C) in science education which involved chemistry education. These concepts arose from the responses of all stakeholders and thus reflect their views on education in Czech schools. We have got their opinions on how education should look like. It is gratifying that their wishes coincide with the views of experts on future science education. But negative finding is that stakeholders state that reality in Czech schools is different. So our findings confirm that Czech educators in reality preferred the view that school science subjects need to copy the structure of science and students should be "little natural scientists." That is why we verified this output in the larger group of teachers, but our findings of Delphi study was confirmed. Teachers who can influence concepts in science education declare that in practice these concepts are not implemented. The reason may be inertia of the old way of science education. But the first step was done – all stakeholders are aware that science education should change and what is very positive they know what changes should be realized in Czech schools. But it is not easy to change teachers' beliefs therefore it is important to pay attention to teacher education in pre- service and in-service as well.

ACKNOWLEDGEMENT

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REFERENCES

Bolte, C. 2008. A Conceptual Framework for the Enhancement of Popularity and Relevance of Science Education for Scientific Literacy, based on Stakeholders' Views by Means of a Curricular Delphi Study in Chemistry. *Science Education International*. 19(3), 331-350.

Bybee, R. W., Fuchs, B. 2006. Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching*, 43(4), 349-352.

Coufalova, J., Minhova, J. , Vankova, J. 2003. Restructuring of teacher training in order to improve its quality. In: *Quality Education in European Context and the Dakar Follow-up.* (pp. 53-57). Nitra: Constantine the Philosopher University.

Darling-Hammond, L. 2000. Teacher Quality and Student Achievement. a Review of State Policy Evidence. *Education Policy Analysis Archives.*

Duffy, G., Roehler, L. 1986. Constraints on teacher change. *Journal of Teacher Education*, 35, 55-58.

Fullan, M. G. 1991. *The New Meaning of Educational Change.* New York: Teachers College Press.

Hanusek, A. E., Kain, F. J., Rivkin, G. S. 2005. Teachers, Schools, and Academic Achievement. *Econometrica*, 2, 417-458.

Herron J. D., Nurrenbern, S. C. 1999. Chemical Education Research: Improving Chemistry Learning. *Journal of Chemical Education* **76** (10), 1353.

Lederman, N. G. 1999. Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of research in science teaching*, 36(8), 916-929.

Osborne, J., Dillon, J. 2008. Science Education in Europe: Critical Reflections. The Nuffield Foundation, London. [online] Available at <http://hub.mspnet.org/index.cfm/15065> [Accessed 12 November 2013].

Osborne. J. F., Ratcliffe, M., Collins, S., Millar, R., Duschl, R. 2001. *What should we teach about science? A Delphi study.* London: King's College.

Osborne, J. F., Ratcliffe, M., Collins, S., Millar, R., Dusch, R. 2003. What "Ideas-about-Science 'Should Be Taught in School Science? A Delphi Study of the Expert Community. *Journal of Research in Science Teaching*, 40(7), 692-720.

Pajares, M. F. 1992. Teachers' Beliefs and Educational Research: Cleaning Up a Messy Construct. *Review of Educational Research,* 62, 307-332.

Pellegrino, J. W., Hilton, M. L. 2012. *Education for life and work: developing transferable knowledge and skills in the 21st century.* Washington, D.C.: National Academies Press.

Powers, S. W., Zippay, C., Butler, B. 2006. Investigating Connections between Teacher Beliefs and Instructional Practices with Struggling Readers. *Reading Horizons*, 47(2).

PROFILES project. 2013. [online] Available at <http://www.profiles-project.eu/> [Accessed 12 May 2014].

Raymond, A. M. 1997. Inconsistency between a beginning elementary school teacher's mathematics beliefs and teaching practice. *Journal for research in mathematics education*, 550-576.

Richardson, V. 1998. How teachers change. *Focus on Basics*, 2(C), 1-10.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Herniksson, H., Hemmo, V. 2007. Science Education NOW: A Renewed Pedagogy for the Future of Europe. [online] Available at < from http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf> [Accessed 12 March 2013].

Škoda, J., Doulík, P., 2009. Vývoj paradigmat přírodovědného vzdělávání. *Pedagogická orientace*, 19 (3), 24-44.

MOBILE LEARNING IN CHEMISTRY CLASSES – AN INTRODUCTION AND PRACTICAL TIPS

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Abstract

Chemistry is considered a difficult subject. The reason for this is the necessary ability to abstract, in order to understand the background and sequences of chemical processes that are macroscopically invisible. This ability must first be acquired – which involves deconstructing existing, mostly incompatible knowledge structures. Media are in this context a necessary teaching aid. Teachers have to use assistance in training students how to set up understanding for chemical processes. Therefore media must be integrated as a part of lessons. It is essential to know which media are suitable and how to use them. A special approach to digital media is inevitable. With the help of a tablet or a smartphone worksheets, films, photos and instruction guides for experiments are accessible at any time. It is always available as a medium for presentations and individual performance tests can be offered, too. Every student knows how to use this media, so it is essential to implement them in a new form of teaching we call "Mobile Learning". The secondary school "Realschule am Europakanal" in Erlangen, Germany, has already successfully integrated tablets as part of the curriculum in all subjects. In project classes students use this medium for all learning purposes. Chemistry also benefits from this new method of open lessons, which allows students to work together, even outside of rigid class rules.

Keywords

Mobile Learning. Smartphone. PC. New Media. Theory of Learning. Models. Experiments. Practical Tips.

INTRODUCTION

In the average school, chemistry is a subject which is very unpopular with students – and therefore also difficult for teachers to teach. One reason for this negative approach is not having the ability to abstract. This is a necessary skill in order to understand the background and sequences of chemical process that are macroscopically invisible. Only those who are able to grasp the concepts of models and their associated resources from the sub-microscopic level, and visualise the processes for themselves, have the possibility to understand chemistry and appreciate it for what it is: a fundamental science that provides explanations for many everyday phenomena. However, establishing this ability to abstract is a great challenge for teachers, as it usually involves deconstructing existing, but incompatible, knowledge structures.

One way of helping teachers was and is the use of various pre-defined media and models as well as a terminology which sets itself apart from everyday language, but is often seen by students as a collection of unrelated letters and symbols. Therefore a rethinking is necessary in the way chemical relationships are taught, in order to meet the needs of students in the 21st century.

The role of communications media as a way of describing scientific chemical relationships to students is fundamental for chemistry lessons. This includes personal forms of instruction, mostly carried out by teachers, as well as non-personal forms such as experiments (which, at the same time, is much more than just a medium), films, diagrams, models or supplements. The most successful medium today, however, is digital – whether in the form of PCs, Tablets or Smartphones. Every student is familiar with these platforms, since they already form a central part of young people's lives, shown in Figure 1 and Figure 2 based on the JIM study 2013 (Jugend, Information, (Multi-) Media) (mpfs.de, 2013).

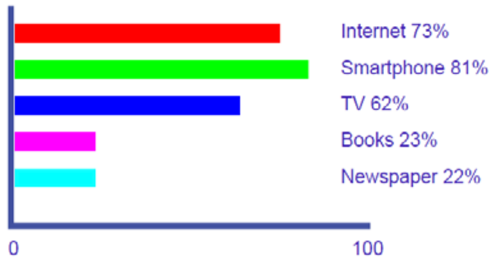

Figure 1: Spare-time activities of students. (Urbanger, based on JIM study 2013)

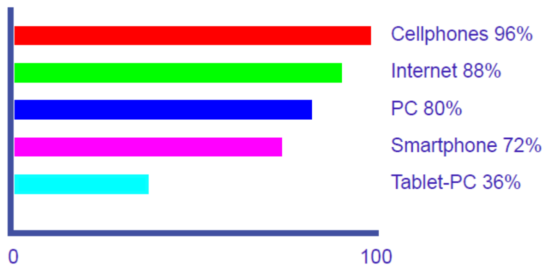

Figure 2: Possession of media devices of students.
(Urbanger, based on JIM study 2013)

It stands to reason that chemistry lessons should incorporate the use of such common skills and media to establish a new form of learning: Mobile Learning.

Considerations for learning theory

The cognitive development of students is characterised by the acquisition of knowledge.

> "Knowledge and the transfer of knowledge are integral components of something, which can be regarded as the basic form of social life, namely the cooperation of two people in the examination of objects in their environment with the aid of appropriate tools" (Schnotz, 1996, p. 18, translated into English language)

Useful knowledge needs not only tools, or media, which serve to transmit knowledge of the topic to the learner, but also constant repetition to independently use the knowledge to develop further knowledge, skills and abilities. One aid could be, alongside media, the inclusion of everyday ideas and knowledge, as long as they are not incorrect or hinder the subject matter. Learning in groups, which Schnotz reduces to only two people, increases the core competencies which also apply to chemistry lessons: social competence, the ability to communicate and the ability to work with media. The useful knowledge gained, which must be the goal of every lesson, can be increased if the teacher can cause an intrinsic motivation for the topic in the students. This can be achieved through independent activities by students, such as experimentation and by using familiar digital media.

In general there are different methods of teaching available, which are geared toward different topics, so as to impart chemical knowledge. On the one hand, the technical subject of chemistry can itself be a possible point of orientation; however in contrast to the everyday experiences of students, this has a prerequisite of already existing knowledge of chemistry. A difficult way, but which is a good choice in a transition subject, is using the "genesis orientation", where the lesson is based on the origin of a particular chemical product or a particular development in chemistry. Today's chemistry lessons are taught as a problem-oriented subject, which, at the beginning of a topic, poses a question from supposed "everyday life" to students. This is sometimes difficult, as the student often require pre-requisite knowledge, in order to recognise a problem and make suggestions. Without previous knowledge no hypotheses can be developed. For teachers this means a change in the way lessons are planned. Depending on what knowledge the students already possess, epistemologically there are three possible situations: The students do not have any previous knowledge. In this case a topic can be introduced by investigating an actual situation, and the students can acquire the knowledge directly. If there is some previous knowledge, the students can develop a working hypothesis, then review this and then by using appropriate methods (e.g. an experiment) it can be verified or disproved. If the circumstances are already known, this can be described in more detail, and it is possible to transfer this knowledge to other, similar chemical circumstances.

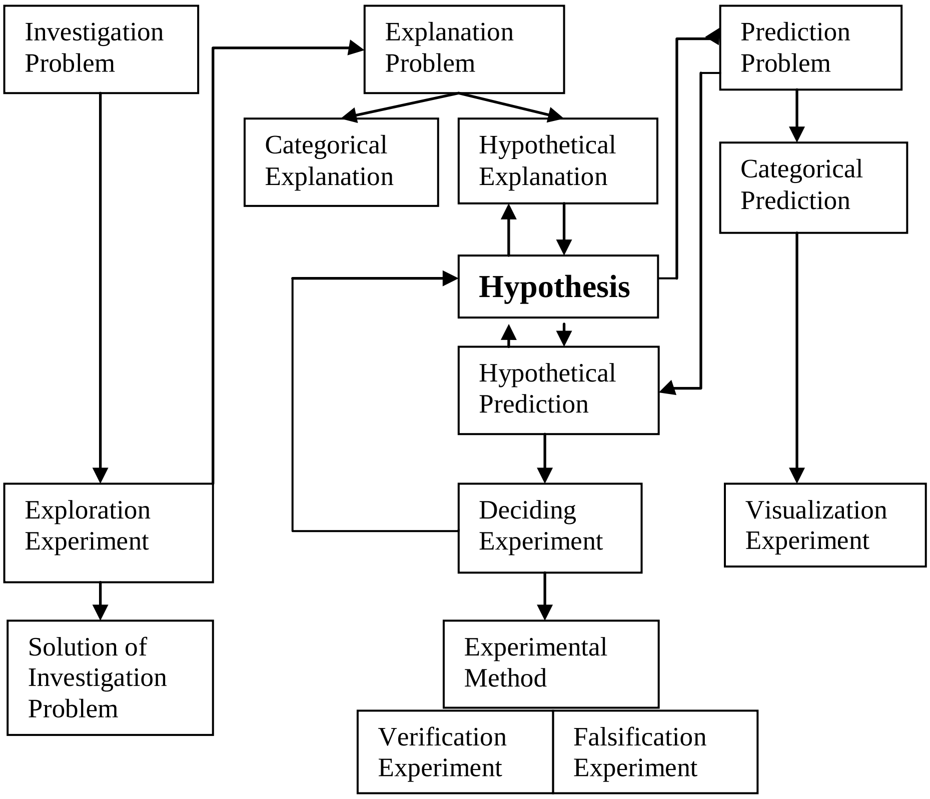

Figure 3: Epistemological Experimental Classification

Ideally each of these three possibilities can be coupled to the scientific method of experimentation, so that, according to Kometz and Legall (Kometz and Legall, 1994), every type of problem is associated with an appropriate experiment. For an Investigation Problem, an Exploration Experiment can be used; if it is an Explanation Problem, a Deciding Experiment is possible; and should a Prediction Problem present itself, then a more details can be acquired using a Visualization Experiment. Figure 3 illustrates a Schema of problem type and their relationships.

Media in Chemistry Lessons

The possibilities of using media in chemistry lessons, both digital as well as "classic" media, are becoming more varied, especially as both forms can be used in combination. Therefore it is inevitable that the use and application of media in chemistry lessons must be considered. This is generally accomplished using the term Media Education, which is required equally for all subjects, but which must be adjusted according to the demands of each subject.

> "As well as well-tried (and indispensable) methods of teaching, such as the experiment [...] or the blackboard, there are more and more modern methods being used such as the interactive whiteboard or the internet, as the can impart essential core knowledge." (Kometz, 2013, p. 364, translated into English language)

Therefore an essential competence is media competence, which should be acquired and used by teachers. Students should use various media to help understand chemical processes and apply that knowledge. Here, the role of media is to connect two levels of chemistry: the macroscopic, material level, which can demonstrate visually, aurally or audio-visually, phenomena such as colour changes, precipitation, temperature changes, sounds, etc.; and the sub-microscopic or particle level, in which can illustrate invisible atomic or molecular changes. The constant switching between levels can make chemistry lessons difficult for students, as they must first learn that the occurrences at the macroscopic level can only be explained with the help of the sub-microscopic level. So for every occurrence at the material level, the student must know about the appropriate sub-microscopic process, in order to acquire useful chemical knowledge. It is at exactly this point where using media can make the difference.

A precise definition of methods for chemistry lessons is based on a classification by Stumpf (Stumpf, 1979, 1980). Teaching methods can be separated into personal and impersonal methods, where personal methods include language, gestures, movements and expressions of the teacher, or the teaching role assumed by students. The impersonal teaching methods represent the so-called subject matter for the lesson. For chemistry lessons these are relatively clearly defined, and can be separated into real existing objects and illustrations. Real object are, according to Kometz, all the natural materials that can be used in lessons, or substances e.g. materials on a specimen holder. Illustrations are digital applications on a PC or Tablet, or a combination of digital background, the model, or – as a decisive and indispensable source of knowledge in chemistry lessons – the experiment. A summary of the classification is shown in Table 3. (Kometz, 2013)

Experiments, depending on the perspective, are not just a medium of teaching, but also learning material, as they serve to impart knowledge. They are also a method of teaching as they allow the acquisition of chemical abilities and competencies, or as a method of realization. The experiment used as a medium in the teaching process therefore allows the transfer of knowledge, it can verify existing knowledge and demonstrate and illustrate this acquired knowledge. The experiment can be adapted to the circumstances of the school or to the situation in the class. It can be adapted for macro, semi-micro or microscopic scales, and also be carried out by either students or teachers. Terminologically, the experiment should not be equated with a test, as an experiment consists of much more than a test, as it involves an evaluation in the forms of observation and explanation (cf. Kometz, 2013)

Table 1: Classification of impersonal teaching methods

Reality:	original prepared	Inanimate or alive
Simulation:	Model Experiment	
Illustration:	audio visual audiovisual	
Symbol:	Graphic Symbol Color	

The model as a medium, considered on its own, allows a further classification with regard to accurately defining depicted reality. Material models are molecular diagrams or substances that can represent an entire group of similar substances. Iconic models are mostly used to illustrate atomic or properties, e.g. valence numbers. In contrast, symbolic models allow the written representation of chemical processes, e.g. reaction equations.

Digital media are becoming more widespread in chemistry lessons. They combine the functions of several other media and clearly expand on these, or allow completely new access for students. Abstract models like simulations are no longer difficult to create thanks to the large number of versatile software programs available for PC or tablet, and can facilitate the acquisition of knowledge. The area of experiments can also benefit from digital support, with an enormous potential in the area of recording measurement values. Furthermore, classical media such as the blackboard or the overhead projector can be combined using an interactive whiteboard, and allows more visually appealing access to knowledge. One property of digital media which cannot be underestimated is the mobility provided by current devices. They can be used outside the rigid structure of the classroom and allow chemical knowledge to be acquired and studied anywhere, and at any time.

Mobile Learning

Learning is the acquisition of knowledge, abilities, skills and the ability to apply them. If the chemistry teacher can succeed in appealing to existing knowledge or abilities, then new chemistry knowledge and skills can be integrated easier. Therefore the logical consequence is a combination of existing abilities in the use of digital media – since every student has them – and the specialised knowledge of chemistry.

New media can be combined in a large variety of ways, from both a technical and a didactic perspective. The different forms of chip-based systems like PCs, Laptops, Tablets or Smartphones can be easily connected to each other thanks to modern connectivity technologies such as Wireless LAN (WLAN) and Bluetooth. Even the obstacle from earlier times – the operating system – is no longer relevant. Files can be sent directly from device to device, or can be stored in so-called Clouds, i.e. data storage space in the World Wide Web, and can be accessed at any time from any device. Similarly wireless communications allow material from the internet to be used anywhere.

The teaching and study material used on the computer systems appeals to different senses in different degrees, depending on what content is being transmitted and how it is displayed (film, text, etc.). The versatile forms of display and presentation, the various demonstrations of course material that can be optimally adjusted to fit the learning requirements, the possibility to quickly edit and annotate the material by both students and teachers and the numerous ways of presentation make these systems indispensable as a modern medium of teaching. Also, the extensive collections of material, which is mostly accessible online, the many sources of knowledge and assistance and the possibility to converse via communications platforms such as chat-rooms and instant messaging services all serve to enhance the teaching and learning processes in the chemistry classroom.

Computer-based learning can lead to higher academic success. This was shown in a meta-study by Kulik and Kulik (Kulik and Kulik, 1991), in which 81% of those surveyed perceived this new form of learning a success. The use of computers or their "smaller relatives" in the classroom is nothing new – it has been around for around two decades – but the technology is constantly improving and the possibilities are becoming ever greater. More and more schools are being equipped with interactive whiteboards, laptops and projectors in order to meet the requirements for media-based education. But this is not enough to allow Mobile Learning.

Mobile Learning can only be achieved when the subject matter, which can still be defined by the teacher, is freed from the rigid structures of the lessons and the classroom. The heterogeneous learning requirements as well as the interests of the students mean that the use of digital media demand much more leeway for self-guided work and the possibility to process the subject matter in locations conducive to motivation. Therefore a requirement for Mobile Learning is student access to a mobile computer system which can access online content. The digital medium must be integrated as a central component of planned lessons and must be able to perform all tasks that would previously have been fulfilled by other media. In particular it must be both a school book and exercise book, cover the entire spectrum of impersonal media, and function as a distribution point for all important material. With the help of a tablet or smartphone, work-sheets, films, photos and experiment guides can be made accessible any time. There is always a medium for presentations available and individual performance tests can be offered. Learning no longer takes place just in the classroom; rather it can take place anywhere that the student feels comfortable and can work effectively. For chemistry lessons this presents a great opportunity, as students can better understand complex sub-microscopic processes using various programs on a tablet or by accessing online knowledge-bases. Since the rigid class structure is removed, smaller study groups can be formed which can enhance communication abilities, can work on abstract chemical topics together, but always with the possibility to consult with other groups. The additional freedom achieved in the laboratory can be used by students – upon consultation with the teacher – for self-planned experiments. This leads to a significant improvement in experimental technique.

Therefore Mobile Learning in chemistry means that knowledge about a particular chemical topic can be acquired at anytime and anywhere; experiments can be self-planned and then carried out in the school laboratory; topics can be discussed with others and students can make use of aids from other subjects (e.g. IT). It also means that the class should meet together with the teacher at the end of a study-phase to present results and share findings with fellow students, especially if model simulations or films were produced during the study-phase.

Practical example

The integration of this learning method in classes and in the normal school day is starting to increase in schools. It must be clear however, that the mere acquisition of tablets is not sufficient. More importantly, the infrastructure demands in the school must be met. Every student with a computer-based learning device must have online access. The school must have WLAN with sufficient coverage. School books must be available either online or as e-books. There must be a way to present material from mobile devices on to a large screen, e.g. with a projector or an interactive whiteboard. It is also a significant challenge for teachers to make the transition to Mobile Learning, as the hitherto existing lesson plans will no longer work. The teacher must disengage his or her self from the role of instructor, and must become a coordinator and moderator, that only provides the material or offers help. In particular, the self-guided experiments present a great challenge, as the teacher must quickly evaluate the experiment for potential danger. The Realschule am Europakanal in Erlangen, Germany, has successfully established the iPad® as a teaching platform, which meets the requirements of Mobile Learning. The tablet is currently used in twelve classes from 7th to 10th Grade. The implementation in chemistry lessons has been successful, as it has in other subjects and the students possess various ways to acquire knowledge.

The tablets have apps for making presentations, writing, drawing, calculating, filming experiments, analysing data, data logging, interactive PTE, modelling of molecules etc. There are Modules for each subject to teach the students social, specialized and media skills, e.g. finding out about important people in chemistry and presenting the achievements in front of the class, demonstrating experiments etc. The Tablet-PC is highly accepted among students and is used for the chosen purposes in school. The parents are teaming up with the concept as well as teachers who work interdisciplinary with the classes. The marks are not different to comparative classes without Tablet-PCs, but social and media skills are better developed. The use of the Tablet-PCs for class tests is accepted and not catchier than other test forms.

In Figure 4 you can see some QR-Codes linking to sites of the school's own blog, YouTube channel and informational page.

Figure 4: QR-Codes to the school's websites.

Future prospects

Mobile Learning is a great chance to teach students not only factual knowledge, but let them obtain socially relevant skills, like social skills, media skills and cognitive abilities. This is important especially in chemistry, which is a misunderstood subject among wide parts of the populace. Of course such a radical change of teaching methods places high demands on the infrastructure of the school and on the ability of teachers to adapt lessons to the requirements of using this medium.

Since the design of the lessons has to be reorganized so that the students can achieve chemical expertise and understanding in an uncommitted, self-regulated and interdisciplinary setting, it is not only necessary to redefine the classroom situation technically and individual related, it is also essential to stop the teacher being an instructor but being a helpful, computer-wise and artistically minded coach. For qualifying the chemistry teachers to be the demanded educator it is necessary to provide training courses in using modern media including necessary programs.

But if it is possible to train the teachers in the necessary skills to allow successful Mobile Learning, to equip the schools appropriately and the students show enthusiasm and motivation for the new methods, then chemistry lessons can be freed from its "niche" and can, like other subjects, be impartially presented as it really is: a fundamental science that can explain everyday phenomena.

References

Barke, H.-D., 2006. *Chemiedidaktik: Diagnose und Korrektur von Schülervorstellungen.* Heidelberg: Springer Verlag.

Barke, H.-D., 2011. *Chemiedidaktik kompakt.* Heidelberg: Springer Verlag.

Cole, R., Todd, J., 2003. Effects of Web-Based Multimedia Homework with Immediate Rich Feedback on Student Learning in General Chemistry. *Journal of Chemical Education*, 80(11), pp.1338–1343.

Hadenfeldt, J., Parchamnn, I. u.a., 2013. Using Ordered Multiple-Choice Items To Assess Students' Understanding of the Structure and Composition of Matter. *Journal of Chemical Education*, 90(12), pp.1602–1608.

Kerres, M., 2012. *Mediendidaktik. Konzeption und Entwicklung mediengestützter Lernangebote.* München: Oldenbourg Verlag.

Kometz, A., 2013. Medienbildung in der Chemiedidaktik. In: M. Pirner, ed. 2013. *Medienbildung in schulischen Kontexten.* München: kopaed. pp.363-384

Kometz, A., 1996. *Zum Einsatz unterstützender Umterrichtsmedien bei Nutzung der Küvettentechnik in Kombination mit Halbmikrotechnik-Gerätesystemen im Chemieunterricht.* Frankfurt / M: Peter Lang.

Kometz, A. and W. D. Legall, 1994. Die Küvettentechnik – Überlegungen zum methodisch-didaktischen Einsatz im Chemieunterricht In: H. Behrend, ed. 1994. *Zur Didaktik der Physik und Chemie.* Alsbach / Bergstraße: Leuchtturm-Verlag. pp.229-231.

Kulik, C.-L. and Kulik, J., 1991. Effectiveness of computer-basedinstruction: An update analysis. *Computers in Human Behavior*, 7(1991), pp. 75–94.

Schnotz, W., 1996. Psychologische Aspekte des Wissenserwerbs und der Wissensveränderung. In: Duit, R. / von Rhöneck, C., ed. 1996*: Lernen in den Naturwissenschaften.* Kiel: IPN Leibniz-Institut für die Pädagogik der Naturwissenschaften an der Universität Kiel

Stumpf, K., 1979. Das Lernen mit Medien. *Der Chemieunterricht,* 10(1), pp. 6-24.

Stumpf, K., 1980. Die Projektion von Experimenten im Chemieunterricht. *Der Chemieunterricht,* 11(1), pp. 5-96.

A FIRST STEP INTO THE CYBER-CLASSROOM - EVALUATION OF A LEARNING SETTING WITH STEREOSCOPIC 3D CONTENT

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Abstract

The Cyber-Classroom offers stereoscopic 3D visualizations, e.g. for curricular Chemistry topics. This visualization technique might improve the understanding of abstract chemical content for example the structure of atoms or chemical bonding. Before investigating the effects of those stereoscopic 3D visualizations on learners' content knowledge and motivation, teachers and students of the twelve Cyber-Classroom schools in Germany have been asked to evaluate the handling of the system and the quality of the modules. Eleven teachers and 114 students participated in the evaluation using a web-based or paper-pencil questionnaire. Through this evaluation very useful information have been gathered to improve the implication of the Cyber-Classroom in schools (e.g. the development of support materials, access to a web-based version). By rating the quality of the modules, similarities and differences between teachers' and students' opinions became visible and will be addressed during a revision of those modules. Further necessary actions such as workshops on the handling as well as on the development of support materials could be identified.

Keywords

3D visualization. Science education. Student evaluation. Teacher evaluation. 3D learning environment.

INTRODUCTION

Changes in our visual culture

Visualisation techniques used in everyday-life as well as in educational settings have changed dramatically since the end of the 19^{th} century. The development first went from drawings to photographs to film. Later computer animated visualization techniques were added to the repertoire and today we can experience stereoscopic 3D movies not only at cinemas but also on home

TV sets. During the past years, stereoscopic 3D technology spread into our everyday-life. In Germany every fifth movie ticket is sold for a 3D film (Agir.Media, 2012). Sales figures for 3D TV sets are increasing (Statista, 2014).

But unfortunately the last step of this rapid change has not reached most classrooms yet. Although first case studies about pilot projects have shown promising results indicating positive effects of 3D visualizations on students' motivation and understanding (Bamford, 2011; Leung, et al., 2012), the majority of universities and schools in Germany lack the equipment for the application of 3D technology. Nevertheless, with further developments the 3D technology is expected to be "slowly finding its way into college classrooms" where students are taken on "fantastic voyages inside the human body, to the ruins of ancient Greece - even to faraway galaxies"(Norbury, 2012). That is why one major question about the future of visualization techniques in education might be: "3D, or Not to Be?" (Norbury, 2012). By creating the Cyber-Classroom project Evonik has taken a serious interest in financially supporting the implementation of modern technology in schools (Evonik, 2011). They take science education into the third dimension in order to enhance motivation for science learning.

Introducing the Cyber-Classroom

In cooperation with the company Visenso twelve German schools all across the country have been equipped with the Cyber-Classroom bundle. This includes a graphics PC, the interaction device VRiiD based on the Wii-controller, a stereo TV device and a set of 3D stereo polarizing filter glasses. Visenso is a leading contractor of Virtual Reality (VR) software for the analysis of numerical results and develops tools for engineers. The Cyber-Classroom software has been developed by engineers, mathematicians and scientists. Currently, modules for schools are available for Art, Biology, Chemistry, Physical Education and Physics. In addition, Google Sketch-up can be used to develop modules (For further information: www.cyber-classroom.de).

Figure 1: Impressions from CYBER-CLASSROOMs (by VISENSO)

All module contain stereoscopic 3D visualizations. Some visualizations are static others animated. They have been illustrated, certain aspects were highlighted and simplifications were made where necessary. In the Biology modules most of the visualizations can essentially be described as scale-ups of objects from the macroscopic level and glimpses into the inside of objects (Figure 2).

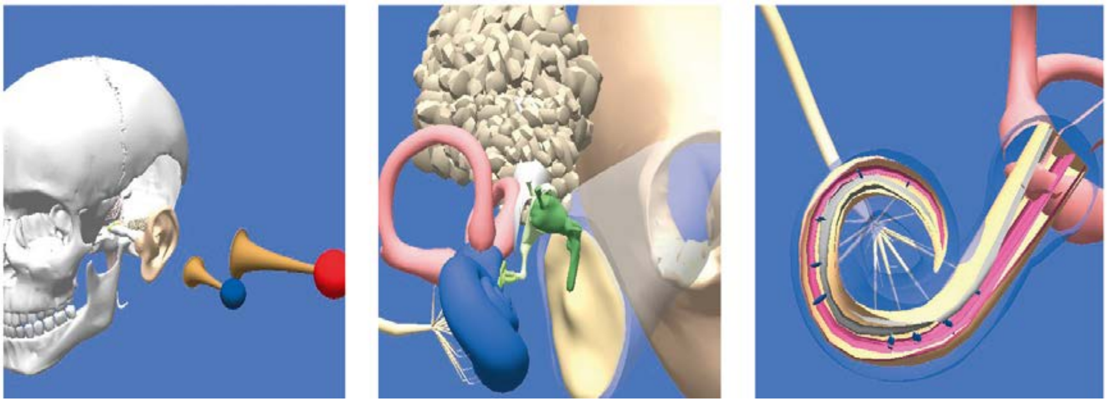

Figure 2: Macroscopic representation in a Cyber-Classroom Biology module (by VISENSO)

3D representations of processes in industrial plants or experimental set-ups in Chemistry are similar to these visualizations. But when it comes to visualizations of the structure of an atom, chemical reactions or reaction mechanisms, these cannot be labelled as modified scale-ups. More accurately, they can be described as visualizations of basic chemical models that are based on theories and experimental evidence (Figure 3).

Figure. 3: Symbolic representation in a Cyber-Classroom chemistry module (by VISENSO)

These microscopic and symbolic chemical representations have been found to be especially difficult to understand for students (Kind, 2004; Wu, et al., 2001). They are abstract and theory-laden. In order to understand them, the students have to link the visual information with conceptual ideas. 3D visualizations offer additional spatial information that could lead to a better understanding. In addition, another positive effect might be an increase in motivation which might foster the interaction with the content and thereby could lead to higher learning outcomes. In preparation of studies that will investigate the effects of stereoscopic 3D visualizations on content knowledge and motivation the handling of the system and the quality of the modules have to be ensured. Therefore a first evaluation of the implementation of the Chemistry modules in schools has been conducted. For this evaluation our main interests were:

1. Do teachers actually use the Cyber-Classroom in their Chemistry lessons?
2. How do teachers and students rate the quality of the Cyber-Classroom chemistry modules?
3. What do students like and dislike about working with the Cyber-Classroom?
4. Which improvements do teachers suggest?

METHOD

To collect the required data two separate questionnaires were designed; one for students and the other one for teachers. Both consist of closed and open question that relate to the different aspects of the evaluation. For further analysis the student questionnaire also contains attitude towards science measures (Kind, Jones, & Barmby, 2007). During the first phase this study was conducted as a web-based survey using Evasys. The contact persons at each of the twelve Cyber-Classroom schools were invited via email to take part in the survey with all their chemistry teachers and at least one class grade 5-9 (age 10-15) and if possible one class grade 10-12 (age 15-18) that have experienced at least one lesson using the Cyber-Classroom. Unfortunately the response rate was poor. Only 8 teachers and 34 students completed the corresponding web-based questionnaire. As a result the identical questionnaires were used as printed versions in the second phase of data collection. The data collection is still ongoing. The following results presents the data collected since the beginning of the evaluation in March 2014 until the end of June 2014. They contain all responses of the web-based and paper versions of the questionnaires.

Sample

Until June 2014 a total of 11 teachers (4 female and 6 male, 1 missing information) and 114 students (30 female and 76 male, 8 missing information) of the Cyber-Classroom schools voluntarily participated in this survey. The students attend grade 7-10 and are aged between 12 and 17. The teachers are aged between 31 and 57. They have between 2 and 32 years of teaching experience.

RESULTS

The data show that the teachers have used the Cyber-Classroom between one and 96 times in their chemistry lessons. Due to the fact that the schools have not been equipped with the cyber-classroom at the same time (July 2011-December 2013) the data cannot be compared but it clearly shows that the Cyber-Classroom has been used to teach chemistry. Teachers have used between one and twelve different modules in their lessons. This clearly indicates that the Cyber-Classroom is used to different extents by the teachers.

To rate the quality of each Chemistry module the German grading scale ranging from 1 to 6 was applied. In this system “1” means “very good” while "5" and "6" are both considered to be failing grades As shown in Table 1 the students’ average rate for the quality of the Chemistry Cyber-Classroom module ranges between 2.23 and 3.82 (good - satisfactory) while the teachers rate between 1.67 and 3.29 (very good - satisfactory). So on average the teachers’ rating is slightly higher. Further analysis shows that the evaluation of students and teachers is very similar for most of the modules (“Atomic structure”, “Atomic model”, “Grease fire”, “Polymers”, “Molecular movement”, “Particle model”). The modules “Accumulator”, “Chemical bonding” and “Blast furnace” are rated higher by teachers than by students. Only the modules “Carbohydrates” and “Chemical equations” get better ratings from students than from teachers.

Table 1: Results of the students' and teachers' rating for each Chemistry Cyber-Classroom module
(Only modules with a student sample size higher than 10 are shown.).

	Students' Evaluation			Teachers' Evaluation		
	sample size	mean value	standard deviation	sample size	mean value	standard deviation
Accumulator	11	3.82	1.47	7	2.43	0.79
Atomic structure	37	2.38	1.28	9	2.44	0.73
Atomic model	38	2.42	1.18	9	2.33	0.71
Chemical bonding	28	3.25	1.17	5	2.40	0.55
Grease fire	31	2.23	1.52	6	2.50	1.22
Blast furnace	36	2.47	1.30	3	1.67	0.58
Carbohydrates	33	2.21	1.05	7	3.29	1.38
Polymers	11	2.82	1.54	7	2.86	0.90
Molecular movement	18	2.56	1.10	5	2.40	0.55
Chemical equations	46	2.57	1.26	6	3.00	1.26
Particle model	66	2.48	1.27	9	2.44	0.73

Asked what they like about working with the Cyber-Classroom 35 students point out that they like the 3D aspect of the visualization. In addition 23 students say that working with the Cyber-Classroom leads to a better understanding of the content. As dislikes, 17 students mention that the controller should be improved and nine students comment that they get a headache when using 3D visualizations.

Two teachers criticise that only small groups of students can use the Cyber-Classroom at a time. Therefore they and four others suggest providing support materials for students that offer learning opportunities for the rest of the class. Two teachers also would like to have a version of the Cyber-Classroom modules that they could access from their personal computers in order to be more flexible when preparing their lessons. Another common suggestion are workshops for teachers with a focus on how to use the Cyber-Classroom and/or the development of support materials for students.

CONCLUSION

The results provide important information for the improvement of the implementation as well as for further studies.

Modules with lower rating results should be revised. Interviews with teachers and students about those modules and their general criteria for good learning modules would be helpful.

A web-based non-stereoscopic version of the Cyber-Classroom has already been developed and will be made accessible for teachers at the Cyber-Classroom schools soon. This addresses two issues: Teachers will be enabled to prepare their Cyber-Classroom lessons using their personal computers and students who tend to get headaches using stereoscopic 3D visualizations or prefer non-stereoscopic visualizations for any other reason can use this web-based version instead.

The development of support material will be a major task. To meet teachers' needs and expectations from the beginning and benefit from teachers' experience joint workshops with teachers and developers are planned for next year.

These actions should improve the implementation of the Cyber-Classroom in schools. In addition they help further increasing the handling of the system as well as the quality of the modules. This is a necessary step before investigating the effects of stereoscopic 3D visualizations in comparison with non-stereoscopic visualizations in future studies.

ACKNOWLEDGEMENT

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REFERENCES

Agir.Media. (2012). *Agir.Media: Kinostatistiken 2012.* Retrieved 07 15, 2014, from http://www.agirmedia.de/download/Statistiken_2012.pdf

Bamford, A. (2011). *The 3D in Education (White Paper).* Retrieved 07 15, 2014, from http://www.dlp.com/downloads/The_3D_in_Education_White_Paper_US.pdf

Evonik. (2011). *Taking a fresh look at chemistry.* Retrieved 07 15, 2014, from http://corporate.evonik.de/en/responsibility/Pages/cyber-classroom.aspx

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International journal of science education , 29* (7), pp. 871-893.

Kind, V. (2004). *Beyond Appearances: Students' misconceptions about basic chemical ideas* (2. ed.). London: Royal Society of Chemistry.

Leung, H., Lee, H., Mark, K.-P., & Lui, K. M. (2012). Unlocking the Secret of 3D Content for Education. Case study of automultiscopic display used for school teaching in Hong Kong. *IEEE International Conference on Teaching, Assesment, and Learning for Engineering (TALE), 20.-23.08.2012.* Hong-Kong.

Norbury, K. (2012). *Campus Technology*. Retrieved 07 15, 2014, from http://campustechnology.com/articles/2012/02/01/3d-or-not-to-be.aspx

Statista. (2014). *Statista GmbH*. Retrieved 07 15, 2014, from http://de.statista.com/statistik/daten/studie/220081/umfrage/prognose-marktanteil-3d-tv-bildschirme/

Wu, H.-K., Krajcik, J. S., & Soloway, E. (2001). Promoting Understanding of Chemical Representations: Students' Use of a Visualization Tool in the Classroom. *JOURNAL OF RESEARCH IN SCIENCE TEACHING , 38* (7), 821-842.

EVALUATION OF THE USE OF NATURAL USER INTERFACE TECHNOLOGY TO CREATE A VIRTUAL CHEMICAL LABORATORY

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Abstract

Natural User Interfaces (NUI) are now widely used in electronic devices such as smartphones, tablets and gaming consoles. We tried to use this technology in the teaching of chemistry in secondary school and high school. We developed a virtual chemistry laboratory in which students could simulate the performance of laboratory activities similar to those they carry out in the real lab. A Kinect sensor, which is an example of a Natural User Interface (NUI), was used to detect and analyse the students' hand movements. We tested the educational effectiveness of this virtual laboratory, by **examining** *to what extent its use increased the students' progress in learning chemistry. The results indicate that NUIs offer an opportunity to enhance the quality of chemical education. Working in a virtual laboratory using the Kinect interface leads to greater emotional involvement by the students. The consequences are better educational results and greater interest in the subject.*

Keywords

chemistry experiments, educational simulation, virtual laboratory, Natural User Interfaces

INTRODUCTION

In the natural sciences such as chemistry, physics, biology and geography, it is important to carry out experiments either in the laboratory or outdoors. In this respect, experimental chemistry creates special opportunities to learn about the physical and chemical properties of substances by engaging the senses of the person conducting the experiment. In an ideal world, students could personally perform all the chemical experiments included in the curriculum as part of their chemistry education. However, this is not possible due to a number of restrictions (Wellington, 2007), including time and costs associated with the performance of the experiments as well as safety concerns. A solution to this situation is offered by virtual laboratories which, to a certain extent, allow students to experiment without the above-mentioned constraints (Millar, 2004; Bilek, 2010). The literature describes different types of virtual laboratories offering varying degrees of involvement in the performance of experimental activities by students (Zeynep and Alipaşa, 2010). Most of the work focused on the computer software using the keyboard or mouse as input interfaces (Chemistry, nd.). The emergence of Natural User Interfaces (NUI) has created new opportunities for operating the simulation software. The software is controlled by natural movements and gestures of the user, making the virtual experiments more natural and intuitive. This enables the development of software with which the user will be more practically involved (Svec and Anderson, 1995).

TECHNICAL ASPECTS OF THE SOFTWARE'S DESIGN

Natural User Interface

Natural User Interfaces (NUI) is a type of interface, which provides the ability to communicate with various devices in ways which are natural to human beings. The task of an NUI is to create an interaction between the human and the machine in such a way that the user is not aware of the existence of the interface. NUI can operate in many different ways, depending on the needs of the user. A commonly used natural user interface is the touch screen interface. It allows the user to move and manipulate objects by touching and dragging their fingers across the screen. In this case, the objects on the screen may respond to touch, as well as real objects. This feedback via a touch-screen interface makes navigation seem more natural than with the keyboard and mouse. Most smartphone or tablet users do not realize that their interaction with the content is mediated by the touch interface (Murphy, 2012).

An example of NUI which particularly interested us is gesture recognition systems. They track the user's movement, which is then translated by the interface into instructions understood by the computer. Some of these systems, including the Nintendo Wii (Control for Wii, nd.) and the PlayStationMove (This Is How I Move, nd.) use accelerometers and gyroscopes for tracking the angle, speed and acceleration of movement. A more intuitive kind of NUI is equipped with a camera and software that recognizes specific gestures and translates them into action. Microsoft Kinect (Kinect for Windows, nd.) or LEAP Motion (LEAP motion, nd.; Kosner, 2012) allow users to interact with the device through body movements, gestures and voice commands. In addition to these common interfaces, there exist others.

They may be based on voice recognition, eye movements or brain wave analysis (Natural user interface).

Technology used to create the software

In creating software that simulates the school chemistry laboratory we relied on existing technologies. We used the Kinect package for Windows SDK. This package offers a number of tools, models and features to help developers create and improve applications that respond to human gestures and voice. It also contains drives for connecting Kinect to a Windows PC (Skeletal tracking, nd.). School chemistry laboratory software was written in the computer C#. Additionally, during the development phase we benefited from the language .NET package of the Windows Presentation Foundation (WPF) which enables the preparation of a graphical user interface. This package was also used to create an on-screen graphic display interface (Windows Presentation Foundation). We also used the universal language of XML tags designed to represent different data in a structured manner (XAML Overview). In our case, it was used to describe the laboratory equipment, the chemicals, the instructions for experiments and the interactions taking place.

The resulting program uses the Kinect for Windows sensor to detect and analyse the movements of the user. This sensor has greater technical capabilities, such as higher scanning resolution and the possibility of smaller distance between the user and the sensor, than the Kinect dedicated for XBOX (Kinect for Windows).

Description of the simulation software

The simulation software used in this research enables a complete simulation of the actions performed as part of an experiment in a school chemistry laboratory. This includes simulating grabbing laboratory equipment and dishes and their appropriate installation. It is also possible to simulate pouring solid and liquid solutions into laboratory dishes and other laboratory activities. The software accurately simulates the movements of poured liquids and the movements of liquids which occur during chemical reactions as well as the movements of solid particles being poured into a laboratory dish. The software makes it possible to simulate 40 chemistry experiments, which are on the junior high school and high school chemistry curricula in Poland, such as, the comparing the chemical reactivity of metals, the characterization of carbon dioxide, obtaining hydrochloric acid by dissolving hydrogen chloride in water, studying the impact of temperature on the solubility of gases in water and on the rate of chemical reactions, or testing hydroxide and the acidity of oxides. We used a correctness monitoring system, whereby actions which are incorrect or inconsistent with the safety principles of laboratory work are signalled to user and blocked. The purpose of this is to familiarize the user with the rules of proper and safe work in the laboratory. In order to conduct research on the effectiveness of the software, we created three different versions of it. In the first version of the software, the student performs various laboratory activities in accordance with instructions provided in real time through a voice-over. In the second version of the software, the voice-over has been replaced by a video depicting the conduct of the experiment. These videos used multimedia instructions for performing the virtual experiments prior to the simulation itself. In the third version, conventional written instructions for experiments are used. Both the video instruction and the conventional written instruction are available to the student, upon request, during the simulations of the experiments. In all three versions, the monitoring system indicates when the student makes a mistake in the laboratory work.

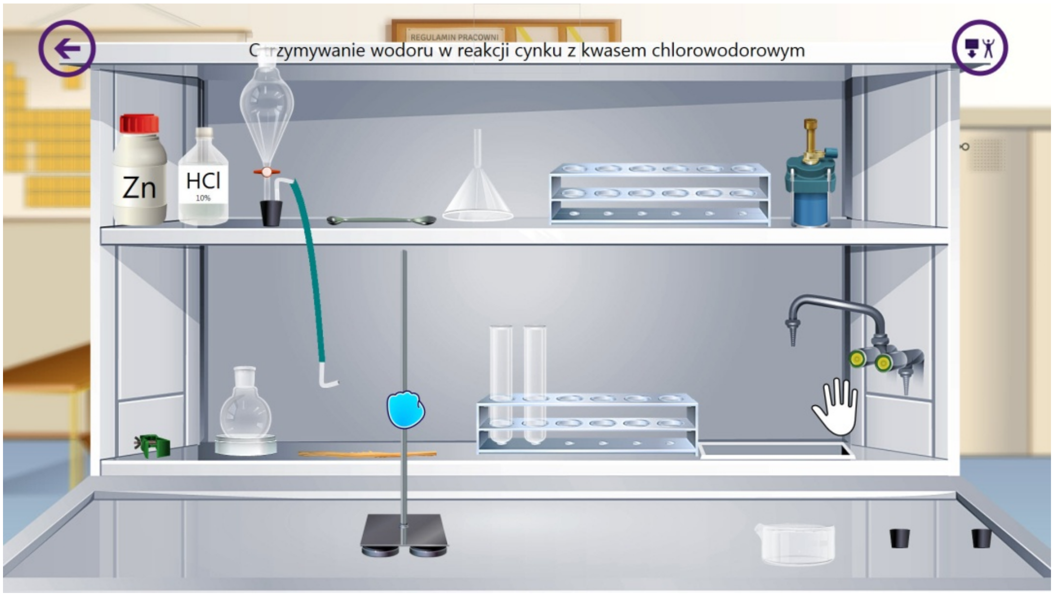

Figure 1: Screenshot from the computer programme show general view of the virtual laboratory

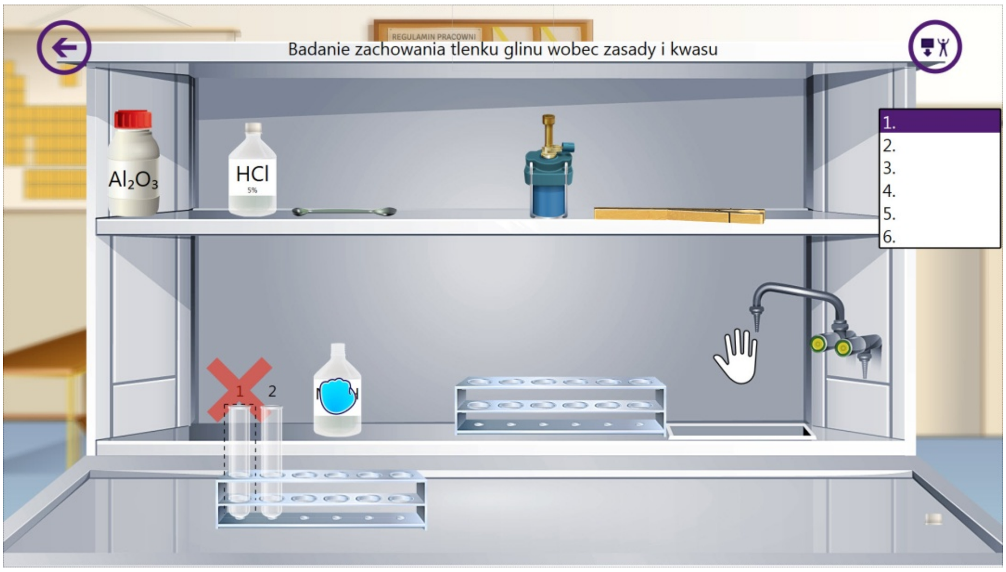

Figure 2: Screenshot show incorrect laboratory procedure

RESEARCH METHODOLOGY

The research problem

We want to examine which version of the chemistry laboratory simulation software gives the best results in terms of preparing students for work in a real school laboratory. This will point to the most effective method of developing laboratory skills, as well as identifying the instructions which are the most appropriate for the majority of the students at each educational level. We were also interested in how working with the chemical laboratory simulator affects the efficiency, confidence and independence of students in a real school laboratory.

Description of student groups

In the Polish education system, there is a three-year junior high school and a three-year high school. Four groups of junior high school students and four groups of high school students participated in the study. The students were in their second year of study in their respective schools, because more hours are dedicated to chemistry during that year than during either the first or the final year. In each school, groups of twenty five students were assigned to different versions of the software at random. Care was taken to ensure that the numbers of students in each group were the same and that they did not change during the study. Altogether, 100 students from each school participated in the study. Average ages were 14 for junior high school students and 17 for the high school students.

The symbols used to designate each group are listed in Table 1.

Table 1: Designations of the groups of students, depending on the didactic tool

groups designation	didactic tool	Number of students [n]
	junior high school	
GKL	first version of the software with voice-over	25
GKF	second version of the software with videos	25
GKT	third version of the software with written instructions	25
GTF	instructions and videos without virtual laboratory software	25
	high school	
LKL	first version of the software with a voice-over	25
LKF	second version of the software with videos	25
LKT	third version of the software with written instructions	25
LTF	instructions and videos without virtual laboratory software	25

The testing procedure

At the beginning of the study each group of students received a didactic tool. One group of students in each school prepared for the performance of experiments in the school chemical laboratory using the first version of the simulation software. The second group of students in each school used the second version of the software, and the third group of students in each school used the third version. We created a fourth group of students in each school to compare the results of working with the Kinect interface simulation software to the results of preparation of chemical experiments without that interface. Therefore, the fourth group of students worked only with the written and video instructions, without access to the virtual laboratory.

At the beginning of the study, all groups of students solved a pre-test designed to determine their initial level of knowledge associated with the chemical experiments performed during the study. Then each group of students followed their usual weekly schedule of chemistry lessons working with the didactic tool assigned to them. After the completion of the planned experiments students solved a post-test. The multiple choice questions which made up this test were related to the experiments they performed. Three months following the completion of the post-test, students were given a distance test. The distance test contained the same multiple choice questions as the post-test but they were arranged in a different order. We also conducted a survey of the students' opinion about the method of preparation for laboratory classes they used, and of the software itself.

The pre-test, post-test and distance test results were analysed according to the taxonomy of educational objectives developed by B. Niemierka (Czupiał and Niemierko, 1977) the main categories and sub-categories of which correspond to Bloom's (Bloom et all, 1956) taxonomy and revised Bloom’s taxonomy (Anderson and Krathwohl, 2001). This taxonomy differentiates between knowledge and skills. At the level of knowledge, the taxonomy recognises as sub-categories objectives related to retention of information (A) and understanding of information (B). At the level of skill which has a higher didactic value, the taxonomy differentiates between application of information in a standard situation (C) and its application to a new problem (D).

The test results were used to calculate the increase in knowledge and skill in each group of students and thus the educational effectiveness of each version of the chemistry laboratory simulation software. We also determined the durability of knowledge in each group of students (Jagodziński and Wolski, 2012). The chi-square test was used to determine the statistical significance of the differences in results

RESULTS

Below we present a summary table of the test results achieved by the junior high school and high school students respectively.

Table 2: Summary of the results of the increase in knowledge, the learning effectiveness of the didactic tools of sustainability of knowledge, achieved by each group of junior high school students working with the didactic tools which were the subject of the study

	Categories in the taxonomy of educational objectives				
	A	**B**	**C**	**D**	**G(generally)**
Group symbol	**Growth of students knowledge [%]**				
GKL	198	217	211	237	214
GKF	180	181	188	163	178
GKT	174	174	175	193	178
GTF	171	160	178	168	169
	Educational effectiveness of each pair [%]				
GKL – GKF	7*	13*	19	37	18
GKL – GKT	5*	25	32	37	23
GKL – GTF	13*	36	30	51	30
	Sustainability of students knowledge [%]				
GKL	83	81	80	80	81
GKF	77	75	73	76	75
GKT	71	76	72	75	73
GTF	69	71	65	68	69

Note: **The sign (*) indicates statistically insignificant results, determined from the chi-square test.**

Table 3: Summary of the results of the increase in knowledge, the learning effectiveness of the didactic tools of sustainability of knowledge, achieved by each group of high school students working with the didactic tools which were the subject of the study

Categories in the taxonomy of educational objectives					
	A	**B**	**C**	**D**	**G(generally)**
Group symbol	**Growth of students knowledge [%]**				
LKL	126	131	127	123	127
LKF	119	108	94	86	102
LKT	123	114	94	89	106
LTF	125	94	80	79	95
	Educational effectiveness of each pair [%]				
LKL – LKF	6*	22	35	43	24
LKL – LKT	3*	16*	35	38	20
LKL – LTF	1*	39	57	55	33
	Sustainability of students knowledge [%]				
LKL	84	82	82	80	82
LKF	84	82	84	80	83
LKT	78	77	77	70	76
LTF	76	79	71	69	74

Note: **The sign (*) indicates statistically insignificant results, determined from the chi-square test.**

After solving the post-test, all groups of students answered a survey. Below we present questions included in survey.

Survey questions:

1. Working in a virtual laboratory using the Kinect interface is pleasant and interesting: a) yes, b) only partly, c) not at all, d) I have no opinion
2. Do you consider using the virtual laboratory at home an appropriate method for preparing to work in the school chemistry laboratory: a) yes, b) only partly, c) not at all, d) I have no opinion
3. Are the instructions provided with the simulation software useful in performing virtual experiments: a) yes in 100 % of the cases, b) yes in about 75 % of the cases, c) half the time, d) only in 25 % of the cases
4. To what extent does the virtual laboratory equipment correctly reflect the actual chemical laboratory: a) 100 %, b) 75 % c) 50 %, d) only 25 %
5. To what extent do laboratory activities performed during virtual experiments reflect the real operations carried out in a school chemistry laboratory: a) 100 %, b) 75 %, c) 50 %, d) only 25 %

6. Has working with a virtual laboratory helped you to work in a safer and more flexible manner in the school chemistry laboratory: a) yes, b) only partly, c) I have no opinion, d) no
7. Has performing virtual experiments increased the efficiency of your work in the school chemistry laboratory: a) yes by about 25 %, b) yes, by about 50 %, c) yes, by about 75 %, d) the efficiency of my work has not increased
8. What caught your attention the most during the work in the school chemistry laboratory: a) the substantive part of the task, b) the manual part of the task, c) the correct installation of equipment, d) the proper performance of the experimental procedure
9. To what extent has working with a virtual laboratory increased your interest in chemistry: a) by 25 % b) by 50 % c) by 75 %, d) it did not increase my interest
10. To what extent did your emotional engagement in the study of chemistry increase following the use of a virtual laboratory with the Kinect sensor: a) by 25 % b) by 50 % c) by 75 % d) the virtual laboratory did not arouse any emotions in me

The survey results are presented in Table 4.

Table 4: The combined results of the survey
(from both junior high and high school)

Question		Anserws			
		a	B	c	d
		[%]			
1		68	25	2	5
2		76	19	3	2
3	GKL, LKL	93	5	1	1
	GKF, LKF	84	11	3	2
	GKT, LKT	71	17	9	3
4		97	2	1	0
5		47	38	12	3
6		89	11	0	0
7		58	27	13	2
8		43	36	13	8
9		39	36	18	7
10		46	27	17	13

* NOTE: The answers to question 3 were divided into three parts according to the type of instructions used

DISCUSSION

The results of the pre-test conducted in the junior high school indicate that the participating students had an evenly low level of knowledge of the topics within chemistry covered in the study. The pre-test results of the participating high school students are on average higher by about 45% than those of the junior high school students, because these students have a larger body of knowledge and skills which they acquired during the study of chemistry in high school. Even levels of knowledge within the groups indicates that the groups were put together correctly and could be used in the study.

The analysis of the results of the post-test administered to the high school students shows that group GKL achieved the best results. Students in this group, when performing virtual experiments, worked according to instructions delivered in real time by a voice-over. It can be concluded that this version of the virtual laboratory software suited the most students, because today's media, to which students are accustomed, is dominated by a combination of video and audio content. The results of group GKF that performed virtual experiments according to instructions in the form of videos with commentaries, are about 11% worse than the results of students in group GKL. Removing the voice-over which offers the instructions for laboratory activities piecemeal as they are performed by the student at their own pace (pieces of information) and replacing it with multimedia content in the form of video in which these activities are given in one chunk and at a pre-determined rate (accumulation of information) reduced the effectiveness of instruction by 18 % (Table 2). The post-test results of the students in group GKT are almost identical to those achieved by group GKF. This shows that the conversion of film instruction to text displayed on the screen does not alter the effectiveness of instruction. This is due to the fact that the text instructions, as well as the film instructions, provide the most important information in a concise, cumulative way. Students of group GTF who worked with text and film instructions but without the virtual laboratory achieved the worst results. Taking away from the students the ability to simulate laboratory activities resulted in less engagement in the experiments, which could result in worse results. Considering the results obtained in terms of the educational objectives, it is apparent that group GKL achieved relatively high scores across all four categories of the taxonomy of educational objectives. The other groups of students, that is GKF, GKT and GTF, achieved similar results in the taxonomic category A. The choice of didactic tools had no significant effect on the degree of differentiation knowledge retention by high school students. This is shown by the results of the educational effectiveness of the didactic tools in taxonomic category A, where the differences are not statistically significant (Table 2). In terms of understanding the message, however, as per taxonomic category B, we observed differences in the educational effectiveness for students only between groups GKL-GKT, on the one hand and GKL-GTF, on the other hand. Interrupting the experiment to read the instructions has as negative an impact on the understanding of the message as the lack of simulation altogether. For students in group GKF, the difference is statistically insignificant. In the case of taxonomic categories C and D, which relate to problem-solving skills, the best results were achieved by group GKL compared with all the other groups of students. This gives the didactic tool used by this group a big advantage because these two taxonomic categories are associated with skills with the highest teaching value. Here the positive impact of voice-over acting as a virtual instructor can be seen most clearly.

With respect to the sustainability of the junior high school students' knowledge, it is the highest among the student in group GKL. Also from this perspective, the use of a virtual laboratory where students were receive voice-over instructions in real time, turned out to be the best combination of the didactic tools.

Analysing the results of the participating groups of high school students, we can say that students from group LKL performed best in the post-test. Students from groups LKF and LKT achieved results similar to each other but lower by about 11 % than the LKL students. The worst results were recorded for group LTF. A comparison of the results achieved by each of the groups of high school students shows that also in this case the educational effectiveness is influenced by the means of conveying the instructions. Considering the results within the different taxonomic categories, it becomes apparent that the method of transmission of messages has no significant effect on the storage of knowledge, because all groups of participating students achieved similar results within the taxonomic category A. This is reflected in the calculation of the educational efficiency of the didactic tools in the taxonomic category A, because the differences in the results in this category are not statistically significant. In the taxonomic category B, only the LTF students achieved worse results than the rest. This can be attributed to the inability to simulate the chemical experiments. On this basis, it can be concluded that practical application has a significant impact on the understanding of the theory (Table 3). In the other two taxonomic categories, C and D, the LKL students achieved the best results. Students from the other groups achieved significantly worse results than group LKL, with students from groups LKF and LKT achieving similar results to each other and students from group LTF achieving the poorest results. These results are reflected in the calculated efficiency of each of the didactic tools combinations in the taxonomic categories. The distance test results of the participating high school students demonstrate the degree of knowledge sustainability, with groups LKL and LKF achieving very similar results in the range of 82 % to 83 %. This supports the idea put forward above that students respond best to information conveyed through the combination of picture and sound. Consequently, students from group LKT who neither followed voice-over commands throughout the simulation nor watched filmed instructions demonstrated lower levels of durability of knowledge. The lack of manual involvement through the virtual laboratory by the LTF students led to them also achieving worse results in terms of knowledge sustainability compared to students from groups LKL and LKF, who had at their disposal the virtual laboratory either with voice-over or filmed instructions.

Based on the survey results, it can be concluded that the virtual chemistry laboratory using the Kinect interface was valued by the students, especially because it allowed them to independently carry out chemical experiments under almost any conditions. There is a co-relation between the results of the survey and the results obtained by students in the post-test and the distance test. Most of the students said that working with the software was interesting and appropriate as a way to prepare for chemistry lessons. They particularly underlined the advantages of the opportunity to work with the software at home. Out of the various methods of communicating instructions for the experiments, the students expressed preference for commands given by a voice-over accompanying the performance of the simulation. They also stated that the graphic elements depicted in the virtual laboratory accurately reflected an actual laboratory. Students also confirmed that the laboratory activities performed as part of the virtual experiments largely resembled the actual operations. Most of the students expressed the view that, after training in a virtual laboratory, they were able to work more safely and more independently in a real school chemical laboratory and that their work was more efficient. After practicing with the virtual laboratory, students were able to focus more on the substantive aspect of the job rather than on the technical side when they were in the real laboratory. The use of a virtual laboratory increased students' interest in chemistry and their emotional involvement in the study of the subject.

REFERENCES

Wellington, J., 2007. America's Laboratory Report: Investigation in High School Science, *Science Education*, 91, (36), 514-515.

Millar, R., 2004. The role of practical work in the teaching and learning science. High School Science Laboratories: Role and Vision. NAS, Washington DC, 3-4.

Bílek, M., 2010. Natural science education in the time of virtual worlds. *Journal of Baltic Science Education*, 9(1), 4-5.

Zeynep, T., Alipaşa, A., 2010. Virtual laboratory applications in chemistry education, *Procedia Social and Behavioural Sciences*, 9, 938-942.

Chemistry labs., *http://onlinelabs.in/chemistry* (accessed Jan 2014)

Svec, M. T., Anderson, H., 1995. Effect of Microcomputer based Laboratory on Students Graphing Interpretation Skills and Conceptual Understanding of Motion, *Dissertation Abstract International*, New York, 55, 8, 23-38

Murphy, S., 2012. Design Considerations for a Natural User Interface (NUI), Texas Instruments Incorporated, Dallas, TX, *http://www.ti.com/lit/wp/spry181/spry181.pdf* (accessed Jan 2014)

Controls for Wii., 2014. *http://www.nintendo.com/wii/what-is-wii/#/controls* (accessed Jan 2014)

This Is How I Move., 2014. *http://us.playstation.com/ps3/playstation-move/* (accessed Jan 2014)

Kinect for Windows., 2014. *http://research.microsoft.com/en-us/collaboration/focus/nui/kinect-windows.aspx* (accessed Jan 2014)

LEAP motion., 2014. *https://www.leapmotion.com/product* (accessed Jan 2014)

Kosner, A. W., 2012. Leap Motion's High-Resolution Natural User Interface Will Make Today's Touch A 'Legacy', Forbes, *http://www.forbes.com/sites/anthonykosner/2012/07/16/leap-motions-high-resolution-natural-user-interface-will-make-todays-touch-a-legacy/* (accessed Jan 2014)

Natural user interface (NUI)., 2014. *http://whatis.techtarget.com/definition/natural-user-interface-NUI* (accessed Jan 2014)

Skeletal Tracking., 2014. *http://msdn.microsoft.com/en-us/library/hh973074.aspx* (accessed Jan 2014)

Windows Presentation Foundation., 2014. *http://msdn.microsoft.com/pl-pl/library/ms754130.aspx* (accessed Jan 2014)

XAML Overview., 2014. *http://msdn.microsoft.com/pl-pl/library/ms752059.aspx* (accessed Jan 2014)

Czupiał, K.; Niemierko, B., 1977. *Methodology of chemical test*, WSiP, Warszawa.

Bloom, B. S.; Engelhart, M. D.; Furst, E. J.; Hill, W. H.; Kratwohl, D. R., 1956. *Taxonomy of Educational Objectives; The Classification of Educational Goals*. Handbook 1: *Cognitive domain*, David McKay: New York.

Andreson, L. W.; Krathwohl, D. R., 2001. A Taxonomy for Learning, Teaching and Assessing: a Revision of Bloom's Taxonomy, *Longman Publishing*, New York.

Jagodziński, P., Wolski, R., 2012. Assesing the Educational Effectiveness of Film of Chemical Experiments for Educating Deaf-Mute Junior High and High School Students, *J.Chem.Educ*, 89, 1122-1127.

Khan, M. K., 2007. Emotional and Behavioral Effects of Video Games and Internet Overuse, Report of the council on science and public health, *http://www.ama-assn.org/resources/doc/csaph/csaph12a07-fulltext.pdf* (accessed Jan 2014)

Flipped classrooms., 2012. *http://net.educause.edu/ir/library/pdf/ELI7081.pdf* (accessed Jan 2014)

Science Education NOW, 2007. A Renewed Pedagogy for the Future of Europe, European Communities. *http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf* (accessed Jan 2014)

E-LEARNING IN CHEMISTRY EDUCATION FOR STUDENTS OF ENVIRONMENTALISTICS

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Abstract

The main features of every educational system are effort to find new approaches, methods and content of education. The finding is influenced by many factors– tradition of university education as the highest degree; grow dynamics of new knowledge in the field of science or technology. They are stimulus for implementation of innovation to the every part of education. Nowadays school systems use the modern technologies in the educational process mainly in the field of information and communication technology (ICT). ICT is possible to use also in many parts of chemistry education. E-learning is one of the way how to incorporate modern didactic techniques in the educational process. It enables fluent acquiring of knowledge and developing their competences. In our article we focus on the importance e-learning for students of environmental sciences. The subject General Chemistry is classes into the first year of study. Our e-learning course offers students possibility how to acquire knowledge about chemical substances and mixtures and their influence on selected parts of environment.

Keywords

Generally Chemistry. Chemical discipline. Element of Environment. Educational Process. E-learning. Chemistry Education.

INTRODUCTION

The human life and our society are depended on biosphere, which we used to meet the needs of (Tölgyessy et al., 1984). The basic components of the biosphere include: air, water, soil, plants, animals, minerals and sunlight (Tölgyessy et al., 1984). Human activities have become an important factor in the redistribution of elements in the atmosphere, soil and water as well as in the biosphere (Hronec, Tóth and Tomáš, 2002). The continued growth of world population and multilateral economic activities are reasons of many quantitative and qualitative changes in the biochemical cycles of elements in the biosphere (Tölgyessy et al., 1984). One of the problems is anthropogenic emissions in atmosphere, which cause primary and secondary pollutants in the air (Hreško et al., 2008). Growth of greenhouse gases concentration is caused also by anthropogenic emissions and lead to increasing of greenhouse effect (Hronec, Tóth and Tomáš 2002).

Anthropogenic emissions of greenhouse gases which cause the change of global climate are one of the most important environmental problems (Hronec, Tóth and Tomáš 2002). Products of photochemical oxidants like chlorine radical come from freons and peroxyacetyl nitrates which destroy ozone (Hronec, Tóth and Tomáš, 2002). The most important part of material flow in environment is its transformation (Bílek and Rychtera, 2000; Prousek, 2005). Transformational reactions could be realised chemically, photochemically and biologically (Prousek, 2005).

Depleting ozone layer causes biological risks. It is the second most important atmospheric global problem (Hronec, Tóth and Tomáš, 2002). Acid rains are treatment for forests, we have problems with waste management and there is lack of drinking water and appropriate food (Bílek and Rychtera, 1999).

We try to find new approaches and fundamentals for increasing amount of very dangerous wastes. Anthropogenic activities bring lot of chemicals to food chain; it leads to many diseases and decreasing life expectancy. It could endanger plants and animals and biodiversity (Hronec, Tóth and Tomáš, 2002). Global problems closely connected with polluting environment are signals for all human activities at our planet (Prousek, 2005).

During last years we could state that there are some positive trends in the field of decreasing amount of pollutants. In spite of there are lot of problematic areas where are endangered parts of the environment (areas with high population density). It is necessary to understand that without world interesting in solving mentioned problems it is not possible to live sustainable (Prousek, 2005). Without our active approach we couldn’t solve problems concerning with our environment (Hilbert, 2002). It is very important to motivate to their environment from early childhood.

The mail goal of our article is to present possibilities of using e-learningu course focused on general chemistry, chemical technology and influence of chemicals and chemical processes on elements of our environment. The course participants were students of study programme Environmentalistics.

CURRENT TRENDS IN CHEMISTRY

Problems of pollutants in environment are usually closely connected with development of chemistry and chemical industry (Prousek, 2005). Chemistry, particularly chemical technology brings a lot of problems such as environmental pollution (Kontrišová et al., 1998). Chemical processes in power engineering, transport and agriculture are the biggest sources of pollutions (Kašiarová and Feszterová, 2008).

Progressively many branches of science originated like biotechnology or genetic engineering (Šrámek, 2000). Nowadays the basis of chemistry is atomic structure and chemical bonds (Šrámek, 2000). Products of the chemical industry are in the every part of our life (Bílek and Rychtera, 1999). Their usefulness is important for us everyday.

The main source of health problems are risk factors polluted environment (Kašiarová and Feszterová, 2010; Noga, 2012). Many hazardous factors don't come from nature; they are produced synthetically (Hronec, Tóth and Tomáš, 2002). Diseases aetiology is usually connected with exposition of many dangerous chemicals (Prousek, 2005). Chemistry could help to decrease amount of gases, liquid and solid wastes and also optimize the quality of air, water, soil. It could help to make better environment (Prousek, 2005).

There are reasons why we have to prepare future environmentalists focused on chemistry, chemical technology and problems which are connected with environment and chemistry. We could resolve them only with active approach and in cooperation with international companies (Hilbert, 1998; Horrigan, 2010).

E-LEARNING IN GENERAL CHEMISTRY EDUCATION

During last decades development of technology markedly influence development not only industry but also educational process (Raczyńska, 2014). Using of ICT make educational process more flexible and enable to work more effectively (Turčáni, Bílek and Slabý, 2003). Attitude of young generation to ICT is very positive because and it enables to unlimited access to the information, new knowledge. Technologies are very important factor which could strongly influence and change ways of using ICT in educational process (Raczyńska, 2014). The important advantage is that ICT enable us to provide and plan materials which are addressed for special group (Stoffa, 2014), in our case for students of the 1^{st} grade. Individualisation of university study using ICT provides possibility of choosing place and time for learning

(Bílek, Poulová and Šimonová, 2012). The key feature is possibility to choice learning velocity and approach at the basis of learning style (Feszterová, 2011; Šimonová et al., 2010). The need of education is increasing and it will be increase also in the future (Juhász, 2000; Lepil, 2010).

Students and also teacher changed in the field of their mutual relationship, in behaviour and in internal way of work with information (Benedek, 2014; Orsághová, Gregáňová and Kecskés, 2014). We started to use new methods and organisational forms of education, new technologies and school supplies. (Prauzner, 2010; Šimonová et al., 2000). In educational process computer could help us to fill many kind of didactical function such as: *motivational, informational, leading, rationalize, control, communicative* and *social* (Stoffová, 2004). The entry requirements and output competencies of students and teachers was changed (Šimonová et al., 2010). The importance of e-learning is increasing (how to realise educational process and learning process with the support of modern technologies) (Bílek and Toboříková, 2010; Šimonová et al., 2010).

At the Constantine the Philosopher University (CPU) in Nitra is sufficient infrastructure for using e-learning. At the web site of CPU, at the portal named EDU in the LMS MOODLE environment there are situated e-learning courses. E-learning is suitable choice in education of different chemical disciplines. For students (1st grade) bachelor study program Environmentalistics (division Protection and Using of Land Area – number 4.3.1) we prepared e-learning course as a part of General Chemistry. It is suitable supplement of Chemistry. The General Chemistry (2 lectures / 2 exercises) with value 6 credits is part of the first grade as obligatory subject, ended by exam.

Visual interpretations of content of education using Power Point presentation, which students attended is oriented on: *chemistry, history of chemistry, chemistry concepts, chemical laws, structure and atom models, mechanics of waves, orbitals, quantum numbers, spin, electron configuration, chemical bond, classical and modern theories of chemical bond, states, chemical energy, reaction rate, catalysis, dynamic equation of chemical reactions, acids and bases (Arrhenius and Bronsted theory), protolytic reactions, Lewis theory acids and basis, autoprotolyse of water, pH, oxidation-reduction, strength acid, stability constants of complex.*

The basic knowledge in the field of general and inorganic chemistry is very important in the study of other part of science (Kozík and Feszterová, 2011). Some parts which connect chemical processes with environment. They are presented in lectures of General chemistry f. e. influence and results of radioactivity on environment, influence of some gases on environment (ozone layer and greenhouse effect), influence of acid rains on environment and importance of redox in environment, electrolysis.

REVIEW OF THEME AND THE GOALS OF RESEARCH

The mail goal of our research was investigate attitudes of student (1^{st} grade, study program Environmentalistics, Constantine the Philosopher University in Nitra to one of their chemical lectures–General Chemistry (presence form, e-learning course). With chemistry and chemical processes students could met at everyday live, their influence we could observe in our environment. With mentioned discipline is closely connected using of interdisciplinarity through transcurricular integration.

In e-learning course General Chemistry students could understand usefulness concrete knowledge and also possibilities of using it in other part of science and in everyday life. E-learning course is focused on inter alia general chemistry, chemical technologies, connection chemistry and environment and also on protect some parts of environment. It allows unlimited access to e-learning educational materials, automatic testing of knowledge, and possibility of interactive communication. It could help students to look for information and to open knowledge from selected field of science (Stoffa, 2014). General Chemistry became the compulsory subject in academic year 2009/2010. Subsequently to General Chemistry we prepared e-learning course with the same name, which we edit and complete every academic year.

Mentioned part of science is part of compulsory subject for students of the first grade. It is interesting for us to how students evaluate its importance for their future job. Our research was realised during five years (2009–2014). Our respondents were students of the first grade bachelor division Protecting and Using Landscape (4.3.1) study programme Environmentalistics from the Department of Ecology and Environmentalistics at Faculty of Natural Sciences CPU in Nitra. (Picture 3) Number of respondents was 142 (55 males and 87 females). We used questionnaire method. We informed their how to work with prepared questionnaire.

Table 1 Number of respondents

Academic year	Number of respondents		
	Total	Males	Females
2009/2010	43	21	27
2010/2011	14	8	6
2011/2012	32	15	17
2012/2013	33	11	22
2013/2014	20	5	15
TOTAL	**142**	**55**	**87**

RESULTS AND EVALUATION

Our results summarize knowledge about selected research area; we applied them to the e-learning course General Chemistry.

The questionnaire was divided into four parts:

- opening (general) questions;
- question focused on knowledge from General Chemistry (oral lectures, e-learning course);
- questions concerned with way of preparing and studying general chemistry;
- questions connected with quality of e-learningu course.

We evaluated questionnaires and found following results. Results have not only informational nature but we achieved lot of information connected with respondent's studies at secondary school, their hobbies and their future orientation.

Opening (general) questions

142 respondents completed lectures from „General Chemistry". (Table 1) They were graduated at Technical and General Secondary Schools (Fig. 1). In the first grade there was 63 % graduated from Technical Secondary Schools (e. g. Wood, Transport, Trade and Services, Building, Art-Industry, Food Processing, Agriculture, Veterinary, Furniture, Gastronomy, etc.) and 37 % graduated from General Secondary Schools (general, language and science focused).

Lectures focused on General Chemistry are part of science education. It was very interesting to investigate how important is mentioned lectures for student's future job.

It is necessary to complete and enlarge knowledge in the field of General Chemistry especially for students who graduated from several Secondary Schools (with different levels of chemistry knowledge). Majority of students had chemistry subjects only during first or second years of study at Secondary Schools.

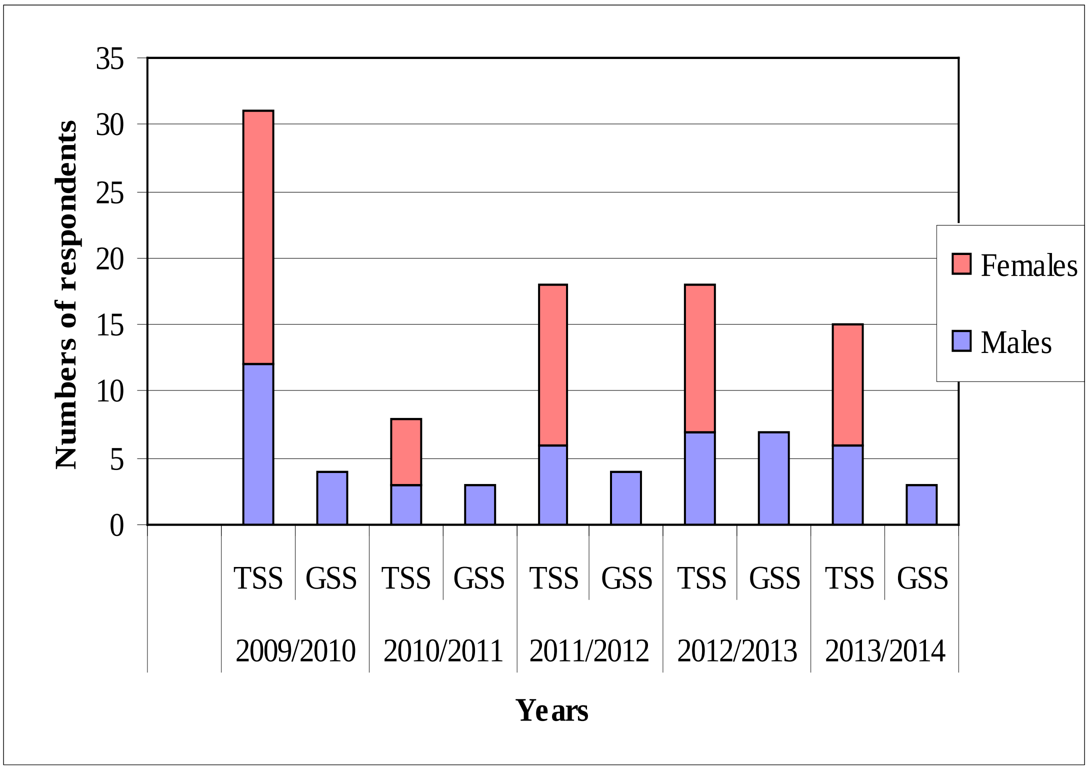

Figure 1 Numbers of respondents in selected years
(Legend: TSŠ - Technical Secondary School; GSS - General Secondary School)

General Chemistry is very abstract for student; it is very important to motivate them and interested them in it. The first step how to motivate students is to prepare interesting lectures to lead them to methodical preparation (Vrábelová, 2005).

Question focused on knowledge from General Chemistry

The second part of question was focused on lectures of General Chemistry. We asked:

- "*Did you attend every General Chemistry lectures?*" (I attended every lesson. I had 1–2 absences. I attended more than 5 lessons. I attended less than 5 lessons. I didn't attend any lectures.) (Picture 5)
- *"How many hours did you prepare on General Chemistry lectures during the semester?"* (One hour per week, more than one hour per week, less than 1 hour per week, I didn't prepare at lessons during the semester.)

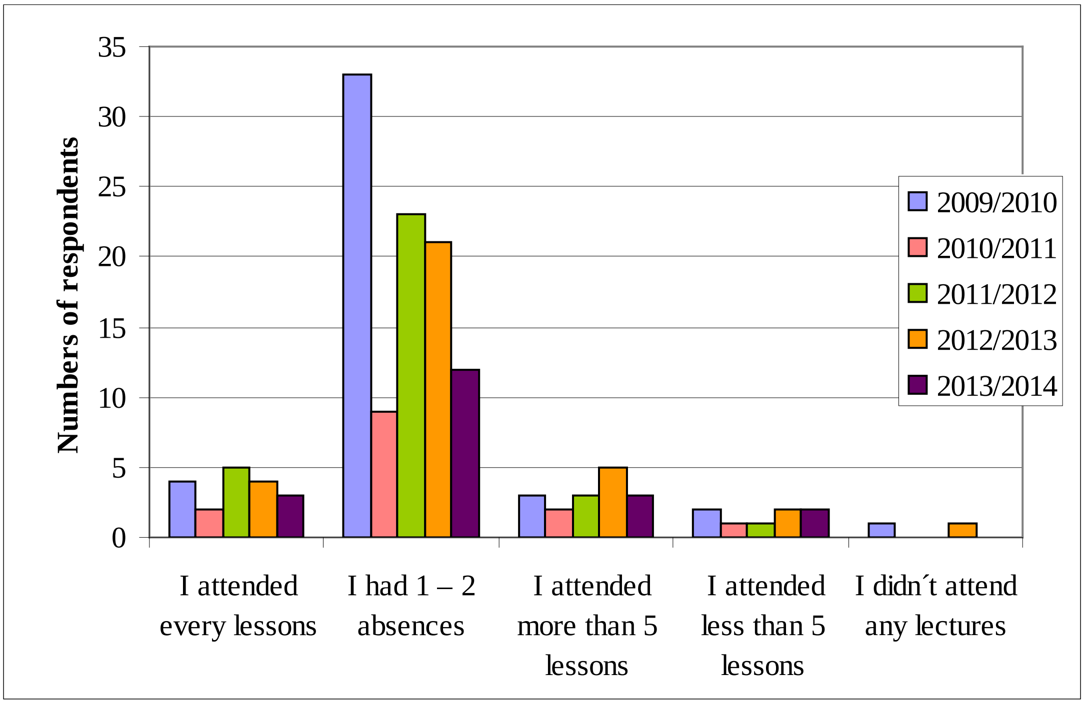

Figure 2 Numbers of respondents on lectures of General Chemistry

Obtained responses we summarised in Table 2. 82 % (116 students of total number 142 respondents) attended every lecture or had just one or two absences. 13 % respondents' (18 students) didn't have any absence. During selected period the most of all respondents had just one or two absence. 1 % respondents (2 students) didn't attend any lecture. On average 17 % respondents (24 students) attended five lessons. In academic year 2009/2010 we started to have General Chemistry lectures. Only one student (2 % of total number in this year) didn't attend any lessons. Similar situation was in academic year 2012/2013, when one student (total number 33) didn't attend any lessons.

The answers on question "*How many hours did you prepare on General Chemistry lectures during the semester (including the study with e-learning course)*?":

- 34 % respondents didn't prepare during the semester;
- 28 % respondents prepared less than one hour per week;
- 6 % respondents prepared more than one hour;
- 22 % respondents prepared one hour (18 females, 13 males).

Table 2 Number of respondents attending on General Chemistry lectures

Academic year	Number of respondents					
	Total	I attended every lessons	I had 1 – 2 absences	I attended more than 5 lessons	I attended less than 5 lessons	I didn´t attend any lectures
2009/2010	**43**					
Males	21	2	18	1	0	0
Females	22	2	15	2	2	1
2010/2011	**14**					
Males	8	1	5	1	1	0
Females	6	1	4	1	0	0
2011/2012	**32**					
Males	15	3	10	2	0	0
Females	17	2	13	1	1	0
2012/2013	**33**					
Males	11	2	8	0	0	1
Females	22	2	13	5	2	0
2013/2014	**20**					
Males	5	2	1	1	1	0
Females	15	1	11	2	1	0
TOTAL	**142**	**18**	**98**	**16**	**8**	**2**

Acquired statements concerning with less spend time to preparing on General Chemistry respondents substantiated less time for studying, less interest on presented themes, less interest on studying in general and other reasons–health or family problems.

“*Why students prepared on General Chemistry approximately one hour per week?”* The reasons were: personal interest on General Chemistry, job in similar area, other interests–good mark from mentioned subject, merit-based scholarship.

The answers on question: “*Were students interested in General Chemistry?*” General Chemistry was interesting for 41 % respondents, 32 % respondents didn’t answer and for 27 % it isn’t interesting.

“Was studying General Chemistry difficulty or not?” For more than half students (56 %) it was very difficult, for 8 % respondents was studying easy and 36 % students didn’t receive any differences in the compare with other subjects.

We also investigated interesting and intelligibility of lectures in oral or in e-learning form. Most of respondents (86 %) prepared for exam both forms - oral and also e-learning. Advantages of using oral form concerned with better understanding to theory, possibility of communication with teacher in the case of misunderstanding. E-learning form was very interesting for respondents because they didn't have any time and environment limitation.

We were interested in students´ interest in various General Chemistry lessons. Just for 1 % students all lessons weren't enough interesting.

Questions concerned with way of studying general chemistry (preparing on exam)

We asked: *How long did you prepare on General Chemistry exam?* 52 % students started with preparation some weeks before exam, 26 % just some day before exam and 10 % respondent studied continuously during semester. Spending time for preparing on exam was for all students was adequate.

Preparing on exam is closely connected with learning management. We investigated if students divided studying text or not, if they repeated some themes. 72 % respondents usually repeated all general chemistry more than one time. 21 % students red texts one time and also one time repeated it. 6 % respondents repeated only the most difficult themes.

62% respondents claimed that some parts of General Chemistry they learnt in the same sequences like they had lectures during semester. 20 % respondents learnt without logical order before exams and they didn't have enough time for repeating. 8 % respondents learnt just the most difficult parts of general chemistry and 10 % prepared step by step during semester.

We compared questions: „*How long did you learn General Chemistry for exam*?" and "*Did you have special order in learning General Chemistry?"* 62 % (52 % + 10 %) respondents prepared during some weeks in the same sequence like they had lectures during semester.

"How long did you prepare on general chemistry exam" 26 % started to learn just some day before exam. In next question is number of students almost same (28 % respondents learnt without logical order and they didn't have enough time for repeating, 8 % just read lessons and repeated only the most difficult parts.

In next questions we investigated approaches to learning, f.e.:

- colour marketing the most important parts in texts;
- techniques for easier retaining text;
- time of learning (morning, day, evening , night);
- attending of courses for memory improvement (fast reading, better retaining, courses focused on working with texts).

Questions connected with quality of e-learningu course

We asked if the General Chemistry course met respondents´ expectations.

We were interested in:

- how often they used e-learningu course during semester;
- which provided information during the course was important and interesting (lectures, books, dictionaries, internet links, test, chat with teachers, etc). For 48 % respondents were the most important lectures in PowerPoint, 33 % lectures in the book form. All respondents identically agreed that test is like a bridge for verification of knowledge. During monitoring academic years everybody used chat with teacher. For respondents were the most interesting following themes: *hybridisation, chemical bonds, orbital, history of chemistry, atom structure, states, periodic table, acids and bases, radioactivity, quant numbers.* For respondents were the less interesting following themes: *atom, chemical reaction, thermochemistry and wave mechanics*.

We investigated, which learning materials respondents used in preparing on General Chemistry exam. We would like to increase quality of our e-learningu course. We were interested in student's opinion in mentioned course. Respondents asked for more variability of control questions (not just test question but also application tasks) and correct results (as suitable feedback in individual learning).

CONCLUSION

Students of daily study program Environmentalistics have two possibilities in the area of preparing on General Chemistry exam: e-learning materials and traditional books. In every semester students obtained questionnaire, they could anonymously compare both studying materials. From responses of 142 students we founded that e-learning course and also books have their own advantages. In the presence form students focused on mainly on understanding content of education. Teachers have lot of possibilities to orientate their students and help them in understanding new knowledge.

At the other hand e-learningu offers mainly self study. There are very important: suitable student materials, additional materials, chat between student and teacher, testing and controlling of knowledge. During preparation e-learningu materials we used basic division of General Chemistry and we accepted purpose of learning.

From the results of the questionnaire we could find out which direction we have to focus in chemical education. It is appropriate to apply to e-learning the results of their own research work and their application in practice, so that we closely linked both theory and practice, but also pointed their mutual applicability. After five years e-learningu in chemistry education for students of Environmentalistics is suitable, slightly applicable in praxis and induces students motivation.

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REFERENCES

Benedek, A., 2014. MINDTHEGAPP™: Connecting global educators and mobile learners. In Stoffová, V. (Ed.)| *XXVI. DIDMATTECH 2013* New Technologies in Science and Education, s. 87-94.

Bílek, M., Poulová, P., Šimonová, I., 2012. E-learning a multimédia jako předmět výzkumných šetření - stručný exkurz do metodologie In Chromý, J. - Šedivý, J. – Drtina, R. (Eds.), Média a vzdělávání. (pp. 13-18). Praha: ExtraSYSTEM Praha, vol. 4.

Bílek, M., Rychtera, J., 1999. *Chemie. Krok za krokem*. 1. vydanie. Staré Hradiště : MOBY DICK.

Bílek, M., Rychtera, J., 2000. *Chemie. Na každém kroku*. 1. vydanie. Staré Hradiště : MOBY DICK.

Bílek, M., Tobořiková, P., 2010. Aktuální výzvy pro počítačem podporované školní chemické experimenty. In: Sborník přednášek z mezinárodní konference v Trojanovicích *Aktuální aspekty pregraduální přípravy a postgraduálního vzdelávaní učitelů chémie*. s. 32-35.

Feszterová, M., 2011. E-learning a jeho prínosy pre oblasť BOZP. In *Media4u Magazine*, Roč. 8, č. X3 (2011), s. 167-171.

Hilbert, H., 1998. Metóda hodnotenia antropického tlaku v krajine v koncepcii synantropizácie-desynantropizácie. In *Acta Universitatis Matthiae Belii* (Sekcia Ekológia a environmentálna výchova), I, s. 1-35.

Hilbert, H., 2002. Environmentálne zdravie vo výchove a vzdelávaní. In *Životné prostredie*, č. 3. Dostupné na internete: <http://www.uke.sav.sk/zp/2002/zp3/hilbert.htm>

Horrigan, B., 2010. Corporate Social Responsibility Agenda.

Hreško, J., Bugár, G., Fehér, A., Jakabová, S., Petrovič, F., Pucherová Z., Tuhárska, K., Vanková, V., Zorád, L., 2008. *Natural resources* : (air, water, soils, biota, ecosystems). Nitra : UKF.

Hronec, O., Tóth, J., Tomáš, J., 2002. *Cudzorodé látky a ich riziká.* Košice : HARLEQUIN QUALITY.

Juhász, Gy., 2000. Internet a kémiaoktatásban. In *16. Kémiaoktatási Világkonferencia Magyar nyelvu eloadások osszefoglalói*, Gyor : Kenguru Kft, s. 2.

Kašiarová, S., Feszterová, M., 2008. The Natural and Anthropological Contamination Sources of the Halčiansky Water Reservoir. In *Chemické listy* 102 (S), 365-366.

Kašiarová, S., Feszterová, M., 2010. Changes in Stream Water Contamination in Select Slovakia Settlements. In *Polish Journal of Environmental Studies*. Vol. 19, no. 2 (2010), p. 343-349.

Kontrišová, O., Beseda, I., Bublinec, E., Kočík, K., Ladomerský, J., Samešová, D., 1998. *Globálne problémy životného prostredia.* Zvolen: Vydavateľstvo TU vo Zvolene, s. 11, 57, 91 – 93.

Kozík, T., Feszterová, M., 2011. Dôležitosť vzdelávania v oblasti bezpečnosti a ochrany zdravia pri práci. In. *Edukacja - Technika - Informatyka : wybrane problemy edukacji technicznej i zawodowej.* Roč. 3, č. 2 (2011), 1. časť, s. 115-120.

Lepil, O., 2010. *Teorie a praxe tvorby výukových materiálů.* Olomouc: Univerzita Palackého.

Nezvalová, D., Hrbáčková, K., Bílek, M., 2010. Konstruktivismus a přírodovědné vzdělávání. In *Inovace v přírodovědném vzdělávání.* Olomouc : Univerzita Palackého, s. 17-54.

Noga, H. 2012. General principles of safety in factories. In Kozík, T., Brečka, P. (Eds.) *Lifelong education in the area of OHS 2012: zborník príspevkov z medz. ved. Symposia*, Nitra: UKF, s. 152-159.

Orsághová, D., Gregáňová, R., Kecskés, N., 2014. Electronics study materials – as a complement of mathematical education at FEM SUA in Nitra. In Stoffová, V. (Ed.)| *XXVI. DIDMATTECH 2013 New Technologies in Science and Education*, s. 206-211.

Prauzner T. 2010. Applications of multimedia devices as teaching aids. In *Annales UMCS, Informatica*, Warsaw: Versita, p. 167-175.

Raczyńska, M., 2014.Odkryweanie wiedzy w bazach danych. In Stoffová, V. (Ed.) *XXVI. DIDMATTECH 2013 New Technologies in Science and Education*, s. 95-101.

Stoffa, V., 2014. Elektronikus tankönyv, elektronikus tananyag és az e-learning, In Stoffová, V. (Ed.)| *XXVI. DIDMATTECH 2013* New Technologies in Science and Education, s. 87-94.

Stoffová, V., 2004. *Počítač ako univerzálny didaktický prostriedok*. Nitra : FPV UKF.

Šimonová et al., 2010. *Styly učení v aplikacích e-learningu*. Hradec Králové: M&V.

Šrámek, V, 2000. *Obecná a anorganická chemie.* Olomouc : Nakladatelství Olomouc, 2000. 263 s.

Turčáni, M., Bílek, M., Slabý, A., 2003. *Prírodovedné vzdelávanie v informačnej spoločnosti*. Nitra: UKF.

Tölgyessy J. et al., 1984. *Chémia, biológia a toxikológia vody a ovzdušia*. Bratislava : VEDA.

Vrábelová, M., 2005. Prvé skúsenosti s MOODLE. In: Fulier, J. (Ed) *IKT vo vyučovaní matematiky*. Nitra: FPV UKF, s. 63-68.

COMPUTER AIDED CLASSES. PREDICTING BIOACTIVITY OF NATURAL COMPOUNDS ON THEIR STRUCTURE

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Abstract

Students of "Bioactive substances and cosmetics" course should have the opportunity to obtain experience with computational tools and numerical approaches usually used in biochemistry. The application of computational techniques for predicting biological activity of the compounds based on their structure are most effective in screening tests. In this paper presents the project of application QSAR methods to estimate of the permeability of the chosen group of ingredients of essential oils, used in topical applications.

Keywords:

QSAR, lipophilicity, terpenoids

INTRODUCTION

Natural compounds possess wide spectrum of biological activities and some of them may be useful in medicine and cosmetics. Essential oils are natural, complex mixtures synthesized by plant as secondary plant metabolites. The constituents of essential oils have been widely used for bactericidal, virucidal, fungicidal, antiparasitical, insecticidal, medicinal cosmetic applications (Król, 2013, Carlson and Hammer, 2011). These mixtures can contain a few dozen various components at quite different concentration, but two or three of them are major components at fairly high concentrations compared to the others, which are present in trace amounts. Many of these oils are composed mainly of monoterenes eg. origanum compactum (30 % carvacrol, 27 % thymol), coriandrum sativum (68 % linalool), mentha piperite, (59 % menthol, 19 % menthone) or anethum grevolens (37 % limonene) (Bakkali,2008). Essential oils are mainly liquid, volatile, colourless lipid soluble liquids. The application of essential oil components depends on the target of their action. Percutaneous absorption of terpenes and their oxygenated derivatives is an area of significant interest with regard to the delivery of these substances to human body. Terpenes are substances with low skin irritancy potential, therefore topical application is typical way of their use in medical or cosmetic purposes.

Human skin is usually hard to obtain as a subject of investigation; therefore, experimental determinations of skin permeability mainly have been conducted using surrogates, in vivo experiments- animal testing. A more interesting alternative has been development of procedures that enables prediction of biological effects directly from chemical structure of investigated compound. Prediction of biological activity of the compound from its chemical structure is generally referred to as quantitative structure-activity relationship (QSAR). The main problem in this method is recognition of the factors affecting biological activity of investigated compounds consistent with assumed target of their action. These factors must have clear physical meaning, are easily interpretable and may be calculated in relatively simple way.

The paper presents the example to use of computer aided techniques and procedures predicting the biological activity of the compounds on the basis of their chemical structure. This is a part of student classes the course of “Chemistry of bioactive substances and cosmetic” concerning the bioactivity of natural compounds.

METHODS AND RESULTS

Physics-chemical parameters determining bioactivity of the compound

Lipophilicity is probably the most widely used parameter affecting the bioactivity of the compounds, because bilipid core of biological membrane is responsible on the passive transport processes in living organisms. The distribution of the test substance between the lipophilic cellular membrane and aquatic phase, which is in contact with the membrane, determines the phenomenon of passive membrane permeation of the substance. The distribution coefficient of biological membrane/water is not easily accessible experimentally. The mostly used parameter for description of passive transport processes of bioactive substances in human body is the logarithm of octanol/water partition coefficient (log P) as the most similar to the investigated biological system. Experimental determination of the values of the partition coefficient is expensive and time-consuming. Moreover, the obtained results are not always completely reliable, particularly when was used indirect methods for determining the partition coefficient. Numerical methods are especially recommended in the initial stage of the research as the method of screening according to special properties in terms of anticipated application of investigated compounds. The set of programs available in VCCLAB was used to determine the values of the logarithm of the octanol/water partition coefficient investigated group of compounds. Due to the fact, that these programs analysing the structure of the molecules stored in the SMILE code, it is necessary to apply the initial conversion of the structure pattern investigated terpenoids in SMILE code, by use of Open Babel software. The average logP values are shown in table 1.

Table.1. The values of the logarithm of the octanol/water partition coefficient investigated group of terpenoids calculated by use of numerical procedures available on VCCLAB and Molinspiration internet platforms.

No.	Group of compounds	Compound	Avarege logP	Molar Weight [g/mol}	Molar Volume [cm^3]	PSA [A^2]	Hydrogen bond Donors NOHNH	Hydrogen bond Akceptors nOH	Rigidity	Dipole moment [D]	Solubility in water [g/dm^3]
1	ALKOHOLS	Cytronellol	3.27(+-0.30)	156.30	181.787	20.228	1	1	5	1.644	0.85
2		Linalol	2.87(+-0.32)	154.28	175.591	20.228	1	1	4	1.496	0.48
3		Geraniol	2.97 (+-0.36)	154.28	175.575	20.228	1	1	4	1.685	1.37
4		Izopulegol	2.71 (+-0.35)	154.28	171.553	20.228	1	1	1	1.843	1.28
5		Terpinol	1.66 (+-0.33)	172.30	184.554	40.456	2	2	1	2.183	8.31
6		S-(-)-α-terpineol	2.57 (+-0.48)	154.28	170.647	20.228	1	1	1	1.719	1.56
7		Karwakrol	3.17 (+-0.21)	150.24	158.572	20.228	1	1	1	1.321	0.47
8		Tymol	3.20 (+-0.22)	150.24	158.572	20.228	1	1	1	1.352	0.64
9		Alkohol perylowy	2.43 (+-0.44)	152.26	165.555	20.228	1	1	2	1.740	1.90
10		Borneol	2.51 (+-0.33)	154.28	165.72	20.228	1	1	0	1.653	0.81
11		Terpinen-4-ol	2.60 (+-0.45)	154.28	170.253	20.228	1	1	1	1.601	2.50
12		Trans-werbenol	2.18 (+-0.39)	152.26	159.857	20.228	1	1	0	1.661	3.51
13		Trans-pinokarweol	2.22 (+-0.33)	152.26	160.413	20.228	1	1	0	1.633	1.76
14		Myrtenol	2.15 (+-0.37)	152.26	160.072	20.228	1	1	1	1.801	1.58
15		I-mentol	2.91 (+-0.31)	156.30	177.21	20.228	1	1	1	1.680	0.56
16		Sobrerol	1.42 (+-0.49)	170.28	178.691	40.456	2	2	1	3.159	26.02
17	DIOLS	Trans-1,2-dihydroksylimonen	1.65 (+-0.34)	170.28	179.246	40.456	2	2	1	2.283	14.57
18		Diol 24	1.78 (+-0.25)	172.30	185.469	40.456	2	2	2	2.259	9.55
19		Diol 23	1.20 (+-0.68)	168.26	173.599	40.456	2	2	2	3.311	11.81
20	ALDEHYDES	Neral	3.11 (+-0.36)	152.26	169.739	17.071	1	0	4	3.030	0.40
21		Myrtenal	2.38 (+-0.33)	150.24	154.236	17.071	1	0	1	3.230	0.90
22		Izonowalal	3.05 (+-0.29)	152.26	170.079	17.071	1	0	4	3.027	0.34

No.	Group of compounds	Compound	Avarege logP	Molar Weight [g/mol}	Molar Volume [cm^3]	PSA [A^2]	Hydrogen bond		Rigidity	Dipole moment [D]	Solubility in water [g/dm^3]
							Donors NOHNH	Akceptors nOH			
23		Cytronellal	3.28 (+-0.38)	154.28	175.951	17.071	1	0	5	2.708	0.36
24	KETONES	(+) – pulegon	2.64 (+-0.43)	152.26	165.11	17.071	1	0	0	3.169	2.29
25		Tymochinon	1.93 (+-0.46)	164.22	161.104	34.142	2	0	1	0.112	1.83
26		Kamfora	2.40 (+-0.40)	152.26	159.858	17.071	1	0	0	2.880	0.88
27		(+) - dihydrokarwon	2.47 (+-0.29)	152.26	165.691	17.071	1	0	1	2.849	0.56
28		R-(-)-karwon	2.48 (+-0.44)	150.24	159.478	17.071	0	1	1	3.264	1.24
29		Izopiperitenon	2.44 (+-0.48)	150.24	159.478	17.071	1	0	1	2.976	1.16
30		Fenchon	2.32 (+-0.42)	152.26	159.858	17.071	1	0	0	2.881	0.88
31		(-) – piperiton	2.65 (+-0.42)	152.26	165.135	17.071	1	0	1	3.153	1.36
32		Werbenon	2.24 (+-0.49)	152.24	153.995	17.071	1	0	0	3.149	3.84
33		Pinokarwon	2.30 (+-0.43)	150.24	154.551	17.071	1	0	0	3.106	0.62
34	CARBOKSYLIC ACID	Kwas peryllikowy	2.52 (+-0.48)	166.24	167.737	37.299	2	1	2	1.751	1.36
35	LACTONES	Lakton 25	1.93 (+-0.31)	166.24	163.545	26.305	2	0	0	3.908	4.12
36		Lakton 26	2.06 (+-0.26)	166.24	163.519	26.305	2	0	0	4.137	5.00
37		Lakton 27	2.21 (+-0.38)	168.26	169.758	26.305	2	0	0	3.818	1.06

Important factor, affecting on permeability of the compound through the biological membrane, is their ability to form hydrogen bonds. The simplest method for estimating the ability to create hydrogen bonds is to determine the number of donor (nOHNH) and acceptor (nON) atoms. The ability of a molecule to penetrate cell membrane depends on the number and strength of hydrogen bonding, which able to form this molecule in water phase. Total dehydration is required so that a substance that is dissolved in water would be permeated through the membrane. Amount of donor (nOHNH) and acceptor (nON) atoms are calculated using Molinspiration procedure (Tab. 1).

Biologically active compounds are frequently present in several three-dimentional conformers as a result of the impact of the environment. Conformers show different bioability in relation to the human body. The parameter which determining the ability of the compounds to change conformationally is the number of on-rotable bonds (NRTB) characterizing so-called "rigidity"of the molecule. The NRTB was determined using Molinspiration procedure (Tab.1)

Molecular mass is the most frequently used parameter described the particle size in calculations related to the permeability of the tested compounds by biological membrane. However, this is not an ideal measure, because it ignores molecular shape. Therefore, in permeability calculations should be preferred molecular volume rather then molecular mass of the investigated molecule. Molar volume of tested compounds was calculated using Molinspiration and VCCLAB (Table 1).

The polarity of the molecule substantially affects their membrane transport. Total polar surface area of molecule (TPSA), defined as that part of the surface of the molecule that is linked with the atoms of nitrogen and oxygen and the hydrogen atoms attached to these heteroatoms, corresponds on the differences in the permeability of the compounds having the some number of nON and NOHNH. TPSA values depend on the type of conformer. Therefore, usually TPSA values were expressed as a weighted average of the TPSA of the lowest conformations energy conformers. The values of the TPSA for particular terpenoids were determined by Molinspiration (Tab 1). Polarity also was characterized by the size of the dipole moment (μ) of the molecule calculated according Avogadro procedure (Tab1).

The factor which cannot be ignored when estimating bioavailability is its solubility in water, because from this environment typically bioactive molecule penetrates through biological membrane into the inside of the body. A calculation of the solubility on the basis of molecular structure was conducted by logS and ALOGpS from VCCCLAB platform. The results shown in table 1.

The analysis of calculation results of physico-chemical parameters of investigated compounds is based on the use of the so-called "Rule of five" proposed by Lipinski (2001) and their modified versions accessible in DruLiTo. These rules are commonly used for the pre-selection of compounds for their biological activity in drug design and cosmetics. According to these rules, calculation results of the investigated terpenoids suggest that the studied compounds are likely to show a satisfactory bioactivity, due to the relatively small size of the particles, optimal lipophilicity and low ability to form hydrogen bonds. On their potential bioavailability also indicate low size of the TPSA.

Skin permeability of the compounds

The absorption of biologically active substances by a human organism depends on the transition of these substances from the external environment into the bloodstream. Absorption may be oral, by inhalation or through the skin at topical application of the bioactive substance on skin surface. Stratum corneum, most outer layer of the skin is the main security barrier preserved body at permeation bioactive substances inside of organism. Parameter describing the penetration process of biologically active substances into the organism is called. Permeability skin factor (Kp).

QSAR equation used to calculate Kp takes into account both parameters describing particle size and its lipophilicity was equation proposed by:

Fitzpatric et al (2004) $\log Kp = -2{,}19 * 0{,}781 \log P - 0{,}0115 MW$

and Barrat (1995) $\log Kp = -2{,}771 + 0{,}769 \log P - 0{,}00734 MV$

According the prediction, significant differences in permeability skin factor values it was observed in these compounds which show high values of rigidity parameter.

Table.2: Skin permeability factor (Kp) determined according Fitzpatric (MW) and Barrat (MV) equations.

Compoud No.	Skin permeability factor [cm/h]		Compound No.	Skin permeability factor [cm/h]	
	MW	MV		MW	MV
1.	0.036572	0.025663	20.	0.030536	0.023698
2.	0.01881	0.014034	21.	0.008682	0.008455
3.	0.02251	0.016758	22.	0.027416	0.021187
4.	0.021716	0.017312	23.	0.039281	0.02883
5.	0.001328	0.001416	24.	0.013128	0.011149
6.	0.010974	0.00897	25.	0.002672	0.003394
7.	0.035879	0.031828	26.	0.008531	0.007966
8.	0.037865	0.033565	27.	0.009674	0.008171

Compoud No.	Skin permeability factor [cm/h]		Compound No.	Skin permeability factor [cm/h]	
	MW	MV		MW	MV
9.	0.009003	0.00763	28.	0.010391	
10.	0.009853	0.008766	29.	0.00967	0.008606
11.	0.011582	0.009522	30.	0.007389	0.006914
12.	0.005747	0.005396	31.	0.013366	0.011344
13.	0.006175	0.005738	32.	0.006404	0.006626
14.	0.005445	0.005098	33.	0.00752	0.0073
15.	0.019158	0.014658	34.	0.007309	0.008624
16.	0.000911	0.001022	35.	0.002533	0.003256
17.	0.001377	0.001521	36.	0.003199	0.004101
18.	0.001648	0.001724	37.	0.00397	0.004814
19.	0.000647	0.000754			

CONCLUSION

Determination of the relationship between biological activity of substance and its structure is one of main tasks of medicinal chemistry and cosmetic. It significantly decreases the number of compounds which one subjected to long-testing and expensive experimental studies.

In this paper was presented the example of estimation of the skin permeability of terpenoids in respect to their usefulness in topical application on the basis their compound structure. This is a part of the project of introduction the students the "Bioactive compound and cosmetic" course to the computational tools and approaches usually used in drug and cosmetic design.

RERERENCES

Bakkami, F., Averbeck, S., Averbeck, S., Idaomar, M., 2008. Biological effects of essential oils. *Food and Chemical Toxicology* 46, pp. 446-475,

Barrat, M. D., 1995. Quantitative structure activity relationshipsfor skin permeability. *Toxicol In Vitro*, 9(1) pp. 27-37,

Carson, C. F., Hammer K., 2011. Chemistry and Bioactivity of Essential Oils, In Thormar H. ed. 2011, *Lipinds and Essential Oils as Antimicrobial agents*, John Wiley 7 Sons, Ltd, Adv Drug Deliv Rev. 2001 Mar 1;46(1-3):3-26.

Drug Likenes Tool (DruLiTo), Available at: http://www.niper.gov.in/pi_dev_tools/DruLiToWeb/DruLiTo_index.html; Accessed 14 July 2014

Fitzpatrick, D., Corish, J., Hayes, B., 2004. Modeling skin permeability in risk assessment- the future. *Chemosphere*, 55, pp. 1309-14,

Molinspiration, available at: http://www.molinspiration.com; Accessed 14 July 2014

Król, S. K., Skalicka-Wożniak, K., Kandefer-Szerszeń, M., Stepulak, A., 2013, The biological and pharmacological activity of Essentials oils In the treatment and prevention of infectious diseases. *Postępy Hig Med. Dosw.* 67, 1000-1007,

Lipiński, C. A., Lombardo, F., Dominy, B. W., Freeney, P. J. 2001. Experimental and computational approaches to estimate solubility and permeability in drug discovery and development settings. *Adv Drug Deliv Rev.* Mar 1; 46(1-3):3-26.

Open Babel, available at: http://openbabel.org/wiki/Main_Page; Accessed 15 July 2014

Virtual Computational Chemistry Laboratory, available at: http://www.vcclab.org, Accessed 14 July 2014.

HOW DO STUDENTS OF CHEMISTRY TEACHING PREDICT THE IMPACT OF GRAPHICAL PART OF DIDACTICAL TESTS?

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Abstract

For the first pilot research in the scope of the project Learning from graphical presentation in science education there has been chosen investigation of the role of non-verbal elements of didactic tests. For solving of this task there was used comparison of the results of pupils of basic school performing two variants of the test with the same content and different form of formulation and arrangement of items (verbal form and form comprising visual information (pictures and graphs). In the contribution there are described starting points of the project, the interpretation obtained, experimental data from the point of view of typology of picture material as a part of didactic tests and mainly the point of view and the attitude of the students of chemistry teaching to the influence of graphical elements to the fruitfulness of students in didactic tests.

Key words

Learning from the Picture Material, Primary Chemistry Education, Didactical Tests and Effectiveness of Non-verbal Part of Didactical Tests, Chemistry Teacher Education.

INTRODUCTION

Visual perception, elaboration of visual information and subsequent creation of adequate conception of pupils and students appears to be substantial part of education of science subjects. Graphical presentation represents in the era of coming information and communication technologies into process of education substantial part of educational materials in all stages of school system. Group of researchers at the

University of Hradec Králové started to work at the research project which aims to analyse various ways of elaborating non verbal (graphical, picture) information during the education of science subjects (Bílek, 2002a). Partial aims of the project focus on description of the function of picture material in educational texts and devices with main concentration to their electronic form i.e. to educational possibility of computer graphics, animation and simulation of science phenomena and their principles and to the description and interpretation of the models and elaboration of visual information of learners. The results should tribute to optimization of the creation and increasing pedagogical effectiveness of educational texts based on multimedia, educational CD-DVD and Internet technology. On the other hand the results should tribute to improving of professional part of chemistry teachers education – improving of subject methodology in area of non-verbal part of educational texts. This is the rationale of the research part of the article.

Theoretical Base I - Verbal and Non Verbal Aspects of Human Education

Sumfleth et al. (2002) similarly as Pavlíková (1999) quote in their works Mayer's Cognitive Theory of Multimedia Learning, which comprises five starting-points for meaningful education supported by multimedia devices:

- Selection of words,
- Selection of images,
- Organisation of words,
- Organisation of images,
- Ways of integration of words and images.

At the same time there is necessary to distinguish three important aspects of effective elaborating of information by learning people:

- Presented verbal information has to be connected with verbal information anticipated by learning people (previous information possessing verbal base),
- Presented visual information has to be connected with visual information anticipated by learning people (previous information possessing picture base),
- Time and space connection presented by visual and verbal information is crucial for learners.

Time and space connection between verbal and visual information is crucial in creating mental models required by learning people for decoding teaching material substantially easier (Sumfleth, Huellen & Telgenbüscher, 2002).

Mareš (1995) gives some differences in the role played by verbal and visual part of human learning from the point of view of pupil's development. In pre school age verbal and non-verbal communication is more connected and the child who still cannot read devotes great proportion of its attention to visual materials. In school age verbal and nonverbal parts start to disconnect and printed or written text prevails. Mareš (1995) also claims that pupils are taught to read systematically. Less attention is devoted to the process of comprehending the text by reading it. Way of learning from visual material and obtaining new information from it is usually not taught at school at all. It is supposed some self-evident plasticity or the fact that the picture possesses self-explanatory attribute.

Very wide and vague notion plasticity but often does not possess the role of sufficiently suitable description of concrete graphical image in the process of education. Let us mention one of known the Mayer's classification of picture material according to its prevailed function classification given in Pavlíková (1999). Picture material may have the following dominated functions:

- Decoration,
- Representation,
- Transformation,
- Organisation,
- Interpretation.

Platteaux et al. (2002) claims in his empiric study on combination of visual and text material in e-course of embryology for students of medicine that the most effective function is the level transformation (visual information helps to decode information given in the text) and the level interpretation (visual information supports imagination of concrete content in the relation to the text). On the other hand the worst effectiveness was recorded for pure decorations as it does not semantic relation to towards the text. Other authors ascribe great importance to the decorative function also and mention its contribution to the evolvement of aesthetic experience and removal of difficult text anxiety etc. (Mareš, 1995).

Weidenmann (1994) in his studies on mastering knowledge by means of picture material establishes several principle problems. First of them is ability to distinguish realistic and logic pictures. Realistic images such as colour photography, detailed drawing, realistic picture or schematic draft describe to certain degree a real closeness to the described object. The main purpose of logical images or schemes is to create adequate conception on connection among some qualitative and quantitative aspects of certain object. Reception of the real world by means of realistic pictures is according to Weidenmann called first order understanding. It corresponds everyday life, outer experience, superficial interpretation etc. This aspect at logical images may but deceive. Then it is necessary to reach second order understanding and decoding implicit connections and relations among qualitative and quantitative aspects of image. Every imager possess according to this theory primary explicit depicting code and primary implicit directing code. Issing developed further this theory by setting apart the specific aspects of image analogy into so-called semiotic classification of categories of pictures (Telgenbüscher, 1998):

- Picture analogies,
- Realistic images (realistic picture and photography),
- Logical images (tables, graphs, diagrams, charts).

From the point of view of science teaching problems Telgenbüscher (1998) introduces important classification in picture distinction according to visual level to:

- Sensory (macroscopic) level,
- Atomic and molecular (sub microscopic) level,
- Symbolic level.

Theoretical Base II - Cybernetic Aspects of the Learning from the Picture Material

From the point of view of education technology and educational cybernetics there is possible to make use of findings about psycho-structured model of the process of learning introduced for example in Frank (1996) or the theory of so called double coding mentioned in Paivio (1986). Research work in the didactic of chemistry which appears to be the most contiguous science learning branch for us was performed by Johnstone (1997). Johnstone similarly as Frank describes in his psycho-structural model of pupil certain building elements (model of operations) crucial for human reception and learning. He distinguishes: Stimulation - Perception Filter (Accommodator) – Working Space in the Memory (Operation Memory) – Long Term Memory

(Storage) influencing accommodator. Johnstone in contrast to Franks cybernetic pedagogy is not engaged with strictly quantitative expressing of the content of the parts of psycho-structural model (in bits) but he divides parts of information content of teaching material into basic and at already well mastered operations ("pieces"), which must be performed in pupils operation memory. Method is sometimes called as "chunking" - dividing. Johnstone in his experiments with high school population in the area of chemical equilibrium discovered empirically the limit of possible operation, which can be performed in operation memory of learning people and called it capacity of operation memory. If learners reach the limit, their ability to solve more complicated tasks dropped substantially. This can be illustrated by easy experiment with keeping row of letters in mind. In time limit 10 seconds as is described in (Bílek, 2002b):

- AVPSNQ (6 letters are memorised without problems),
- MPLSVCAEOKNZ (12 letters causes substantial problems to memorize),
- MOCVLKNESZAP (12 letters of the previous task divided into four words makes memorizing possible again).

Example derived from the chemistry area demonstrates differences in memorizing structural and functional chemical formula (for example CH_3 - CH_2 - COO - CH_3).

This proves the application of so called "supering" i.e. creating of supersigns. Realization of making super signs is possible by two ways by creating of classes and complexes. In the scope of our project there are prepared experiments with graphical material and searching similar dependences.

Theory of double coding tries to assign the same meaning to both verbal and non-verbal processes. Information is according to this theory processed in memory in the two separate coding systems having close mutual relations. A lot of empiric results prove that double coded information is memorized substantially better. Well known is also information about certain changes in relation of both these above mentioned coding systems in dependence of the age of learners (Mareš, 1995).

Theoretical Base III - Several Examples of the Influence of Picture Material to Learning in Science Subjects

In spite of the fact, that learning from picture material is so far very little investigated problem of scientific research, it was possible to analyse in the first literature search part of our above mentioned project several important studies having this set and proving positive influence of the picture material applied under certain specifically defined conditions. Sumfleth et al. (2002) presented results of Mayer and Galini on the influence of combination of verbal and visual information. Research was performed with for groups of respondents. First group had for its disposal text about technical device without pictures. The second might use images having description of various components; the third group had pictures with description of components and explanation of their function, and the fourth the organically arranged sequence of pictures, with description of components and explanation of their function („steps and parts"). Out of these four groups the fourth achieved he best results and substantially better results in education than other three groups. Similar research having similar results was later arranged by Sumfleth, Hüllen and Telgenbüscher. This presents a combination of text and picture material of the chemistry for the 12th year of study at high school. The concrete teaching material concerned addition reaction of bromine to double binding between carbon atoms. Other research about learning from picture material in the subject matter of chemistry, which we analysed, can be found in Pavlíková (1999), Gnoyke (1995) or Telgenbüscher (1998).

METHODOLOGY OF RESEARCH

First pilot research of our above mentioned project (Bílek, 2002a) concerned investigation of the role of non-verbal elements of didactic tests (Bílek, Slabý, Konířová & Hruška, 2003). There were compared the results of two groups of pupils of basic school solving two variants of the test having the same content as to subject matter but different form of submitting of items (verbal form for the first group and the form comprising images or graphs (non verbal elements)). There was proved positive but not distinct influence of graphical elements in the most of test items to the success by solving test tasks (see example on Figure 1). Relatively weak pupils (as to study results) achieved the biggest difference.

The second part of the pilot project was devoted to investigation of the influence of the attitude of pupils to learning to study results in verbal and picture test by using of "Index of Learning Styles (ILS) – part „verbal versus visual" learning attitude (Solomon, Felder, 2001). In this part there were supposed much better results by those pupils who we able to make use of harmony between the form of the test and their attitude toward learning (visual attitude - picture test and verbal attitude - verbal test). This assumption was but not proved. Pupils with verbal attitude achieved much better results by learning solving the picture variant of the test (Bílek, Slabý, Konířová & Hruška, 2003).

The important role in teaching from the picture material by analogy to the verbal learning is based by previous knowledge. Series of research works is consequently focused on comparative study of reception of pictures by so called experts (having certain level of knowledge of presented subject matter) and so called non-specialists (who have minimum knowledge in the area learned). This fact plays by our view important role in educational process from the teachers as expert in the selection of adequate presentation of the subject matter.

We concentrate to this aspect in connection with some investigation in the area of didactic tests of chemistry at basic school in the third part of our project (mentioned in this paper). We examined prognosis of students of chemistry teaching concerning the influence of picture elements of didactic test to success of students in the tests.

RESULTS AND DISCUSSION

Important role in teaching from the picture material is based by previous knowledge. Our research topic focuses on comparative study of reception of pictures by so called experts (having certain level of knowledge of presented subject matter) and so called non-specialists (who have minimum knowledge in the area learned). We examined prognosis of students of chemistry teaching to the influence of picture elements of didactic test to the success of students in the tests.

The students were made to formulate their opinion about the differences in results in individual items of the test: will the average result be substantially better in the test item of the variant with pictures scale 4 or better in the test item of the variant with pictures scale 3 or the same for both variants scale 2 or better at picture variant scale 1 or substantially better at picture variant scale 0 (expert assessment at the scale 4 – 0; value 2 represents insignificant influence of the form of item of the didactic test). Results of group of future chemistry teachers are presented in Table 1.

Nr. 18

Jak obecně postupujeme při ředění kyselin (především kyseliny sírové): 2,06

a) přiléváme vodu do kyseliny,
b) přiléváme po tyčince kyselinu do vody,
c) přiléváme po tyčince vodu do kyseliny,
d) přiléváme kyselinu do vody.

10,1 %

30,4%

Nr. 18

Jak obecně postupujeme při ředění kyselin (především kyseliny sírové):

a) b) c) d)

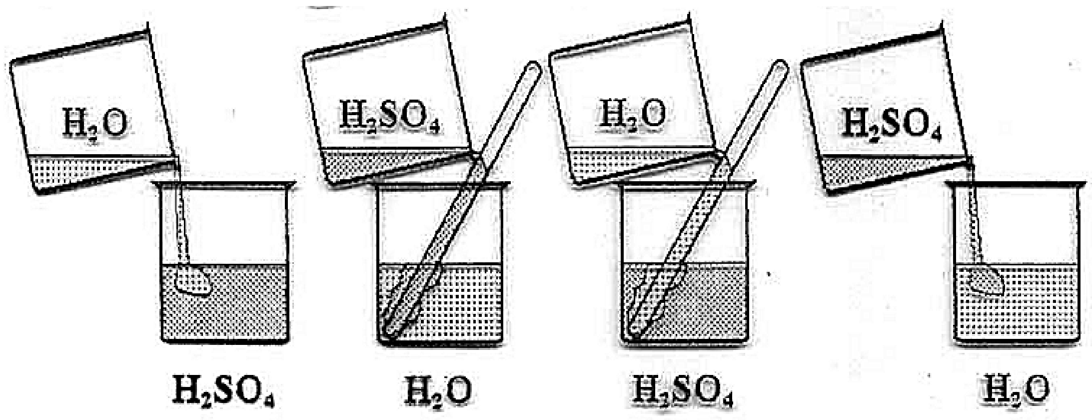

Fig. 1 The scan of two variants the 18th test item (estimation 2,06 out of 4 given by number in circle and results of tests (10,1% and 30,4%) given by other two numbers shows underestimation of prognosis from future teachers)

Table 1 Results of group of future chemistry teachers in prognosis of picture influence

Nr. of Item in Test	Average of Pointing Scale Evaluation from Future Teachers	Percentage of Successfully Responds of Pupils in Verbal Form of Test	Percentage of Successfully Responds of Pupils in Graphical Form of Test
1	2,33	36,9	9,9
2	2,61	34,3	39,9
3	2,78	24,3	24,9
4	2,39	57,8	71,2
5	3	48,7	46,7
6	1,17	87,9	51,8
7	2,22	66,7	61,0
8	3	79,0	78,2
9	1,5	26,5	22,3
10	3,06	60,6	82,6
11	3,17	51,2	60,6

Nr. of Item in Test	Average of Pointing Scale Evaluation from Future Teachers	Percentage of Successfully Responds of Pupils in Verbal Form of Test	Percentage of Successfully Responds of Pupils in Graphical Form of Test
12	2,78	39,7	45,9
13	2,39	41,4	47,8
14	1,89	86,9	94,9
15	1,38	43,9	69,2
16	2,67	65,4	62,7
17	2,33	35,9	28,0
18	2,06	10,1	30,4
19	3,72	62,6	51,3
20	2,56	34,1	43,3

Out of the examination performed there follow some interesting conclusions, which may serve as starting point for further research in mentioned area. Let us mention some important findings:

1. Students suppose at most test items of the test (13 items out of 20 items) positive influence of the picture elements to test results of pupils of basic school.
2. Students estimated only by 9 items of the test (out of 20 items) correctly positive, weak or negative influence of picture elements (with 5 percent tolerance).
3. Students substantially overestimated positive influence of the symbolic expressing of situation in comparison with verbal description. (For example: “symbolic versus verbal definition of amount of substance” – substantially better results were achieved by students; “record of proton number as part of the symbol of the element” - it was achieved only a tiny difference on behalf of the picture variant i.e. symbolic expression though the subsequent discussion held with students proved knowledge of Piaget theory of teaching stages (here was proved only isolated knowledge without application ability of this matter etc.).
4. Students substantially underestimated auxiliary information obtained from graphs in comparison with tables (properties of halogens).
5. Students substantially overestimated the influence of the drawing of chemical apparatus to solving of the task (task concerning selection of distillation apparatus, task including either drawing or description of the position of the hydrometer in the cylinder by finding of the density of given liquid).

CONCLUSION

The main aim of the mentioned project there was analysis of the ways of pupils/students learning by means of visual devices in the following contexts: from static to dynamic images, the consequences of excessive and insufficient stress of plasticity, ways of verifying of the effectiveness of learning from picture materials, contribution to classification of the learning styles using picture material in comparison with results of known research in the area of learning styles from text materials, influence of the way of presentation of material.

In the presented part of research activity were monitored results of chemistry teacher's education in the area of impact of nonverbal elements of educational materials. It is evident that student's knowledge about elaboration of graphical information by pupils is very rudimentary, fragmented and consequently little useful.

Partial results obtained cannot be overestimated so far due to limited number of respondents and short experience with methodology of used research. Consequently further research will address larger number of respondents, will comprise rearrangement of research methods and used devices and transition to analysis of electronic forms of educational materials making use of findings of the research of classical forms of presentation of teaching materials.

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REFERENCES

Bílek, M. 2002a. *Learning from Graphical Presentation in Science Education*. Proposal of Research Project, Czech Grant Agency (GAČR 406/02/1165), Hradec Králové: PdF UHK.

Sumfleth, E., Huellen, R., Telgenbüscher, L. 2002. Optimierung von Bildern für den Chemieunterricht. *ChemKon*, 3, 122 – 129.

Pavlíková, A. 2002. About Didactical Starting-Points of Educational Environment Creation in Conditions of Distance Learning (in Slovak). In *eLearn – Žilina 2002* (pp. 89 – 94). Žilina: EDIS – Publisher of Žilina University.

Mareš, J. 1995. Learning from Picture Material (in Czech). *Pedagogika*, XLV, 318 - 327.

Platteaux, H. et al. 2002. Pedagogical evaluation of a Web-based training in embryology: A study of image-text combinations. In *4th ICNEE – Proceedings* (p. 2.1/45), Lugano: net4net.

Weidenmann, B. (Hrsg.) 1994. *Wissenserwerb mit Bildern. Instruktionale Bilder in Printmedien, Film/Video und Computerprogrammen.* Bern – Göttingen – Toronto – Seattle: Verlag Hans Huber.

Telgenbüscher, L. 1998. *Zur Visualisierung von chemischen Konzepten - Untersuchung von Lernumgebungen und Lernparametern für effektives Lernen mit Bildern.* (Dissertation), Essen: Universität.

Frank, H. 1996. *Bildungskybernetik/Klerigkibernetiko.* Bratislava und Nitra: Esprima und SAIS, 1996.

Paivio, A. 1986. *Mental Representations: a Dual Coding Approach.* New York: Oxford University Press.

Johnstone, A. H. 1997. *J. Chem. Educ.*, 74, 262 – 268.

Bílek, M. 2002b. Cybernetics Aspects of Visualisation in Science Education (in Czech). In: E. Poláková (ed.), *Die Kybernetik in die Theorie und Praxis* (pp. 123 – 128), Nitra: UKF.

Pavlíková, A. 1999. *The Analysis of Picture Material in Chemistry Text-books by View of Learning* (Diploma Thesis in Slovak), Trnava: PdF TU.

Gnoyke, A. 1995. *Das Lernen mit Bildern in der Chemie - Aktion und Interaktion von Wahrnehmen und Denken.* (Dissertation), Essen: Universität.

Bílek, M., Slabý, A, Konířová, V., Hruška, L. 2003. Investigation of the Influence of Non-verbal Parts of Didactical Tests in Primary Chemistry Education. In: M. Bílek (ed.), *Visualisation in Science and Technical Education* (pp. 49 – 54), Edition: Didactics of Science and Technical Subjects, Volume 2, Hradec Králové: Gaudeamus.

Mašek, J. 1995. Some Aspects of Teaching of Visual and Audio-Visual Literacy (in Czech). In *MEDACTA 95* (pp. 39 – 44), Nitra: PdF UKF.

Turčáni, M., Fojtík, R., Polák, J. 2001. Distance Teaching and e-Learning in Informatics (In Slovak). *Technológia vzdelávania*, 10/IX., 2 – 7.

Slabý, A., Bílek, M. 2001. Promotion of Geometrical Imagination by Mathematical Modelling and Visualization in Technical Teacher Training. In: A. Melezinek (Hrsg.), *Lust am Lehren, Lust am Lernen* (pp. 416 – 419), Leuchturm-Schriftenreihe Ingenieurpädagogik, Band 45, Alsbach: Leuchturm-Verlag.

Solomon, B. A., Felder, R. M. 2001. *Index of Learning Styles (ILS Questionnaire)* [online]. Available at: htpp://www2.ncsu.edu/unity/lockers/users/felder/public/ILSdir/ILS-b.htm (Accessed 2001-03-06)

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