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Serbian Chemical Society

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Faculty of Chemistry

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European Variety in University Chemistry Education

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University Chemistry Education for the Challenges of Contemporary Society

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PREFACE

The conference entitled 7th EuroVariety – European Variety in University Chemistry Education has been organized by the University of Belgrade – the Faculty of Chemistry, the Serbian Chemical Society and the EUCheMS Division of Chemical Education. The main aim of the Conference is to provide an opportunity to share knowledge and experience relating to the important issues concerning university chemistry and chemical technology education in order to prepare future students to better respond to their personal needs and the needs of the contemporary society and to meet the labour market requirements. Therefore, the conference theme "**University Chemistry Education for the Challenges of Contemporary Society**" points out the need for continuous reconsideration of the connections between BSc, MSc and PhD chemistry studies and the contemporary professional, social and scientific challenges.

Over 70 participants from 29 countries have shared their experiences in their presentations offering their insights, pointing up the challenges and suggesting new solutions regarding the following Conference topics:

- Development of the university curricula for BSc, MSc and PhD chemistry studies
- Competency-based university chemistry education
- Chemistry education through university-industry partnerships
- Laboratory work as an element of problem solving and inquiry-based chemistry education
- Ethical guidelines and university chemistry education for sustainable development
- The use of ICT in chemistry education at the 3rd level
- The role of history of chemistry and philosophy of science in university education
- Cultural heritage and chemistry education
- Development of educational competencies of academic chemistry teachers
- Evaluation of learning outcomes and problems relating to assessment in HEIs
- The contemporary chemistry teachers' education and the long-term professional development of chemistry teachers.

Summaries in this Book of Abstracts deal with the practical aspects of teaching chemistry and research into chemistry education at both undergraduate and postgraduate levels with the aim of enabling students to build key professional and transferable skills needed in order to be successful in a highly competitive labour market and life in the rapidly changing world.

I wish all participants a successful conference and fruitful discussion. I hope you will all enjoy your stay in Belgrade.

Dragica Trivic

Head of the Local Organizing Committee

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TABLE OF CONTENTS

CONFERENCE PROGRAMME

Time	Wednesday 28th June	
13.00 - 14.00	Registration in the University of Belgrade	
14.00 - 14.30	Opening ceremony - Congress hall of the University of Belgrade Professor David Cole-Hamilton, President of the EUCheMS Professor Iwona Maciejowska, President of the EuCheMS Division of Chemical Education Professor Vesna Mišković-Stanković, President of the Serbian Chemical Society Professor Živoslav Tešić, Vice-Rector of the University of Belgrade Professor Ivanka Popović, Vice-Rector of the University of Belgrade Professor Ivan Gržetić, Dean of the University of Belgrade – Faculty of Chemistry	
14.30 - 15.30	Plenary Lecture (Congress hall): ***Learning in the 21st century laboratory,*** Michael Seery, School of Chemistry, University of Edinburgh, Scotland (Introduced by Iwona Maciejowska)	
15.30 - 17.15	Parallel sessions	
	Room A: **Development of the university curricula for BSc, MSc and PhD chemistry studies** Chair: Peter E. Childs	Room B: **Laboratory work as an element of problem solving and inquiry-based chemistry education (Part I)** Chair: Mustafa Sozbilir
	1. ***Integrating key skills in the undergraduate chemistry curriculum,*** Elizabeth M. Page and Matthew J. Almond, University of Reading, Department of Chemistry, United Kingdom 2. ***Learning about research in the early stages of postgraduate studies,*** Liliana Mammino, University of Venda, South Africa 3. ***The potential for using the TEMI approach in 3rd level chemistry teaching,*** Peter E. Childs, Sarah Hayes and Laurie Ryan, University of Limerick, Ireland 4. ***The university curricula for doctoral studies of chemistry teachers in the Czech Republic,*** Hana Čtrnáctová, Charles University – Faculty of Science, Czech Republic 5. ***Computational modeling and Lewis Structures,*** Lars Eriksson and Ilana	1. ***Adding a project-based component to a conventional physical chemistry laboratory,*** Georgios Tsaparlis and Giannoula Pantazi, Department of Chemistry, University of Ioannina, Science Laboratory Center (EKPhE) of Preveza, Greece 2. ***The effect of inquiry-based analytical chemistry laboratory on pre-teachers' perceptions of laboratory environment***, Burak Feyzioğlu, Adnan Menderes University, Faculty of Education, Turkey 3. ***Cognitive task analysis applied to laboratory curriculum,*** Robin Stoodley, Elizabeth Gillis and Kerry Knox, Department of Chemistry, University of British Columbia, Canada, Department of Education, University of York, United Kingdom 4. ***An instructional design to teach concepts regarding phases of matter to visually impaired students***, Aydin Kizilaslan and Mustafa Sozbilir, Atatürk University,

	Kaufmann, Stockholm University, Sweden 6. ***Chemistry teaching and the science of complexity: how to promote systemic thinking***, Marek Frankowicz, Faculty of Chemistry, Jagiellonian University, Poland 7. ***Chemical weapons in university curricula - a way to safer society***, Ljubodrag Vujisić, Vlatka Vajs and Vele Tešević, University of Belgrade - Faculty of Chemistry, Center for Chemistry, Institute for Chemistry, Technology and Metallurgy - University of Belgrade, Serbia	Department of Mathematics & Science Education, Turkey 5. ***Student research projects as a point of collaboration between high school and research institutes***, Kanateva A., Koliasnikov O., Morozova N., Sigeev A. and Smolyanskii A., A.V. Topchiev Institute of Petrochemical Synthesis of Russian Academy of Sciences, Advanced Educational Scientific Center, Kolmogorov's boarding school of Moscow State University, A.N. Nesmeyanov Institute of Organoelement Compounds of Russian Academy of Sciences, Branch of JSC Karpov Institute of Physical Chemistry, Russia
17.15 - 17.30	Coffee break	
17.30 - 19.00	Poster session (ground floor)	
19.00 - 19.30	Keynote Lecture (Congress hall): ***Can chemistry education be informed by practice in the arts, humanities and social sciences?*** Matthew J. Almond, Department of Chemistry, University of Reading, United Kingdom (Introduced by Rachel Mamlok Naaman)	
20.00 - 21.30	Welcome reception in the University of Belgrade (ground floor)	

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Time	**Thursday 29th June**	
9.00 - 10.00	Plenary Lecture (Congress hall): ***Adapting a model of participatory action research for developing chemistry teacher training***, Silvija Markic and Yannik Tolsdorf, Ludwigsburg University of Education - Institute for Science and Technology, University of Bremen - Institute for Didactics of the Sciences, Germany (Introduced by Martin Bilek)	
10.00 - 10.30	Keynote Lecture (Congress hall): ***Developing best practice in university laboratory education***, Natasa Brouwer, Faculty of Science, University of Amsterdam, Netherlands (Introduced by Ron Blonder)	
10.30 - 11.00	Coffee break	
11.00 - 12.15	Parallel sessions	
	Room A: **The contemporary chemistry teachers' education and the long-term professional development of chemistry teachers**	Room B: **Development of educational competencies of academic chemistry teachers**

	Chair: Luca Szalay	Chair: Silvija Markic
	1. ***Seeking to improve students' experimental design skills***, Luca Szalay and Zoltán Tóth, Eötvös Loránd University - Faculty of Science, University of Debrecen - Faculty of Science and Technology, Hungary 2. ***Innovation in pregraduate chemistry teachers' education and their professional development – implication of Project Mascil***, Martin Bilek and Veronika Machkova, Department of Chemistry, Faculty of Science, University of Hradec Kralove, Czech Republic 3. ***Creation of chemistry workbooks in cooperation with a daily newspaper***, Ján Reguli, Mária Orolínová and Katarína Kotuľáková, Department of Chemistry, Faculty of Education, Trnava University, Slovakia 4. ***Professional development of chemistry teachers through seminars by the society of chemists and technologists of Macedonia***, Marina Stojanovska and Vladimir M. Petruševski, Faculty of Natural Sciences and Mathematics, Ss. Cyril & Methodius University, Republic of Macedonia 5. ***Turkish chemistry teachers' views on cooperative learning***, Mustafa Ergun, Ondokuz Mayis University, Faculty of Education, Turkey	1. ***Questioning skills and argumentation in chemistry***, Rachel Mamlok Naaman, Weizmann Institute of Science, Israel 2. ***Croatian pre-service teachers' beliefs about teaching and learning chemistry***, Lana Saric and Silvija Markic, University of Split, Croatia, Ludwigsburg University of Education - Institute for Science and Technology, Germany 3. ***Exploring chemistry student teachers´ knowledge about diagnostic – a longitudinal study***, Yannik Tolsdorf and Silvija Markic, University of Bremen - Institute for Didactics of the Sciences, Ludwigsburg University of Education-Institute for Science and Technology, Germany 4. ***A collection of tasks from International Chemistry Olympiads: an excellent resource for teaching/learning chemistry***, Vojin Krsmanovic, University of Belgrade - Faculty of Chemistry, Serbia
12.15 - 13.30	Parallel sessions	
	Room A: **Laboratory work as an element of problem solving and inquiry-based chemistry education (Part II)** Chair: Odilla E. Finlayson	Room B: **Evaluation of learning outcomes and assessment related problems in HEIs** Chair: Dušica D. Milenković
	1. ***Assessing laboratory work – does what we do make sense?***, Odilla E. Finlayson and Mike Casey, CASTeL, School of Chemical Sciences, Dublin City University,	1. ***Conflict between calculations and underlying concepts: case of tertiary level students***, Dušica D. Milenković, Tamara N. Hrin, Mirjana D. Segedinac,

	School of Chemistry, University College Dublin, Ireland 2. ***Encouraging independent thought and learning in first year practical classes***, Philippa B. Cranwell, Fred J. Davis, Joanne M. Elliott, John E. McKendrick, Elizabeth M. Page and Mark J. Spillman, Department of Chemistry, University of Reading, United Kingdom 3. ***Peer assessment and feedback as a tool for effective chemistry laboratory session***, Mamun Rashid, Manchester Metropolitan University, United Kingdom 4. ***Principles of development of a chemistry unit to visually impaired students***, Mustafa Sozbilir, Aydin Kizilaslan and S. Levent Zorluoglu, Atatürk University, Department of Mathematics & Science Education, Turkey 5. ***A project-based biochemistry laboratory course on protein folding, misfolding and aggregation***, Natalija Đ. Polović, University of Belgrade - Faculty of Chemistry, Serbia	Milan T. Segedinac and Goran Savić, University of Novi Sad, Faculty of Sciences, Serbia 2. ***Investigating Indonesian university students' ability to solve equivalent conceptual and algorithmic questions***, Habiddin and Elizabeth Page, Chemistry Department, University of Reading, United Kingdom, Universitas Negeri Malang, Indonesia 3. ***Assessing Quebec elementary teacher students' understanding of heat and temperature***, Abdeljalil Métioui, Louis Trudel and Mireille Baulu MacWillie, Université du Québec à Montréal, Université d'Ottawa, Université Sainte-Anne Pointe de l'Église, Canada 4. ***Efficiency of solving systemic multiple choice questions in organic chemistry at university level: an eye tracking analysis***, Tamara N. Hrin, Dušica D. Milenković, Mirjana D. Segedinac, Milan T. Segedinac and Goran Savić, University of Novi Sad, Faculty of Sciences, Serbia 5. ***"That mechanistic step is productive": comparing organic chemistry students' backward oriented reasoning with their professor's expectations***, I. Caspari, M. L. Weinrich and N. Graulich, Institute of Chemistry Education, Germany, Department of Chemistry, University of Massachusetts Boston, United States
13.30 - 14.30	Lunch	
14.30 - 15.00	Keynote Lecture (Congress hall): ***Science problem solving and other higher-order thinking tasks: the role of selective cognitive variables,*** Georgios Tsaparlis, Department of Chemistry, University of Ioannina, Greece (Introduced by Liberato Cardellini)	
15.00 - 16.00	Parallel sessions	
	Room A: **Competency-based university chemistry education; Ethical guidelines and university chemistry education for**	Room B: **Use of ICT in the 3rd level of chemistry education**

	sustainable development Chair: Marek Frankowicz 1. ***How to match chemistry curricula, qualifications framework and professional standards***, Marek Frankowicz, Faculty of Chemistry, Jagiellonian University, Poland 2. ***Fundamental reasonings in problem solving***, Liberato Cardellini, Marche Polytechnic University, Italy 3. ***Development of evaluation criteria assessment of chemistry students***, Robert Zakrzewski, Faculty of Chemistry, University of Łódź, Poland 4. ***Directed integration of an initiative for university-wide education for sustainable development into chemistry degree programmes***, M. Coffey, A. Dharmasasmita and P.Molthan-Hill, Nottingham Trent University, United Kingdom	Chair: Ron Blonder 1. ***The challenges of developing an interactive online course for in-service chemistry teachers***, Ron Blonder, Weizmann Institute of Science - Department of Science Teaching, Israel 2. ***Models and visualisation: a teacher education speciality course***, Jan Lundell, Department of Chemistry, University of Jyväskylä, Finland Room B: **The role of history of chemistry and philosophy of science in university education** Chair: Carla Morais 1. ***Chemistry by (the etymology of the) words: strategies to teach chemistry and challenge the borders of specialization***, João C. Paiva, Carla Morais and Luciano Moreira, Faculdade de Ciências, Universidade do Porto, Faculdade de Engenharia, Universidade do Porto, Portugal 2. ***H. E. Armstrong (1848-1937): The forgotten pioneer of IBSE***, Peter E. Childs, University of Limerick, Ireland
16.00 - 16.30	Coffee break	
16.30 - 20.00	Guided tour: Visit the Royal Palaces. The tour includes the Royal and White Palaces and the Royal Chapel dedicated to the patron Saint of the Royal Family – St. Andrew the First Called.	
20.00 - 22.30	Conference Dinner in the Restaurant "Three hats", situated in Skadarlija – the old, romantic-bohemian quart of Belgrade	

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Time	Friday 30th June		
9.00 – 9.30	Room A: **Chemistry education through university-industry partnerships** Chair: Jurica Bauer		
	1. ***Industrially relevant projects as a teaching tool in chemistry***, Jurica Bauer, Jordy van Angeren, Lucia Baljeu-Neuman, Rosalba Bellini, Ewald Edink, Lieke van Hemert, Mark Jansen, Samira Kabli, Iris Kuiper-Dijkhuizen, Maarten Kuiper, Roland Meesters, Mark Verheij, John Vessies, Bojd Vredevoogd, Anass Znabet, Inholland University of Applied Sciences, The Netherlands 2. ***BASF and Corporate Citizenship*** **-** Simon Franko, Managing Director at BASF Slovenia d.o.o., BASF Croatia d.o.o., BASF Serbia d.o.o		
9.30 - 10.00	Coffee break		
10.00 - 11.30	Workshops		
	Room A: ***How to prepare our students to enter job market?*** Iwona Maciejowska, Pascal Mimero, Faculty of Chemistry, Jagiellonian University, Poland, CESI Engineering School, Centre of Lyon, France	Room B: ***Team based learning – take an academic, a class of students and scratch cards!*** Natalie Brown, Laura Hancock, Graeme R. Jones, Tess Phillips and Daniela Plana, School of Chemical and Physical Sciences, Lennard-Jones Laboratories, Keele University, United Kingdom	Room C: ***A student designed curriculum: developing a project-based introductory chemistry laboratory course*** Vasiliki Lykourinou, Alejandro Rovira, Emily Navarette, John de la Parra, Northeastern University, United States
11.30 - 12.00	Chemistry show ***Connection between inquiry-based science education (IBSE) and education for sustainable development (ESD) – resources for science teachers***, Stevan Jokić and Ljiljana Jokić, Institute for Nuclear Sciences - Vinča, AKM Edukacija, Serbia		
12.00 - 12.30	Closing ceremony		
12.30 - 13.30	Lunch		

PLENARY LECTURES

PL-1. ***Learning in the 21st century laboratory***, Michael K. Seery, School of Chemistry, University of Edinburgh

PL-2. ***Adapting a model of participatory action research for developing chemistry teacher training***, Silvija Markic and Yannik Tolsdorf, Ludwigsburg University of Education, Institute for Science and Technology - Chemistry Education (Primary Science Education), University of Bremen – Institute for Didactics of the Sciences – Chemistry Education, Germany

LEARNING IN THE 21st CENTURY LABORATORY

Michael K. Seery

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Laboratory work is at the core of scientific curricula and it is hard to imagine a programme in science without some practical component. But despite a significant amount of resources and time devoted to laboratory work, literature indicates that it can be a poor learning environment. In this talk, I identify some well-established principles from the literature regarding learning in the laboratory and illustrate how they may be incorporated into our laboratory curriculum. This includes re-considering the role of preparatory work in advance of the laboratory, incorporating inquiry learning into laboratory work, and refocussing assessment and feedback so that the entire feedback cycle is considered. Technology is a powerful enabler in achieving many of the desirable developments in reconsidering laboratory work and some general aspects of this will be discussed, along with the use of digital badges to enable "micro-accreditation" or individual student achievements in completing particular laboratory skills and instrumentation. Our work in this area demonstrates that this approach can be used to package a modern and flexible approach to learning in the laboratory. Finally, the process of changing a laboratory curriculum is an enormous administrative and technical task: some approaches to iterative change will be discussed.

ADAPTING A MODEL OF PARTICIPATORY ACTION RESEARCH FOR DEVELOPING CHEMISTRY TEACHER TRAINING

Silvija Markic[1] and Yannik Tolsdorf[2]

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Diagnostic knowledge is one of the main competences that teachers in general and chemistry teachers in particular should possess. This knowledge is needed whenever one deals with heterogeneity, models of lesson design and individual support. Since the importance of diagnostic knowledge with the view on rising diversity and heterogeneity in schools is increasing, there is a need for including diagnostic knowledge in teacher training.

Following this aim, first of all, chemistry student teachers need to be sensitive for diversity and heterogeneity in order to perceive different dimensions. Furthermore, they need to know how to diagnose these and to deal with it. Starting from here, the question is: *how should the university courses be designed?* Teaching methods were developed and implemented in chemistry education courses at our university.

Since the model of Participatory Action Research (PAR) has been well established for the development of teaching and learning materials for secondary school, it has been used for the development of chemistry student teachers´ university courses. However, it was noticeable that in some points there were limits of the original model during the adaptation to higher education. So for example the group line-up was changed, since more and different experts beside teachers and chemistry educators are needed. Thus, difference to the original model of PAR seems more productive if the work on a course development on diagnostic knowledge is a constructive exchange of practitioners with different experiences and theoretical knowledge in this topic, e.g. chemistry educators, chemistry teachers, special needs educators, language educators, intercultural education expert etc. Finally, the model has been extended, especially with the focus on the team and the cooperation partners. In the talk the developed model will be presented and depictured on an example. The experiences with the developed model of PAR will be reflected and indicated.

Keywords: Participatory Action Research, Development of higher education, Chemistry student teachers training, Diagnostic knowledge

KEYNOTE LECTURES

KN-1. ***Can chemistry education be informed by practice in the arts, humanities and social sciences?*** Matthew J. Almond, Department of Chemistry, University of Reading, United Kingdom

KN-2. ***Developing best practice in university laboratory education***, Natasa Brouwer, Faculty of Science, University of Amsterdam, Netherlands

KN-3. ***Science problem solving and other higher-order thinking tasks: the role of selective cognitive variables***, Georgios Tsaparlis, Department of Chemistry, University of Ioannina, Ioannina, Greece

CAN CHEMISTRY EDUCATION BE INFORMED BY PRACTICE IN THE ARTS, HUMANITIES AND SOCIAL SCIENCES?

Matthew J. Almond

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This oral presentation will explore areas where university-level chemistry education may be informed by practice in the Arts, Humanities and Social Sciences. I am Professor of Chemistry Education at University of Reading, teaching analytical and inorganic chemistry but I have held the position on Dean of Arts, Humanities and Social Sciences. I have led curriculum reviews in subjects such as History, Philosophy and Film, Theatre and Television. What can chemistry learn? I believe that the concept of “reading for a degree” is stronger in the arts and humanities; moreover, courses are designed to find out more of “what students think?” rather than just “what do they know?” Student involvement in curriculum design is also stronger in the arts and humanities. I shall discuss some examples of university chemistry teaching which are based upon a model which is perhaps more familiar to colleagues in arts and humanities – for example seminar-based teaching. I believe that this presentation will be of interest to colleagues with wide-ranging interests in university education.

Keywords: University Chemistry Education, Arts and Humanities, Seminars, Reading lists, Independent learning

DEVELOPING BEST PRACTICE IN UNIVERSITY LABORATORY EDUCATION

Natasa Brouwer

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In most chemistry and engineering programmes laboratory courses are an essential curriculum component. They have a potential to achieve a number of practical and theoretical objectives, such as learning manipulative techniques and linking them to theory, to interpret data and to solve problems, but also to interact with other students and staff, and last but not least to learn successfully navigate the lab itself. Subsequently, the demands on students (and instructors) are huge. The effectiveness of laboratory classes is thus often not achieved to its full ambition. Different studies into the impact of laboratory courses have stressed the key role of laboratory instructors for higher science education. This role is in particular demanding for newly appointed university teachers.

To improve this situation, the ECTN working group Lecturing Qualifications and Innovative Teaching Methods is developing an online course on teaching in laboratory classes entitled “Developing best practice in university laboratory education”. The course is targeted at relatively inexperienced university teachers and aims to provide methods and resources to improve laboratory teaching practice at the university. The course will be available in 2018.

The content of the online course “Developing best practice in university laboratory education” is chosen based on an inquiry among the university teachers from 16 universities in 8 countries and a survey in a group of students. The course is divided in several modules focused in relevant didactics and pedagogical concepts. The design of the course will support active (peer-)learning of the participants and knowledge sharing across the universities. In this talk the development of the course will be presented and the power of an active learning approach in online courses will be discussed based on the experiences from the teaching practice at the University of Amsterdam such as an online pre-master programme.

SCIENCE PROBLEM SOLVING AND OTHER HIGHER-ORDER THINKING TASKS: THE ROLE OF SELECTIVE COGNITIVE VARIABLES

Georgios Tsaparlis

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A basic feature of problem solving in science is the difference between exercises and real problems. In an exercise, a well-known and usually practiced procedure is followed (an algorithm). On the contrary, a real or complex problem is not algorithmic and requires conceptual understanding and the contribution of high-order cognitive skills (HOCS) and a number of mental resources. A considerable difference in student performance on chemistry problems that require algorithmic or conceptual understanding has been demonstrated (Niaz, 1995). In addition, a number of cognitive/psychometric variables have been shown to be important contributors to student high ability and achievement in science problem solving and other higher-order science tasks. Variables such as working-memory capacity, mental-space capacity (*M*-capacity), disembedding ability (degree of field dependence-independence), developmental level, the mobility-fixity dimension, and convergent/divergent thinking are involved in learning and in the execution of cognitive tasks, and can be predictive of the student performance. Examination of the limitations of the Johnstone and El-Banna model led to the necessary conditions for it to be valid. A study of organic chemical synthesis problems, with a simple logical structure and varying *M*-demand, showed the pattern of the expected drop in performance, being more striking in the case of the students without previous training. Developmental level played often a role in conceptual understanding and applications, but less so in circumstances involving complex conceptual situations and/or chemical calculations, where disembedding ability appeared to be involved. Examination of the effect of the mobility-fixity dimension showed that in most cases the mobile subjects demonstrated higher mean achievement than the fixed subjects. Convergence-divergence has been studied in relation to student understanding of chemistry and of physical changes. Manipulation of the logical structure as well as of the *M*-demand of algorithmic chemical equilibrium problems led to the conclusion that all examined cognitive variables were correlated with achievement only when the logical structure was fairly complex and even when the *M*-demand was relatively low, with working memory maintaining some importance and developmental level

playing the dominant part. Finally, special interest present the non-algorithmic and open-ended problems. In the case of non-algorithmic problems, developmental level showed lack of correlation and working-memory capacity also showed weak correlation, while functional *M*-capacity and disembedding ability played a very important role. In the case of open-ended problems, a positive correlation between *M*-capacity and both algorithmic and open-ended problem solving was recorded, while a threshold effect was demonstrated.

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Niaz M. (1995). Progressive transitions from algorithmic to conceptual understanding in student ability to solve chemistry problems: A Lakatosian interpretation. *Science Education*, *79*, 19-36.

ORAL COMMUNICATIONS: Development of the university curricula for BSc, MSc and PhD chemistry studies

OC-1. ***Integrating key skills in the undergraduate chemistry curriculum***, Elizabeth M. Page and Matthew J. Almond, University of Reading, Department of Chemistry, United Kingdom

OC-2. ***Learning about research in the early stages of postgraduate studies***, Liliana Mammino, University of Venda, South Africa

OC-3. ***The potential for using the TEMI approach in 3^{rd} level chemistry teaching***, Peter E. Childs, Sarah Hayes and Laurie Ryan, Department of Chemical Sciences, EPI*STEM, SSPC, University of Limerick, Ireland

OC-4. ***The university curricula for doctoral studies of chemistry teachers in the Czech Republic***, Hana Čtrnáctová, Charles University – Faculty of Science, Czech Republic

OC-5. ***Computational modeling and Lewis Structures***, Lars Eriksson and Ilana Kaufmann, Department of Materials and Environmental Chemistry, Stockholm University, Department of Mathematics and Science Education, Stockholm University, Sweden

OC-6. ***Chemistry teaching and the science of complexity: how to promote systemic thinking***, Marek Frankowicz, K. Guminski Theoretical Chemistry Department, Faculty of Chemistry, Jagiellonian University, Poland

OC-7. ***Chemical weapons in university curricula - a way to safer society***, Ljubodrag Vujisić, Vlatka Vajs and Vele Tešević, University of Belgrade - Faculty of Chemistry, University of Belgrade - Center for Chemistry, Institute for Chemistry, Technology and Metallurgy, Serbia

OC-1

INTEGRATING KEY SKILLS IN THE UNDERGRADUATE CHEMISTRY CURRICULUM

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Contemporary undergraduate chemistry courses typically include subject content within the first two years that is fundamental, and frequently generic, to allow the student to go on and explore more advanced and applied concepts in later modules. This type of course design is universal and clearly successful in meeting its aims in most cases. However, in order to secure graduate level employment our graduating students must increasingly be able to demonstrate competence in a range of key professional and transferable skills, as well as academic subject knowledge. The job market is highly competitive, especially for the BSc chemist, and employers are looking for graduates with the ability to work both independently and in teams, to communicate verbally as well in writing, to problem solve and to apply and research information, as well as many other skills (Overton and Hanson; Taber, 2016; SE Universities Biopharma Skills Consortium, 2010). The development and articulation of transferable skills is now a key requirement for Royal Society of Chemistry accreditation of undergraduate courses (Royal Society of Chemistry) and is attracting increasing attention from university quality assurance managers concerned about employability statistics.

Over the past 8 years at Reading we have developed and implemented a progression of modules within our undergraduate courses that support students in the logical development of these skills through chemistry-based activities, and prepare them for final year research projects and future employment. This talk will describe the nature of the modules and explain how the content aligns with the core chemistry curriculum. It will present evidence to demonstrate the impact of the activities on transferable skills development and as preparation for employment. It will also explain how the modules can be explicitly shown to meet the new accreditation requirements and will highlight the way in which they help prepare students to become independent learners.

Keywords: Transferable skills, Independent, Employability

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LEARNING ABOUT RESEARCH IN THE EARLY STAGES OF POSTGRADUATE STUDIES

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At the University of Venda (UNIVEN, South Africa), after completion of a 3-year BSc degree, there are three postgraduate levels: a level called Honors (Hons), with expected duration of one year, and the standard MSc and PhD levels with expected duration of two and three years respectively. The Hons level marks the transition from undergraduate to postgraduate studies, as it includes both standard courses with final exams and a small research project. It is the level where students are expected to learn about research in all its components: literature review, preparation of a research proposal, carrying out the actual research and reporting results. Like all transitional levels, it poses the challenges of learning new things which may not be rooted in prior instruction or learning experience. In particular, learning to do research means learning new approaches and acquiring new attitudes, which demands personal responsibility and independence. Designing a research approach is something new with respect to performing experiments following a lab manual. Reporting results in a complete and organized way requires language and logic mastery, besides full understanding of the nature of the performed research.

The presentation considers the challenges encountered by chemistry students at Hons level and also in the early stages of MSc studies, analyzing them in terms of transition from undergraduate to postgraduate learning. It outlines the way in which known difficulties such as diffuse poor language mastery and second language instruction complicate the transition by affecting the speed and extent with which students can learn new approaches. Difficulties in writing the final document (a mini-thesis for Hons, a standard thesis for MSc, and PhD) are given particular attention as they have heavy impact even for students who have acquired good abilities with the design and implementation components of research.

Keywords: Design of research, Language mastery, Logic mastery, Time-planning, Undergraduate-to-postgraduate transition

THE POTENTIAL FOR USING THE TEMI APPROACH IN 3rd LEVEL CHEMISTRY TEACHING

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TEMI, Teaching Enquiry with Mysteries Incorporated, was an FP7 project which ran from 2013-2016 (www.teachingmysteries.eu). The main aim of the project was to use scientific mysteries to engage second-level students in inquiry by arousing their curiosity. The University of Limerick was one of the project partners and although the main target audience was second-level teachers, (Childs *et al.*, 2016) we also tried out the approach successfully with primary teachers. In discussion with third level science lecturers we realised that the approach could be used to engage third level students, particularly in the first year, either in lectures, tutorials or lab classes. A teaching session is started by showing students a mystery, either directly or using a video, and then encouraging them to work in small groups to discuss the mystery, suggest explanations and hypotheses, and outline how they could test their ideas. This is an example of active learning and getting students involved in their own learning, combined with peer instruction. The use of active learning in lectures has been shown to have positive learning outcomes (Freeman *et al*., 2014). The TEMI project used the 5E model as a framework for enquiry but a mystery can be used just as an engagement activity at the start of a session to get students thinking about a topic. In the talk examples will be given of how the approach could be used in first year chemistry courses e.g. using the blue bottle or the disappearing precipitate.

Keywords: IBSE Mysteries, Peer learning, Active learning

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THE UNIVERSITY CURRICULA FOR DOCTORAL STUDIES OF CHEMISTRY TEACHERS IN THE CZECH REPUBLIC

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Since the 1950's, chemistry teachers in the Czech Republic have been prepared at science or pedagogy colleges. In the 1970's, the PhD studies of chemistry teaching graduates also started. Until the end of the 1980's, these studies were done as so-called "scientific preparation" in the discipline of *Theory of Chemistry Education*, finished by the acquisition of scientific rank and title "CSc." (*Candidate of Science*). During over 20 years, over 200 students went through this preparation; 45 of them, i.e. around 20%, finished their studies successfully (Bílek, 2003; Čtrnáctová, 2008, 2012). However, despite the students' interest and clearly high demands of these studies, it was not included in the newly accredited PhD disciplines after 1989. In 2004 there was the first accreditation of a separate chemical education PhD programme in the Czech Republic.

Today, this type of studies is accredited at the faculties of science of three Czech universities – Charles University (Prague), Palacky University (Olomouc) and Hradec Kralove University (Hradec Kralove) as a four-year PhD study program "Didactics of Chemistry". The total number of students in each year is 12-15; the studies proceed according to the individual study plan of each student.

The curriculum of these studies is pretty much analogical at all these universities. It contains studies in the selected subjects, pedagogical practice, inclusion in national and international chemistry education events, publication of interim results, and most of all, creating and defending PhD thesis (Abell and Lederman, 2007; Čtrnáctová and Klečková, 2011; Stuchlíková *et al*., 2015).

This contribution aims to inform about curriculum and structure of these studies, about the number and individual study plans of the participants of this study program, about its conditions and requirements, and about the themes and results of the PhD theses in years 2004-2016 in the Czech Republic.

Keywords: Chemical education, PhD study, Curriculum, Individual study plan, PhD thesis

Acknowledgement: Financial support of the PROGRES project of Charles University is gratefully acknowledged.

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COMPUTATIONAL MODELING AND LEWIS STRUCTURES

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The construction and drawing of Lewis structures in order to understand chemical bonding and the geometries of simple molecules in general chemistry and introductory courses do sometimes cause considerable trouble to students. Lewis structures are mostly used for deriving plausible molecular structures as well as to distinguish between alternative structure models. Within the realm of organic chemistry they may also give clues to the stable intermediates and shed some light on alternative reaction mechanisms.

For computational modeling there are free software packages such as Avogadro or Gabedit available. These can be used for the creation of molecular models or visualization. Furthermore, quantum chemical calculations can be done with quantum chemistry packages such as NWChem or PSI4.

Two requirements for the construction of an acceptable Lewis structure are that all valence electrons are accounted for and that the octet rule is obeyed, at least for the second row elements. Distinguishing alternative Lewis structure models is usually done by calculating formal charge of the atoms and choosing the model that minimizes the distribution of formal charge over all atoms.

A few selected molecules which generate considerable questions from traditional construction of Lewis structures are: N_2O, SO_4^{2-}, HSO_3^-, O_3 and FHF^-.

We suggest that a modeling session with construction of Lewis structures should be connected to and complemented by molecular modeling of the corresponding molecules. Quantum chemistry computations are clearly possible with modern laptop computers, thus enabling the users to compare predictions from different theories and also detect limitations of the theories. The outcome of the calculations may give both geometrical outcome as well as electronic information.

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OC-6

CHEMISTRY TEACHING AND THE SCIENCE OF COMPLEXITY: HOW TO PROMOTE SYSTEMIC THINKING

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Although there is abundant popular science literature dealing with complexity, chaos theory, fractal geometry etc., such topics are in general absent from most chemistry curricula. Teaching complexity to chemistry students may broaden their views and prepare them to work in interdisciplinary environment, even far from typical "hard sciences". In the paper experiences from the Jagiellonian University in Krakow of how to introduce elements of "new science" of complexity will be presented. The author developed relevant course modules at three levels: undergraduate (1st year of Biophysics, course module "Nonlinear Processes"), graduate (1st year of 2nd cycle Chemistry, course module "Theoretical Chemistry 2") and doctoral (elective course "Synergetics"). The stress is put on showing universality of complex phenomena. In particular, applications of methodology originating from chemistry (kinetic equations, reaction-diffusion processes etc.) to other areas of science (biology, ecology, sociology etc.) are shown. For example, the chemical scheme: $A + X \rightarrow 2X$, $X \rightarrow D$, can be also used in ecology (evolution of population of herbivores X) and epidemiology (A – healthy person, X – sick person). Hysteresis and phase transitions can also occur in social systems. Kinetic equations and cellular automata have been used to model historical processes.

Each course participant has to prepare an "essay" describing in a popular way an example of self-organisation in natural or social systems. Examples of essays are "Dynamics of Marital Interactions: Divorce Prediction and Marriage Repair", "Noise-Induced Transitions in Photochemical Reaction", "Animal Coat Patterns", "Pattern Formation on Catalytic Surfaces", "Nyos – The Killing Lake" and even "A Mathematical Model of Humans-Zombie Interaction". Students are encouraged to present their essays during seminars, summer schools etc., thus promoting systemic thinking and 'scientific literacy'. It turned out that even the first-year undergraduates without solid mathematical background are able to prepare high-quality, creative and sophisticated papers on "unusual" topics.

Keywords: Complexity, Interdisciplinarity, Theoretical chemistry, Creativity

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CHEMICAL WEAPONS IN UNIVERSITY CURRICULA - A WAY TO SAFER SOCIETY

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Chemistry has been used as a tool of war for thousands of years. The earliest tools were poisoned arrows, Greek fire, water poisoning by hellebore plant extracts, etc. Apart from the chemicals used in the early wars, the modern chemical weapons (CW) were created during WWI and took more than one hundred thousand lives and caused around million casualties. Today CW have been regulated/prohibited by the Chemical Weapons Convention (OPCW, 2005) signed by 192 state parties. The implementing body for CWC is the Organisation for the Prohibition of Chemical Weapons (OPCW).

Nowadays, when fear of terrorism is bigger than ever, society needs a better insight into CW, safety and widely used industrial chemicals with terrible potential. In the current curriculum CW is studied mostly from military point of view and the focus is more on the weapons than on chemistry. Authors suggest that the development of chemical weapon related courses in a chemistry curriculum could be a way to achieve safer society. CW courses could cover different topics, e.g. ethics in science, history of chemistry, safety in chemistry and chemical industry, organic and bioorganic chemistry, biochemistry, analytical chemistry, environmental and industrial chemistry, multiple usage chemicals, green chemistry as an alternative to widely used CW related chemicals, etc. Development of a CW syllabus could be supported by various internet-based resources used for education for peace (www.opcw.org/special-sections/education, http://multiple.kcvs.ca, www.thefiresproject.com). Diversity of chemicals covered by CWC in combination with multi-disciplinary approach is a great foundation for development of different student skills: science ethics, problem-solving skills, safety skills, 21st century searching skills, team skills… The authors created a new graduate course called Chemical weapons at Faculty of Chemistry, University of Belgrade in 2016/17. The syllabus of CW can be seen on the internet (www.chem.bg.ac.rs/predmeti/279H1-en.html).

In conclusion, the chemistry behind chemical weapons is quite diverse and the authors suggest that undergraduate or graduate course Chemical weapons could be very interesting and beneficial for both chemistry major/minor students.

Keywords: Chemical weapons, Curriculum development, Misuse of chemicals, Green chemistry, CBRNE

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ORAL COMMUNICATIONS: Competency-based university chemistry education

OC-8. ***How to match chemistry curricula, qualifications framework and professional standards***, Marek Frankowicz, K. Guminski Theoretical Chemistry Department, Jagiellonian University in Krakow, Poland

OC-9. ***Fundamental reasonings in problem solving***, LiberatoCardellini, Marche Polytechnic University, Italy

OC-10.***Development of evaluation criteria assessment of chemistry students***, Robert Zakrzewski, Department of Chemical Education and Science Popularization, Faculty of Chemistry, University of Łódź, Poland

OC-8

HOW TO MATCH CHEMISTRY CURRICULA, QUALIFICATIONS FRAMEWORKS AND PROFESSIONAL STANDARDS

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Curriculum design and modification is a multiple-criteria decision making (MCDM) process. It has to reconcile different factors and trends, such as: national legislative framework (national qualifications framework, curricular standards), European standards and guidelines related to the Bologna developments, recent progress in research, rapidly changing trends of the labour market etc. One also has to take into account new teaching and learning methodologies (including ICT) and dynamics of changes in secondary education. Our ideal "21st Century Graduate" should be creative, employable, ready to work in an interdisciplinary and international environment… In other words, something like *Sus lanata oviponens lactans*…

In the case of chemistry curricula, three main directions of development of regulations and guidelines shall be taken into account – first, chemistry-related educational reference frameworks, such as ECTN Eurobachelor/Euromaster/Eurodoctorate standards; second, chemical professional standards and guidelines (such as CChem, EurChem, etc.); third, various global standards (Global Competence Matrix, New skills for new jobs, Novum Trivium, N-tuple Helix etc.).

A promising way of matching various requirements, trends and challenges related with curriculum design for 21st century "global chemists" could be the Sectoral Qualifications Framework (SQF) approach. SQF are usually developed by professional associations and other stakeholders connected directly with the world of work. However, there are also examples of academia-driven SQF activities, in partnership with external stakeholders. The author participated in two TEMPUS projects: "DEFRUS" (SQF food sciences and technology) and "ELFRUS" (SQF land management and cadaster); in both projects level descriptors matching both professional standards and curricular standards were elaborated. The methodology developed under those projects can be applied to the design of SQF for Chemistry; the concept of such "ChSQF" and a proposal for its structure will be presented and discussed.

Keywords: Curriculum design, Qualifications framework, Professional standards

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FUNDAMENTAL REASONINGS IN PROBLEM SOLVING

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Stoichiometric calculation can facilitate conceptual learning and be an irreplaceable means of acquiring higher-order cognitive skills. Unfortunately, our students seem to believe that this activity does not require much effort and many develop the attitude that coming up with the answer is more important than understanding the process of solution. Students are asked to explain, illustrate, represent and argue the steps in solving problems. This is because they have to develop the expert's attitude of spending some time analysing a problem qualitatively (Cardellini, 2006).

The majority of high school students enter my class without being able to solve the problems connected with density. Great improvement has been found using the worked examples: with the best students, the correct solutions exceed 90% (Sweller *et al*., 2011). However, there are students who, even after repeated solutions of many examples, fail to put together the necessary steps in a meaningful way. These kinds of students have been called "rule learners" (Herron and Greenbowe, 1986). For many years, this problem has been used to measure the difficulties of the students: 10.00 mL of a solution of H_2SO_4 which is 2.485 % by weight (density 1.015 g/mL) are diluted to 100.0 mL. How many millilitres of NaOH 1.000×10^{-2} M are necessary to neutralize 20.00 mL of the H_2SO_4 solution prepared before? 144 written exams in a course attended mostly by students who have difficulty in committing themselves to studies have been used to study the recurrent errors. 43 % of the solutions contain one or more errors, and the type and frequency of errors will be presented. It is not possible to provide a recipe to help these students. Probably, a strong motivation in the students themselves is required to succeed in chemistry, which not all students have (Dweck, 2000; Ryan and Deci, 2000).

Keywords: Conceptual learning; Higher-order cognitive skills; Motivation; Problem solving; Worked examples

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DEVELOPMENT OF EVALUATION CRITERIA ASSESSMENT OF CHEMISTRY STUDENTS

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Mandatory examination system in Poland has existed since 1999, when the Central Examination Board and the regional examination boards were established. External, universal matriculation exam has been passed since 2005. Education reform brings new requests, which is closely associated with the new requirements: validation and assessment of learning. There is the concept of evaluation-criteria in the new law regulation. The concept is based on an obligatory process of applying the quality criteria in checking and evaluating exam tasks. It requires careful selection of the relevant criteria with an indication of their importance.

During the studies of the preparation for the teaching profession the subject associated with the competence-criteria evaluation was introduced. This item is designed to acquaint the student with the form and organization of external examinations with special emphasis on the matriculation examination in chemistry.

Keywords: Matriculation exam, Competence-criteria evaluation

ORAL COMMUNICATIONS: Laboratory work as an element of problem solving and inquiry-based chemistry education

OC-11. ***Adding a project-based component to a conventional physical chemistry laboratory***, Georgios Tsaparlis and GiannoulaPantazi, Department of Chemistry, University of Ioannina, Science Laboratory Center (EKPhE) of Preveza, Greece

OC-12. ***The effect of inquiry-based analytical chemistry laboratory on pre-teachers' perceptions of laboratory environment***, BurakFeyzioğlu, Adnan Menderes University, Faculty of Education, Department of Science Education, Turkey

OC-13. ***Cognitive task analysis applied to laboratory curriculum***, Robin Stoodley, Elizabeth Gillis and Kerry Knox, Department of Chemistry, University of British Columbia, Canada, Department of Education, University of York, United Kingdom

OC-14. ***An Instructional Design to Teach Concepts regarding Phases of Matter to Visually Impaired Students***, Aydin Kizilaslan and Mustafa Sozbilir, Atatürk University, Department of Mathematics & Science Education, Turkey

OC-15. ***Student research projects as a point of collaboration between high school and research institutes***, Kanateva A., Koliasnikov O., Morozova N., Sigeev A. and Smolyanskii A., A.V. Topchiev Institute of Petrochemical Synthesis of Russian Academy of Sciences (TIPS RAS), Advanced Educational Scientific Center (faculty) – Kolmogorov's boarding school of Moscow State University, A.N. Nesmeyanov Institute of Organoelement Compounds of Russian Academy of Sciences (INEOS RAS), Branch of JSC Karpov Institute of Physical Chemistry, Russia

OC-16. ***Assessing laboratory work – does what we do make sense?*** Odilla E Finlayson and Mike Casey, CASTeL, School of Chemical Sciences, Dublin City University, School of Chemistry, University College Dublin, Ireland

OC-17. ***Encouraging independent thought and learning in first year practical classes***, Philippa B. Cranwell, Fred J. Davis, Joanne M. Elliott, John E. McKendrick, Elizabeth M. Page and Mark J. Spillman, Department of Chemistry, University of Reading, United Kingdom

OC-18. ***Peer assessment and feedback as a tool for effective chemistry laboratory session***, Mamun Rashid, Manchester Metropolitan University, United Kingdom

OC-19. ***Principles of Development of a Chemistry Unit to Visually Impaired Students***, Mustafa Sozbilir, Aydin Kizilaslan and S. Levent Zorluoglu, Atatürk University, Department of Mathematics & Science Education, Turkey

OC-20. ***A project-based biochemistry laboratory course on protein folding, misfolding and aggregation***, Natalija Đ. Polović, University of Belgrade – Faculty of Chemistry, Serbia

ADDING A PROJECT-BASED COMPONENT TO A CONVENTIONAL PHYSICAL CHEMISTRY LABORATORY

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In a previous study (Tsaparlis and Gorezi, 2005, 2007), a modification of a conventional expository physical chemistry laboratory was proposed and evaluated, aiming at accommodating a project-based component. The study was carried out in the spring semester of 2014-15, with students of the same university and department, following the same compulsory physical chemistry laboratory course, under the responsibility of the same instructor (the first author). There were a number of differences between the two applications, as follows: (1) the students used a modern manual for the conventional experiments; (2) the instructor was very much involved in improving the students' translations of the papers; in clarifying the theoretical and experimental aspects of the projects, and in improving the students' PowerPoint presentations; and (3) this time the students did not perform the experiments; instead, they only had to study the papers, prepare a written report, construct a PowerPoint presentation, and present their project work to their student mates in the final seminar. For the evaluation of the project approach, a sample of 64 students replied individually and anonymously to a questionnaire which examined the following issues: students' views on the difficulties encountered in project work, their opinions about group work, the development of general abilities by the laboratory project work, their satisfaction with their project, their preference for the various projects used, and suggestions for improvement of the project work. In addition, a comparison with the conventional laboratory course was carried out with respect to the development of knowledge abilities. The study supplied further evidence that a project-based component is useful and has the potential to overcome many of the serious problems of the conventional laboratory. A number of the features and advantages of the project work of the former study were maintained. However, the fact that no experiments were executed by the students in the laboratory constitutes a fundamental drawback of the current study.

Keywords: Physical chemistry education, Physical chemistry laboratory instruction, Project-type cooperative laboratory work

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OC-12

THE EFFECT OF INQUIRY-BASED ANALYTICAL CHEMISTRY LABORATORY ON PRE-TEACHERS' PERCEPTIONS OF LABORATORY ENVIRONMENT

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In this research, the effect of inquiry-based analytical chemistry practices on science pre-teachers' perceptions of general chemistry laboratory environment was examined by a case study. Activities prepared according to 5E model and Predict-Observation-Explain strategy were implemented in a period of 11 weeks to 37 science pre-teachers who were taking analytical chemistry lessons. The change which occurred within 11 weeks in three pre-teachers' perceptions of laboratory environment who were randomized among pre-teachers in the class in which the practice had been performed was examined with its student-cohesiveness, open-endedness, integration, rule-clarity and material-environment dimensions. With the purpose of observing the effect of the inquiry based approach, pre-, inter- and final negotiations regarding the laboratory environment were made with the study group, and reflective diaries they have prepared within each activity period were examined. With the purpose of determining the level to which the inquiry has been actualized, practices were observed during a period of 11 weeks by two observers independent of the study, and this level was analyzed by taking into consideration the Reformed Teaching Observation Protocol form.

While at the introduction to the lesson, pre-teachers were regarding the laboratory practices only as reinforcing and supporting practically the theoretical knowledge lectured, especially after the 5th week they indicated the laboratory practices as a significant part of the scientific process. Initially, students found strange the practice type in which a pre-experiment theoretical knowledge was not provided and indicated that they had difficulties, especially in designing an experiment (first 3 weeks). However, encountering different experiments regarding the solution to the same problem and associating these to the theoretical knowledge changed their perspective on the practice in the next weeks (as from weeks 4 and 5). The change which occurred within 11 weeks in three pre-teachers' perceptions of laboratory environment in all dimensions was examined and discussed in this paper.

Keywords: Pre-teachers' perceptions, General chemistry laboratory environment, Inquiry based analytical chemistry laboratory

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OC-13

COGNITIVE TASK ANALYSIS APPLIED TO LABORATORY CURRICULUM

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The chemistry laboratory is central to chemistry education. It is common that undergraduate laboratory courses have many learning objectives. These may include developing hands-on skills, practicing the scientific method, maintaining a laboratory notebook, determining uncertainties, writing in scientific style, practicing critical thinking, working with partners, and so on. With so many objectives, it is difficult to determine what students experience or learn. We will describe use of Carl Wieman's (2015) list of cognitive tasks in experimental research as a viewpoint for: a) thinking about the objectives of experimental chemistry courses, b) selecting course development goals, and c) optimizing design of new experiments for the chemistry laboratory.

At the University of British Columbia, our 3rd year laboratory course has a unique and flexible structure. Students select their own set of experiments, meaning that each student receives a unique learning experience. We studied the breadth and depth of student experience with the cognitive tasks and will share our conclusions including the strengths and weaknesses of our approach.

Keywords: Laboratory, Teaching Experimental Science, Curriculum analysis, Skills for Research

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AN INSTRUCTIONAL DESIGN TO TEACH CONCEPTS REGARDING PHASES OF MATTER TO VISUALLY IMPAIRED STUDENTS

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The abstract concepts of science make it difficult for students with visual impairment to learn these concepts. The aim of this study is to investigate the efficacy of designed instruction model on visually impaired students' learning concepts regarding phases of matter. An instructional design was developed by using a design based research method.

The study consists of three basic stages. In the first stage of the study visually impaired students' learning needs for the concepts regarding phases of matter were identified. In the second stage, teaching materials and activities were designed. In the last stage, the applicability, practicability and contributions of these teaching materials and activities to understanding were evaluated.

The sample of this study consists of six visually impaired 8th grade students, including one blind. Data were collected through tests, interviews and observations. As a result of data analysis, the learning and achievement levels of students in acquiring the concepts were found to be considerably improved. It has been found that they have learnt most of the concepts related to phases of matter. According to the normalized gain analysis, students' learning achievement level of the concepts was measured to be 68 %. As a result, the instructional design model including teaching activities and materials that are designed according to the needs of the students with visual impairment contribute positively to their academic achievements.

Keywords: Visually impaired students, Learning chemistry

STUDENT RESEARCH PROJECTS AS A POINT OF COLLABORATION BETWEEN HIGH SCHOOL AND RESEARCH INSTITUTES

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Research activity is a powerful method for engaging students in science and it allows bridging a gap in curricula between the 2nd (high school) level and the 3rd level of chemistry education. It is the reason to stimulate a laboratory research work at the level of high school.

MSU has a long story of teaching talented high school students. They have been studying in university's high school founded by A.N. Kolmogorov (AESC MSU) for over half a century. During the last decade a system of supporting chemistry education via research activity was elaborated. An important part of the system is collaboration with research institutes to involve students to work together with qualified chemists on actual problems of current science with modern laboratory equipment.

The institutes are stimulated to work with younger students to attract them to continue their career in their field of science. Researchers of institutes have a possibility to work with highly motivated high school students. AESC MSU has partnership contacts with institutes of Russian Academy of Science (INEOS RAS, TIPS RAS) and State Corporation Rosatom (Branch of JSC KIPC).

Tens of AESC students have performed individual research projects in these organizations in the last years. They usually present the projects at school conference. The students with more successful researches have a possibility to acquire a skill of presentation of their results at the advanced level. Many times they were awarded at contests, made reports at conferences and took part in exhibitions of student projects, including international ones. Most of them have chosen the education in chemistry-related areas at the university level and have early publication activity in comparison with their peers.

Thus, the collaboration of AESC MSU with research institutes is very effective and allows realizing the early introduction to science for students as well as rejuvenation of the institute's teams of researchers.

Keywords: Research activity, Research institutes, High school, Education, Collaboration

ASSESSING LABORATORY WORK – DOES WHAT WE DO MAKE SENSE?

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Laboratory activities form an integral part of all university chemistry degree programmes, with students spending at least one third of their direct interaction time in laboratory. The activities can serve as an intense learning experience for students in that they are exposed to translating theoretical knowledge into practice, they use specialist techniques, and they become more confident in handling materials. The activities also present opportunities for students to engage in critical thinking about what they are doing, why the experiment is being conducted in this particular manner, what the results of the experiment are and if they are meaningful, and in communicating these results effectively with tutors and lecturers. While these are the aims and intended learning outcomes that are normally noted for laboratory work, (and further elaborated on by several authors, including Reid and Shah (2007), and Bruck and Towns (2010)), the question arises as to the extent to which lecturers and students engage in these learning situations and whether the assessments conducted are a reflection of the lecturer’s learning intentions.

In this study, laboratories are organized as separate modules in one institution whereas they form an integral module with theoretical lectures in the other. Lecturers who are involved in undergraduate laboratories were asked to articulate their learning intentions for their undergraduate laboratories and to describe the evaluation and assessment of the actual student learning outcomes for each laboratory. A snap shot of the students attending these labs was also obtained to determine the particular outcomes that they focused on. Finally, the assessment protocols were examined and compared to the learning intentions.

Based on the data collected, questions are posed as to what learning can be inferred from particular forms of assessment, are these appropriate (valid/reliable), what does it mean to achieve a high mark in laboratory modules, what variations are evident between 1st year and pre-project year, are there particular instances of practice that should be extended, are there differences between integration of laboratory with lectures versus running stand-alone labs, all focused towards increasing learning within the laboratory.

Keywords: Assessment, Laboratory study, Practical work

Acknowledgement: Authors acknowledge input from staff and students in both institutions.

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OC-17

ENCOURAGING INDEPENDENT THOUGHT AND LEARNING IN FIRST YEAR PRACTICAL CLASSES

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Encouraging independent student thought and learning is a key component of a UK undergraduate degree. In the final year of both BSc and MChem programmes, students are expected to undertake an independent research project that contributes at least 25 % to their final degree mark. It is often the case, however, that independent thought and experimentation are not included in undergraduate practical work until the latter stages of a degree, therefore students are not always thoroughly prepared to carry out investigative research work. Anecdotal evidence has shown that both BSc and MChem students find the transition from a formal, taught, laboratory situation with a defined outcome to an open-ended research project daunting. In order to address this we have redesigned the first-year practical course to enhance student engagement and development. This was achieved by embedding independent thought and experimentation into the curriculum, which served to address the significant transition from a dependent to independent learner.

Keywords: Practical, Independence, University, Chemistry, Engagement

OC-18

PEER ASSESSMENT AND FEEDBACK AS A TOOL FOR EFFECTIVE CHEMISTRY LABORATORY SESSION

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The laboratory-based exercises form an integrated scheme of chemistry practical work. All the exercises introduce basic followed by modern advanced techniques to the students, which are required by a practising chemist. Students use these techniques from their first year and they form the basis for the more advanced experiments that are carried out in subsequent academic years (Roecker, 2007). The laboratory classes are designed to reinforce material taught in lectures and help to develop chemistry experimental concept (Reid, 2008). Students need to develop a solid foundation in the basic principles and procedures of laboratory safety to deepen their knowledge and link their laboratory experience, as they progress through their career (Havdala and Ashkenazi, 2007). Besides this, students need to learn the "why" and "how" behind safety issue, so that they can point out safety factors and can make decisions that reflect their personal safety values and relevant knowledge (Dalgarno, 2009). A qualified chemist is expected to have a good writing skill to interpret results with competency in preparative and analytical tasks (Hanson, 2010). It was anticipated that involving students in a peer assessment exercise with a consistent marking and positive feedback would help students to develop learning and experimental skills in the laboratory experiments.

In this article, we will discuss the outline of effective laboratory session including setting up and delivering the peer mark exercise through online tools. The laboratory session consists of pre-lab, pro forma and publication style report exercise with peer assessment and feedback. Here, we will briefly discuss these steps, summarise the feedback from the students and discuss plans for future implementation.

Keywords: Peer assessment, Feedback, Laboratory work, Online toolkit

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PRINCIPLES OF DEVELOPMENT OF A CHEMISTRY UNIT TO VISUALLY IMPAIRED STUDENTS

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Science education has been identified by some special educators as a one of the most useful and most valuable content area for many students with special needs. It is obvious that visually impaired students perform as effectively as other students in science if their needs due to lack of vision are taken into consideration.

In this study, we developed an instructional design to teach the concepts regarding matter and heat in the light of the students' individual needs and investigated the efficacy of instructional design model developed following the implementation. The study was conducted as a Design Based Research (DBR) method. DBR is used as a response to the gap between basic and applied research practices. The participants of this activity were eight students, including three blind students.

The study was carried out in three steps. At the first step, visually impaired students' individual needs were identified in terms of scientific process skills and conceptual understanding regarding matter and heat. At the second step of the study, instructional materials (instructor's guide and student handouts), activities and activity materials were designed. Some essential principles such as 'color contrast should be considered in the student handouts and materials should be directed at acquiring cognitive content as well as affective and psychomotor skills' were defined when developing materials. At the last step, the instructional materials and the learning process in terms of appropriateness, effectiveness and competency were evaluated. For this purpose, data gathered through tests and semi-structured interviews were subjected to descriptive analysis to determine the efficiency of instructional design. The average level of achievements corresponding to the instruction in the post-test is found to be 55.5 %.

Keywords: Visually impaired students, Learning chemistry

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OC-20

A PROJECT-BASED BIOCHEMISTRY LABORATORY COURSE ON PROTEIN FOLDING, MISFOLDING AND AGGREGATION

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The protein folding problem is the most important unsolved problem in structural biochemistry. Having in mind the importance of protein folding, misfolding and aggregation in many different disciplines (from biophysics to biomedicine), understanding of both theory and practice by master students of biochemistry is of the greatest importance for development of their research career.

A new laboratory course to offer training in protein folding, misfolding and aggregation to master students of biochemistry has been developed at the Department of Biochemistry, University in Belgrade - Faculty of Chemistry. The course centers on both theoretical and practical aspects of structure transitions during the hot/cold denaturation and aggregation of model proteins, monitored by applying biochemical methods, such as analytical HPLC gel filtration, electrophoresis mobility shift, as well as biophysical approaches and techniques, such as differential UV and Fourier transform infrared (FT-IR) spectroscopy. The practical was based on problem and research-based learning which enables students to get insight into the scientific methodology.

At the beginning of the course students worked through a short series of tutorials on bioinformatics, protein structure and stability. Since different proteins can perform many different activities, this lab course can be run as an open-ended experiment, leaving the open possibilities for students to propose mini-projects regarding protein stability in the presence of various agents. Guided by the supervisor students formulated research aim and designed experiments. During the lab work, students gradually gained confidence and started to work independently. Lab journals were evaluated by supervisor in the real time. Final reports were presented in the form of mini-manuscripts and oral presentations.

All of the surveyed students agreed that the project helped them to learn techniques and methods, to improve their experimental and problem-solving skills, and to increase their confidence and motivation for working in biochemical research laboratories.

Keywords: Protein folding, Aggregation, Project-based learning, Research-based learning

ORAL COMMUNICATIONS: The contemporary chemistry teachers' education and the long-term professional development of chemistry teachers

OC-21. ***Seeking to improve students' experimental design skills***, Luca Szalay and Zoltán Tóth, Eötvös Loránd University, Faculty of Science, Institute of Chemistry, University of Debrecen, Faculty of Science and Technology, Department of Inorganic and Analytical Chemistry, Hungary

OC-22. ***Innovation in pregraduate chemistry teachers' education and their professional development – implication of Project Mascil***, Martin Bilek and Veronika Machkova, Section for Chemistry Didactics, Department of Chemistry Faculty of Science, University of Hradec Kralove, Czech Republic

OC-23. ***Creation of chemistry workbooks in cooperation with a daily newspaper***, Ján Reguli, Mária Orolínová and Katarína Kotuľáková, Department of Chemistry, Faculty of Education, Trnava University, Slovakia

OC-24. ***Professional development of chemistry teachers through seminars by the society of chemists and technologists of Macedonia***, Marina Stojanovska and Vladimir M. Petruševski, Institute of Chemistry, Faculty of Natural Sciences and Mathematics, Ss. Cyril & Methodius University, Republic of Macedonia

OC-25. ***Turkish chemistry teachers' views on cooperative learning***, Mustafa Ergun, Ondokuz Mayis University, Faculty of Education, Department of Mathematics and Science Education, Turkey

OC-21

SEEKING TO IMPROVE STUDENTS' EXPERIMENTAL DESIGN SKILLS

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We reported the results of some empirical research at the 6th Eurovariety on Chemistry Education. We investigated whether students' scientific thinking skills could be developed by a simple form of inquiry-based science education (IBSE), when students design, carry out and discuss one or more steps of traditional experiments. We also wanted to know what effect this had on students' factual knowledge. Fifteen chemistry teachers and six hundred and sixty fifteen-year old students were involved in the project. The results were published in 2016 (Szalay and Tóth, 2016) and influenced the pre-service and in-service chemistry teacher education at university level. Following on, a project started in September 2016, funded by the Content Pedagogy Research Program of the Hungarian Academy of Sciences, to investigate further ways of introducing IBSE into public education of chemistry. In this project students do six sets of chemistry experiments set in a relevant context in each academic year from grade 7th to grade 10th. Students in the control group follow step-by-step instructions to carry out the experiments. Students in the first experimental group follow step-by-step instructions, but also design related experiments. They do not, however, carry out these designed experiments. Students in the second experimental group design and carry out the experiments that the other two groups do by following a step-by-step instructions. All participating students took a pre-test in the beginning of the project and will take a post-test at the end of each academic year. The tests aim to measure participating students' abilities to design experiments, as well as their factual knowledge and their attitude towards learning chemistry. The tests will be based on the content knowledge students have been taught. Each test will be structured and questions grouped according to Bloom's taxonomy. Statistical analysis will be used to identify significant effects. Some pre-service chemistry teacher students participate in the present project. The results will be influencing the chemistry teacher education at all levels.

Keywords: Inquiry-based science education, IBSE, IBST, IBL, Research-based chemistry education

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INNOVATION IN PREGRADUATE CHEMISTRY TEACHERS' EDUCATION AND THEIR PROFESSIONAL DEVELOPMENT – IMPLICATION OF PROJECT MASCIL

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The education system in the Czech Republic is at this time under substantial changes. They relate to wider policy perspectives (macro level), school level (meso-level) and classroom level (micro-level), and teachers' education, too. The contribution for innovation in mathematics and science (incl. chemistry) education and relative teachers' education is project of European Union Seventh Framework Programme (FP7/2007-2013) Mascil (Mathematics and Science in Life) (Maass *et al*., 2013). The main objectives of Mascil project – inquiry based learning (IBL), as well as relations to world of work (WoW) are a big challenge for improvement of school practice and teacher's education in Czech Republic. The implementation of the Mascil project objectives in pre-graduate teacher's education and in professional development (PD) courses takes place by project developed materials and activities: IBL task at Mascil Web-portal database (http://www.mascil-project.eu), problems of the month (ditto), Mascil Toolkit, "good practice" from Czech curriculum reform Web-portal (http://rvp.cz), etc. The Mascil based PD model, identical for teachers, future teachers and multipliers, was structured as follows: two face-to-face (F2F) meetings; dealing with participants' final work based on presentation of their own created or modified IBL task and experiences of its using in their classroom (IBL task from Mascil database or from other sources modified by Mascil recommendations).

The implementation of the Mascil project outcomes in the Czech Republic, particularly in teacher's PD, brought supportive arguments for positive evaluation of the implementation of IBL and WoW. Examples from chemistry teacher's education will be added as a part of the presentation.

Keywords: Chemistry teacher's education, Project Mascil, IBL, Teacher's professional development

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OC-23

CREATION OF CHEMISTRY WORKBOOKS IN COOPERATION WITH A DAILY NEWSPAPER

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For the last ten years Slovak publishers *Petit Press* has provided an educational project "SME (We are) at School" for pupils of primary and secondary schools. The aim of this project is to share knowledge in an amusing and creative way using the daily newspaper SME. Joined classes receive original workbooks that contain special educational texts and interactive tasks, which can be solved with the help of articles in the print or online version of the newspaper. In this way pupils improve their skills to search for and work with new information. They also learn to consider reliability of the found information.

Three workbooks on "Chemistry around us" were created in this project. Daily newspaper does not offer enough articles on topics concerning chemistry, so our tasks were aimed at the articles in the web archive www.sme.sk.

The first workbook for primary schools was devoted to substances used in everyday life (food ingredients, washing agents, cosmetics, pesticides, medicines). Two workbooks created next year were dedicated to organic chemistry. Several topics dealt with the same issues, but the level of provided information and difficulty of the tasks were different as one workbook was prepared for primary schools, the other one for secondary schools. The topics involved properties of various substances, oil and other fossil and alternative fuels, polymers and plastics. Further parts of the text for primary schools uncovered chemistry of cigarettes, anabolic steroids, food and nutrition. Secondary school students solved tasks concerning chemistry of some cosmetic products. Optical activity and other properties of various sweeteners were introduced, too. The last group of substances included halogen derivatives of hydrocarbons.

The teachers who participated found the project and provided workbooks very inspiring and useful.

Keywords: Consumer chemistry, Organic chemistry, Work with information, Project SME at school

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PROFESSIONAL DEVELOPMENT OF CHEMISTRY TEACHERS THROUGH SEMINARS BY THE SOCIETY OF CHEMISTS AND TECHNOLOGISTS OF MACEDONIA

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The Society of Chemists and Technologists of Macedonia was founded in 1946 as an association of scientific and research workers who are active in chemistry, applied chemistry and technology. The main activities of the Society are the publication of the Macedonian Journal of Chemistry and Chemical Engineering – MJCCE and the organization of scientific conferences.

Within the Society there are 4 divisions, among which is the Division of Education in Chemistry. In the last few years, this Division started several activities for school students and teachers. Chemistry competitions for lower secondary and upper secondary school students, participation in the International Chemistry Olympiad (IChO) and seminars for teachers have been organized by the Division of Education in Chemistry (within the Society) together with the Institute of Chemistry.

The main goals of the seminars are professional development of chemistry teachers, deepening their competences and qualifications and enrichment of their experience in different fields of chemistry, thus making the teaching process more effective. Some topics that were discussed in these seminars involved low-cost experiments by using everyday chemicals, conceptual understanding and higher-order questions, ICT in the chemistry teaching, etc. An essential part of the seminars is exchange of expertise and ideas among school teachers, on one hand, and among school teachers and university teachers, on the other. Therefore, we planned workshops as a necessary part of the seminars in which all teachers were involved. Furthermore, one section of each seminar (called 'By teachers – for teachers') was devoted to school teachers' practice. Teachers have contributed by sharing interesting experiments, models, teaching methods, homework tips, application of ICT in chemistry teaching, teachers networking and many other ideas.

We believe that all these activities will help teachers to acquire new skills and better ways to use their pedagogical content knowledge to deliver the content to students. We hope that students will also benefit and that most of these activities will find its place in chemistry teaching thus increasing the students' interest and love for chemistry.

Keywords: Chemistry teaching, Pedagogical content knowledge, Professional development, Seminars, The Society of Chemists and Technologists of Macedonia

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TURKISH CHEMISTRY TEACHERS' VIEWS ON COOPERATIVE LEARNING

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Cooperative learning model is a learning approach which enables group members to help each other in an academic subject and in which learners are active. Lately, there have been a variety of different instruction methods and techniques in teaching Chemistry course.

In this study, the views of chemistry teachers about jigsaw method, which is one of the techniques used by chemistry teachers in cooperative learning model, have been analyzed. Survey research – a quantitative research design – is used in this study which aims to examine the views of teachers about this instruction technique. Theoretical knowledge and application levels of cooperative learning model have been measured for 24 chemistry teachers. A theoretical and applied training in cooperative learning model has been provided for chemistry teachers and it lasted 8 hours in total. Within context of cooperative learning model workshop, jigsaw technique has been applied to chemistry teachers showing how to teach particulate nature of matter which is an important subject in chemistry. Prior to the activity, cooperative learning model knowledge and application level identification scale (Doymuş, 2012) has been applied to 24 chemistry teachers.

The findings obtained in this study indicate that although chemistry teachers claim they are already experienced in cooperative learning model prior to the activity, it seems that they only make use of cluster technique during application and that they are worried about losing control of the classroom during these activities. It is also understood from data analysis that learning teams are not created according to principles and rules of cooperative learning model, that the most appropriate grade for this model is the 10^{th} grade, as far as the subjects in chemistry curriculum program are concerned, and, lastly, using this instruction model with students has appeared to be useful, effortless and encouraging. Chemistry teachers have expressed that there has been an increase in their research skills and attitudes towards learning during cooperative learning model application.

Keywords: Chemistry teacher, Cooperative learning, Jigsaw

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ORAL COMMUNICATIONS: Use of ICT in the 3rd level of chemistry education

OC-26. ***The challenges of developing an interactive online course for in-service chemistry teachers***, Ron Blonder, Weizmann Institute of Science - Department of Science Teaching, Israel

OC-27. ***Models and visualisation: a teacher education speciality course***, Jan Lundell, Department of Chemistry, University of Jyväskylä, Finland

OC-26

THE CHALLENGES OF DEVELOPING AN INTERACTIVE ONLINE COURSE FOR IN-SERVICE CHEMISTRY TEACHERS

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An interactive online course was developed for in-service chemistry teachers called "Introduction to materials and nanotechnology". The course is based on an academic course developed to expose high-school teachers to modern research topics, introduce them to nanoscience, generate teacher interest, and increase chemistry teachers' nanoliteracy by teaching them the basic principles of nanoscience. The course featured enhanced videos that were recorded with a commercial software package (Camtasia) for preparing online course lectures. The lectures were designed as short slideshow presentations that were accompanied by recorded explanations by the lecturer. The enhanced slideshow presentations are recorded directly into the instructor's computer without an audience. The advantages of this approach include the possibility of controlling the length of the videos and thus, splitting a typical lecture given in the university environment into several shorter clips. Each topic can be divided into short videos geared to keep the attention of the students who will watch them online. The software used also provides additional options such as integrating quizzes into the lectures. However, there was a downside: in our experience, lecturers found it difficult to give an appealing talk by talking directly to a computer without receiving any feedback from students who watch the talk, namely, without any interaction between the lecturer and the students. In addition, the use of the videos in an LMS environment like Moodle is very challenging regarding creating interactivity among the students. Pedlet and Moodle forums were used to create interactions among the students. In this lecture I will present these means of interaction and the perception of the teachers who participated in the online course.

Keywords: ICT, Online course, Interactivity, Nanotechnology, Chemistry teachers

OC-27

MODELS AND VISUALISATION: A TEACHER EDUCATION SPECIALITY COURSE

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Digitalisation, information and communication technologies (ICT) and computational modelling are becoming more prevalent in chemistry education all the time. They are also becoming indispensable tools to understand and communicate chemical phenomena, chemical concepts and to create new information and knowledge. Therefore, it is necessary to employ the tools and methods of ICT-supported scientific research and inquiry in chemistry education to provide modern and many-faceted possibilities to learn and study chemistry.

These challenges and possibilities of ICT-supported chemistry education needs also to be extended into chemistry teacher education to provide in-field and teacher students' views, knowledge, skills, hands-on training and capabilities to use modern ICT-assisted methods and tools in educational practices.

This report focuses on the specialization course entitled "Models and visualization", which is given to chemistry teacher students at the University of Jyväskylä. The target of the course is to introduce, familiarize and provide ways of adopting modern ICT-supported teaching and learning methods in chemistry education. The course focuses especially on 2D/3D modelling and representations of models in chemistry education, how to apply computational chemistry to support learning and understanding of chemical phenomena and concepts, and how to use animations as learning and assessment tools. The course is connected with research projects (Aksela and Lundell, 2008; Akaygün and Lundell, 2017) which are connected with the development of course activities and with providing new understanding of meaningful use of ICT in chemistry education.

Keywords: Modelling, Computational chemistry, Teacher education, Visualization

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ORAL COMMUNICATIONS: Ethical guidelines and university chemistry education for sustainable development

OC-28. ***Directed integration of an initiative for university-wide education for sustainable development into chemistry degree programmes***, M. Coffey, A. Dharmasasmita and P.Molthan-Hill, Nottingham Trent University, United Kingdom

OC-28

DIRECTED INTEGRATION OF AN INITIATIVE FOR UNIVERSITY-WIDE EDUCATION FOR SUSTAINABLE DEVELOPMENT INTO CHEMISTRY DEGREE PROGRAMMES

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Nottingham Trent University (NTU) offers all students (25000+) the opportunity for an additional academic award which focuses on education for sustainable development (ESD) to supplement their degree programme. In this initiative, the Sustainability in Practice Certificate (SiP), participants demonstrate how their discipline can be applied in the wider context of sustainable development (Molthan-Hill *et al.*, 2015). Whilst the NTU Business School adopts compulsory participation in the SiP, for others, including Chemistry, participation is optional.

The theme for the SiP is “Food for Thought”. Participants explore how their subject applies to one of many aspects of food sustainability (Puntha *et al.*, 2015). The scheme is relatively new and uptake by students for whom the award is optional is patchy, with relatively low engagement levels for Chemistry students, a behavior seen for some other subjects (Jones *et al.*, 2008; Zeegers and Clark, 2014). This may be due to sustainability being viewed as a purely environmental issue, with weaker awareness of its social and economic dimensions.

This present work details how the SiP requirements are aligned with coursework for a module available to Level 5 NTU Chemistry degree students to facilitate participation. This module (Applied Instrumental Analysis) focuses on the development of understanding and practice of a wide range of analytical chemistry applications.

Module coursework requires students to comprehend primary literature papers relating to the instrumental chemical analysis of food in relation to food safety, security, taste studies, composition analysis or contamination screening (e.g. Sapozhnikova *et al*., 2015). Students produce a poster which contextualizes this studied literature to suit a wider audience. This work aligns with the SiP requirements at two key stages of a five-stage process to award. By contextualizing ESD directly to the course content of the chemistry programme, engagement in the SiP by chemistry students has improved.

Keywords: Food, ESD, Analytical chemistry, Certificate, Curriculum

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ORAL COMMUNICATIONS: Evaluation of learning outcomes and assessment related problems in HEIs

OC-29. ***Conflict between calculations and underlying concepts: case of tertiary level students***, Dušica D. Milenković, Tamara N. Hrin, Mirjana D. Segedinac, Milan T. Segedinac and Goran Savić, University of Novi Sad, Faculty of Sciences, Serbia

OC-30. ***Investigating Indonesian university students' ability to solve equivalent conceptual and algorithmic questions***, Habiddin and Elizabeth Page, Chemistry Department, University of Reading, United Kingdom, UniversitasNegeri Malang, Indonesia

OC-31. ***Assessing Quebec elementary teacher students' understanding of heat and temperature***, Abdeljalil Métioui, Louis Trudel and Mireille Baulu MacWillie, Université du Québec à Montréal, Université d'Ottawa, Université Sainte-Anne Pointe de l'Église, Canada

OC-32. ***Efficiency of solving systemic multiple choice questions in organic chemistry at university level: an eye tracking analysis***, Tamara N. Hrin, Dušica D. Milenković, Mirjana D. Segedinac, Milan T. Segedinac and Goran Savić, University of Novi Sad, Faculty of Sciences, Serbia

OC-33. ***"That mechanistic step is productive": comparing organic chemistry students' backward oriented reasoning with their professor's expectations***, I. Caspari, M. L. Weinrich and N. Graulich, Institute of Chemistry Education, Germany, Department of Chemistry, University of Massachusetts Boston

OC-29

CONFLICT BETWEEN CALCULATIONS AND UNDERLYING CONCEPTS: CASE OF TERTIARY LEVEL STUDENTS

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Chemistry concepts often pose substantial challenges to students, and for this reason, students are inclined to use algorithm-based strategies, without proper reasoning. According to the literature, this has been particularly manifested in chemical calculations (Beall and Prescott, 1994; Schmidt and Jigneus, 2003). Our investigation was, therefore, guided by the following research question: Are students prone to use the adopted algorithms and to follow heuristics, even if the task is meaningless? To answer this question, a test consisting of five seemingly simple calculation tasks was constructed and applied to a group of students majoring in chemistry teaching. Although apparently simple, each of the tasks contained information which made it impossible to solve.

One by one the tasks had been presented to students, and they were required to provide the resolving procedures and comments on the problem solving steps and task requests. The problem solving process included two phases. In the first, reading phase, an eye-tracking methodology was employed. The time spent on task reading was measured as well as the time spent on reading certain words within the task. In the second phase, the time spent on calculations was measured and written comments were collected. Additionally, students were asked to evaluate the difficulty of each task using 7-point Likert scale.

Two key results have emerged from this research. First, when faced with calculations, students pay little attention to the text and focus mainly on the given numerical values. Second, analysis of the collected comments revealed that tested students do not possess functional knowledge, since none of them has expressed any doubts about the task requests and all of them provided their resolving procedures for each task.

Keywords: Eye tracking, Chemistry calculations, Mental effort, Student teachers

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INVESTIGATING INDONESIAN UNIVERSITY STUDENTS' ABILITY TO SOLVE EQUIVALENT CONCEPTUAL AND ALGORITHMIC QUESTIONS

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The typical approach to chemistry teaching in secondary schools in Indonesia is often initiated by presenting chemical rules and is followed up by doing exercises (solving problems). Generally, the questions follow what is presented in the teaching and textbooks and usually require students to simply apply the rules they have learnt. Traditional teaching & learning at university-level stresses the rules, formal definitions, equations and algorithms, and this is principally adequate to enable them to pass courses but does not allow them to apply knowledge that requires higher-order thinking skills such as solving conceptual questions (Bailin, 2002; Zoller and Pushkin, 2007). This study aimed to investigate students' ability to solve equivalent conceptual and algorithmic questions on chemical kinetics. 149 students from two Indonesian universities (State University of Malang and Haluoleo University) participated in this study. To reveal students' conceptual and algorithmic abilities, a conceptual - algorithmic pair instrument as suggested by Costu (2010) was implemented. The instrument provided several conceptual and algorithmic question pairs in which each pair investigated the same chemical kinetics concept and required the same procedure to solve. Conceptual questions were provided pictorially while algorithmic questions were presented as in standard chemistry textbooks. By comparing students' answers to both types of questions, students' ability in both types of approaches is revealed. The results showed that many students can answer the algorithmic questions well, but failed when answering the equivalent conceptual one. For instance, in the question of determination of reaction order by the initial rates method, 30.87 % answered the algorithmic question correctly, but failed the conceptual one; 1.34 % answered the conceptual correctly but failed the algorithmic one. This study confirms previous work as published by Salta and Tzougraki (2011), Stamovlasis *et al.*, 2005. Finally, a few suggestions for teaching practices are discussed.

Keywords: Chemical kinetics, Conceptual question, Algorithmic question

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ASSESSING QUEBEC ELEMENTARY TEACHER STUDENTS' UNDERSTANDING OF HEAT AND TEMPERATURE

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Research conducted with students (primary and secondary) shows that the majority have conceptual difficulties regarding notions of heat and temperature (Sözbilir, 2003; Chu *et al*., 2012). The purpose of this paper is to present the results of a research on the conceptions of 128 Quebec (Canada) students enrolled in their third year of university in a program to train primary teachers on the notions of heat and temperature. Note that the formation of these students is in the humanities and they all took a chemistry course during their secondary studies. To do this, we constructed a multiple-choice questionnaire consisting of five questions. The selected questions are related to situations in their environment. For each question, they had to explain their choice of an answer. At the methodological level, this step is essential to be able to identify the student conceptions. As illustrations, the following are the misconceptions identified in our analysis of the data collected:

1. The change of state of the matter does not require a constant temperature.
2. If a wooden object and another metal object are touched in a room at the ambient temperature, their temperatures will be the same even if the metal is cooler to the touch.
3. Their temperatures will be different because they do not react in the same way to temperature.
4. The temperature is a measure in degrees to indicate the level of heat of a place or person.
5. The mercury contained in a thermometer expands when it is heated so that the particles which constitute it expand.

We will see that these conceptions are relevant to the development of teaching strategies based on conceptual conflict.

Keywords: Conception, Heat, Temperature, Student, Elementary school

EFFICIENCY OF SOLVING SYSTEMIC MULTIPLE CHOICE QUESTIONS IN ORGANIC CHEMISTRY AT UNIVERSITY LEVEL: AN EYE TRACKING ANALYSIS

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This study applied an eye tracking technique to examine university students' visual attention while doing a test of knowledge about organic chemistry reactions. The test contained five tasks, and each task had three tiers. The first tier was presented as a systemic multiple choice question with three graphical options (constructed according to Fahmy, 2015), the second tier required students' explanation for the selected option in the first tier, while the third tier was confident tier. Fifteen fourth-year university students participated in this study in March 2017, and their written responses and visual attention were recorded by Gaze Point eye tracker. In addition to this, each student was subjected to the recorded semi-structured interview. Firstly, the average performance score and average time for solving each task were calculated, showing that students spent similar time on each task. However, their performance scores differed. Also, in most cases, they were not sure about the provided responses. Additionally, fixation duration between chosen and rejected option was compared (according to Tsai *et al*., 2012), and students' written and verbal responses were analysed. Applied assessment format, in combination with eye tracking technique and interview protocol, provided an opportunity to deeply evaluate university students' cognitive structures in organic chemistry.

Keywords: Eye tracking, Organic chemistry, Systemic multiple choice questions, Three-tier test

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"THAT MECHANISTIC STEP IS PRODUCTIVE": COMPARING ORGANIC CHEMISTRY STUDENTS' BACKWARD ORIENTED REASONING WITH THEIR PROFESSOR'S EXPECTATIONS

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In organic chemistry, college student reasoning often lacks a deeper understanding of basic concepts underlying mechanisms. When asked *why did you propose this mechanistic step?* in many cases, students answer *because it gets me to the product* (Bhattacharyya and Bodner, 2005). This strategy indicates that students are considering subsequent steps in a mechanism to decide what happens in a prior step. A backward tendency in reasoning about mechanisms, like some other examples of teleological reasoning (Talanquer, 2007), is not necessarily a strategy of novices nor contradictory to the strategies expected by professors.

We used the concept of chaining (a reasoning strategy employed by biologists to elucidate mechanisms (Darden and Craver, 2002; Darden, 2002; Machamer *et al*., 2000) as a lens to qualitatively compare existing data (Weinrich and Sevian, 2017) of organic chemistry student reasoning and the expectations of their professor. Chaining relies on an understanding of mechanistic reasoning that either mirrors the process of the mechanism in the forward direction (forward chaining) or in the reverse direction (backward chaining). Transferring this concept, which was previously used in physics and biology education (Russ *et al*., 2008; van Mil *et al*., 2013), to organic chemistry led to the identification of different chaining types, one of which is inter-step backward chaining (reasoning about subsequent mechanistic steps in order to propose a prior step).

Uses of inter-step backward chaining in student responses and the professor's expectations lacked the justifications that would indicate why it is appropriate to use inter-step backward chaining and how the proposed step can also be arrived at using forward chaining. Furthermore, students used inter-step backward chaining in different combinations with other chaining types than were expected by their professor. These findings support the necessity of objective definitions of expectations in mechanistic reasoning in organic chemistry classrooms. We present a framework for defining these expectations and discuss implications of the framework for improving students' understanding of sound mechanistic reasoning in organic chemistry.

Keywords: Organic chemistry, Mechanistic reasoning, Backward chaining

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ORAL COMMUNICATIONS: Development of educational competencies of academic chemistry teachers

OC-34. ***Questioning skills and argumentation in chemistry***, Rachel Mamlok Naaman, Weizmann Institute of Science, Israel

OC-35. ***Croatian pre-service teachers' beliefs about teaching and learning chemistry***, Lana Saric and Silvija Markic, University of Split, Croatia, Ludwigsburg University of Education, Institute for Science and Technology - Chemistry Education (Primary Science Education), Germany

OC-36. ***Exploring Chemistry student teachers´ knowledge about diagnostic – a longitudinal study***, Yannik Tolsdorf and Silvija Markic, University of Bremen – Institute for Didactics of the Sciences – Chemistry Education, Ludwigsburg University of Education, Institute for Science and Technology - Chemistry Education (Primary Science Education), Germany

OC-37. ***A collection of tasks from International Chemistry Olympiads: an excellent resource for teaching/learning chemistry***, Vojin Krsmanovic, University of Belgrade - Faculty of Chemistry, Serbia

OC-34

QUESTIONING SKILLS AND ARGUMENTATION IN CHEMISTRY

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Asking questions is an important comprehension-fostering (Levy Nahum *et al*., 2010) and self-regulatory cognitive strategy. The act of composing questions focuses students' attention on the content of the phenomena and involves concentrating on the main ideas while checking to see whether the content is understood (Blonder *et al*., 2015). This paper describes a study which focuses on the ability of college chemistry students to ask meaningful and scientifically sound questions. Two aspects were investigated in this study: (a) the ability of students to ask questions related to their observations and findings in an inquiry-type experiment (a practical test), and (b) the ability of students to ask questions after critically reading a scientific article. The student population consisted of two groups: an inquiry-laboratory group (experimental group) and a traditional ("cook-book" like) laboratory-type group (control group). We investigated three common features: (1) the number of questions that were asked by each of the students, (2) the cognitive level of the questions, and (3) the nature of the questions that were chosen by the students, for the purpose of further investigation. Importantly, it was found that students in the inquiry group who had experience in asking questions in the chemistry laboratory outperformed the control group in their ability to ask more and better questions.

Keywords: Chemistry education, Chemistry laboratory, Inquiry laboratory, Students' questions

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OC-35

CROATIAN PRE-SERVICE TEACHERS' BELIEFS ABOUT TEACHING AND LEARNING CHEMISTRY

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The importance of beliefs for teacher's action in the classroom is well known. They influence teachers' representation of science, science knowledge and organisation of the knowledge and information. Keeping teacher professional developments in mind, student teachers' beliefs need to be examined and sought out by educators. They should be developed into the direction of teaching chemistry due to recent reforms and teaching and learning theories. Beliefs of both, pre- and in-service teachers should be the centre of focus of teacher educators. There are different studies accomplished in different educational backgrounds and different educational systems about teachers' beliefs. Due to the political system, culture and religion they are, in most of the cases, not comparable. Since the war in Croatia (the 1990s) there have been many changes in the country that had influence on the educational system as well. Despite that, there are no studies in Croatia focusing on the teachers' beliefs or their development. The presented study evaluates Croatian chemistry student teachers' beliefs about chemistry teaching and learning at the beginning, in the middle and at the end of their university chemistry teacher training program. Participants were instructed to draw themselves as chemistry teachers in a typical classroom situation in chemistry and to answer four open questions. Data analysis follows a pattern representing a range between the predominance of more traditional versus more modern teaching orientations in line with educational theory focusing on: 1) Beliefs about Classroom Organization, 2) Beliefs about Teaching Objectives and 3) Epistemological Beliefs. The data depictured mostly traditional and teacher-centered knowledge by all of the participants. Changes are hardly noticeable. The results will be presented in detail as well as the first implication for the university chemistry teacher education in Croatia.

Keywords: Pre-service teachers' beliefs, Initial teacher education, Teacher professional development, Chemistry

OC-36

EXPLORING CHEMISTRY STUDENT TEACHERS´ KNOWLEDGE ABOUT DIAGNOSTIC – A LONGITUDINAL STUDY

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Diagnostic knowledge is an area which belongs to Pedagogical Content Knowledge (PCK). PCK is especially important for professional teachers and therefore should be one of the central constructs in teacher training. Since the importance of diagnostic knowledge with the view to rising diversity and heterogeneity in schools is increasing, there is a need for including diagnostic knowledge in higher education. Using a developed model of Participatory Action Research, university teacher training for chemistry education focusing on the development of chemistry student teachers' diagnostic knowledge was established. In the meaning of a longitudinal case study the improvement of this knowledge has been evaluated.

For the present study, the definition of diagnostic knowledge is based on Jäger (2006) and can be classified into three main dimensions: (i) Technological Knowledge, (ii) Conditional Knowledge and (iii) Knowledge of Change. The study is focusing on a group of 20 chemistry student teachers. The evaluation has been done over a period of two years and student teachers visited different seminars and internship at school. Their diagnostic knowledge was evaluated at different points during their university teacher training program. This qualitative study is based on a structured narrative questionnaire focusing on Jäger's dimensions.

The results of the longitudinal study show that the participants possess knowledge about diagnostics in chemistry teaching. However, their knowledge level appears to be quite low and can be described as naïve especially at the beginning of their training. At the end, the knowledge is more advanced but not very high. Furthermore, differences and changes between the time points of the training program exist. The results will be presented and discussed in consideration of the course structure. Further implications will be made.

Keywords: Diagnostic knowledge, Longitudinal study, Teacher training, Seminar structure

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A COLLECTION OF TASKS FROM INTERNATIONAL CHEMISTRY OLYMPIADS: AN EXCELLENT RESOURCE FOR TEACHING/LEARNING CHEMISTRY

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The International Chemistry Olympiad (IChO) is a well-known chemistry competition for upper secondary school students (Apotheker, 2005). It began in Prague, Czechoslovakia, in 1968 with participants from three countries: Czechoslovakia, Hungary and Poland. In the next ten years the number of participating countries was about 15. They were European countries and the Soviet Union. Later the competition really became international. Students from 60 to 70 countries participate in IChO every year. In 1980 the first collection of competition tasks was published (Sirota and Mahackova, 1980). Professor Sirota continued with compilation and edition of competition tasks. They were published and available free of charge in electronic form from the IChO International information centre in Bratislava, Slovakia (see the links in References). The collection contains more than 300 theoretical and 100 practical tasks from 45 Olympiads (1968-2013). According to regulations of IChO, the organizers of each Olympiad engaged the chemists from university schools and industry to prepare the tasks. Authors of particular tasks are not known although some of them were present at particular Olympiads. The collection of tasks contains a lot of excellent tasks and it includes many modern aspects of chemistry (environmental chemistry, green chemistry, fullerene, etc). The collection was mainly used for preparation of students for the next Olympiad. These tasks are also a good resource for teaching/learning chemistry at university or upper secondary school level. However, there is no evidence in the literature about such use of these tasks. The exception is the paper of I. Parchmann (Parchmann, 2011) as well as some of her papers with co-authors. The complexity of tasks and their high professional level make them suitable for inclusion in some university courses. Examples of some interesting tasks suitable for university courses in inorganic, analytical, industrial and environmental chemistry will be given.

Keywords: IChO, Collection of tasks, Teaching/learning chemistry, International Chemistry Olympiad

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IChO, www.icho.sk or www.iuventa.sk/en/subpages/icho/past-competition-tasks.alej

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ORAL COMMUNICATIONS: Chemistry education through university-industry partnerships

OC-38. Is there a future outside of chemistry after a chemical degree? Professional challenges for a career evolution, Pascal Mimero, CESI Engineering School, Centre of Lyon, France

OC-39. ***Industrially relevant projects as a teaching tool in chemistry***, Jurica Bauer, Jordy van Angeren, Lucia Baljeu-Neuman, Rosalba Bellini, Ewald Edink, Lieke van Hemert, Mark Jansen, Samira Kabli, Iris Kuiper-Dijkhuizen, Maarten Kuiper, Roland Meesters, Mark Verheij, John Vessies, Bojd Vredevoogd, Anass Znabet, InHolland University of Applied Sciences, The Netherlands

IS THERE A FUTURE OUTSIDE OF CHEMISTRY AFTER A CHEMICAL DEGREE? PROFESSIONAL CHALLENGES FOR A CAREER EVOLUTION

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One can raise a crucial and stressing question: how to perform a successful career evolution after several years of professional activity, moving to another company by choice or by constraint? The answer could be found by looking at the 2015 European survey (Salzer *et al.*, 2015) showing a variety of issues for chemists, and at a tricky equation between employers' expectations, market needs and your own skills! Employers' requirements now seek complementary skills: hard skills focusing on technical applied knowledge, expertise, etc. and soft skills focusing on competences not really developed during the academic years, and which are increasingly appreciated.

Soft skills can be addressed by involving interactive processes: interpersonal skills (behaviour, collaboration, communication…), tools/methodologies (problem solving, creativity, analytic thinking...), associated with transversal approaches (management, quality, ethic, safety, environment, project…).

After a Master 2 / Engineering / Ph.D. diploma in chemistry, there is a potential evolution even outside of chemistry. To enlarge the scope and illustrate the case, we will enlighten the French context of Life Long Learning, with training programs enabling chemists to facilitate the evolution within or outside a company: a) to pursue a career in the chemistry environment by updating their knowledge, acquiring new skills, developing new activities … (CPE Continuing Education Department); b) to give a new impulse in their career by reaching more transversal jobs (Project Management, R&D Coordination, Portfolio or Program Management, Industrial Risk Assessment, Quality Management, Regulatory Affairs, etc.) (CESI Engineering School).

Looking at the situation during the professional life, 3 factors may be combined: 1. Human Resources Service of a company may assist the professional development of their employees; 2. Chemical Societies, Professional or Sectorial Unions and Associations may also provide assistance and training programs; 3. Your strong will to develop yourself and take the risk to switch. A real professional challenge and also real success stories to illustrate those career evolutions will be presented.

Keywords: Continuing education, Career evolution, Lifelong learning

Acknowledgement to CPE Continuing Education Department and CESI Engineering School.

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CPE Continuing Education Department, Professional Training Programs, www.cpe.fr

CESI Engineering School, Specialized Post-Graduate Masters, www.eicesi.fr

OC-39

INDUSTRIALLY RELEVANT PROJECTS AS A TEACHING TOOL IN CHEMISTRY

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The Life Sciences and Chemistry (LSC) cluster within the Inholland University of Applied Sciences located in Amsterdam, The Netherlands, offers a four-year BSc study with three majors: biotechnology, biomedical research and chemistry. The study shapes the students into independent professionals skilled to conduct research in one of the three fields, qualifying them to face the challenges of the job market or to pursue further education.

In close collaboration with the industrial partners in the region, the LSC cluster also conducts innovative research in many diverse fields like plant breeding, seed technology and bee diseases. The research is supported by a centre of excellence for chemical analysis and is carried out by both the staff and the students. In this environment the students acquire hands-on knowledge through conducting research and get to experience the academic curiosity as well as the industrial demand. Inholland strives to maintain a strong connection and balance between education and applied research of interest to the industrial sector in the region and beyond. This is accomplished by means of research mini-projects carried out in small groups as well as through more elaborate and demanding individual student internship and graduation projects.

This contribution aims to present the chemistry curriculum at Inholland along with several representative examples of student research projects. The successes and limitations of teaching chemistry through research (mini)projects of industrial relevance will be analyzed and discussed.

Keywords: Industry, Research, (Mini)Project, Internship, Application

ORAL COMMUNICATIONS: The role of history of chemistry and philosophy of science in university education

OC-40. ***Chemistry by (the etymology of the) words: strategies to teach chemistry and challenge the borders of specialization***, João C. Paiva, Carla Morais and Luciano Moreira, Faculdade de Ciências, Universidade do Porto, Faculdade de Engenharia, Universidade do Porto, Portugal

OC-41. ***H. E. Armstrong (1848-1937): The forgotten pioneer of IBSE***, Peter E. Childs, University of Limerick, Ireland

CHEMISTRY BY (THE ETYMOLOGY OF THE) WORDS: STRATEGIES TO TEACH CHEMISTRY AND CHALLENGE THE BORDERS OF SPECIALIZATION

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Chemistry teachers in Higher Education are often restricted to a limited area of knowledge. However, they not only have to disseminate knowledge among their peers, but they also have to teach college students or to communicate with lay audiences. Unfolding chemistry jargon is pretty much a contemporary challenge, because "academics make use of these [chemistry] terms without often realizing the exact meaning of the underlying words" (Beezer, 1940; Loyson, 2009, p. 1195; Loyson, 2010). One needs to provide scholars with multidisciplinary resources that bridge etymology and history to chemistry content knowledge (Lazlo, 2013). In this paper, we present an ongoing project of a book and website about chemistry lexicon. The project, based upon a variety of sources, such as lists of etymological derivations (Nechamkin, 1958) and dictionaries (e.g., Larrañaga *et al.*, 2016), goes beyond defining chemistry terms (concepts, instruments and techniques) and tracing their etymological roots and cultural significance. It also proposes educational strategies to use them in Higher Education and in other formal and informal settings. To learn the ways of words, students are most likely to engage in analogical reasoning, to develop critical views on the nature of science, and to challenge the boundaries of specialization (Paiva *et al.*, 2013). We have reflected upon the process of undertaking this project, the ways to explore its affordances and its social relevance. While looking into words of our academic lexicon in a different perspective, we have been surprised. We have learnt that acid comes from a Latin word meaning *needle* and is rooted in the Indo-European language meaning *sharp*. Thus, *acid* can be linked with sharp objects, not only with food and taste. Language can be a switchblade to fight back the intellectual insulation effects of specialization and engage scholars and students in a fascinating world of words.

Keywords: Chemistry lexicon, Chemistry etymology, Chemistry history, Teaching strategies, Higher education

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H. E. ARMSTRONG (1848-1937): THE FORGOTTEN PIONEER OF IBSE

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Most books and articles identify the Americans John Dewey (early 1900s) and Jerome Bruner (1960s) as the originators of inquiry-based science education (IBSE). However, the idea of heuristic science teaching was first suggested and promoted by Professor H.E. Armstrong from the 1880s onwards. His ideas and influence in the U.K. in the early 20th century has been overlooked in the history of inquiry-based science education (IBSE). Armstrong promoted his idea that learning science should be by doing not just by listening from around 1884, based on his own third level experience, in a series of lectures and articles (Armstrong, 1902; Brock, 1973). Armstrong had been influenced by the German school of research-based teaching, pioneered by Justus von Liebig, and his own experiences of teaching chemistry at tertiary level made him realise the deficiencies of contemporary school science education. He changed the way he himself taught at third level and started to promote his ideas to scientists, the public and to teachers. He defined heuristic methods thus:

"Heuristic methods of teaching are methods which involve placing students as far as possible in the position of discoverers,—methods which involve their finding out instead of being merely told about things." (Armstrong, 1902)

Armstrong had a major influence on the way science was taught in the U.K. in the early part of the 20th century and was the source of a stream of inquiry-based science pedagogy which resulted in the Nuffield science teaching projects of the 1960s. *This 'new pedagogy' of IBSE was rediscovered by the Rocard Report (Rocard, 2007).*

Keywords: IBSE, Secondary education, Tertiary education

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POSTER PRESENTATIONS: Development of the university curricula for BSc, MSc and PhD chemistry studies

PP-1. ***Chemistry for non-chemical university programs in the field of agriculture and forestry***, Valdas Paulauskas, Aleksandras Stulginskis University, Lithuania

CHEMISTRY FOR NON-CHEMICAL UNIVERSITY PROGRAMS IN THE FIELD OF AGRICULTURE AND FORESTRY

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Aleksandras Stulginskis University (ASU) is a state university in Lithuania dedicated to both teaching and research in the field of agriculture, forestry, ecology, hydro- and agro-engineering. There are no degree programs in chemistry or chemical engineering at ASU. Nevertheless, different chemistry courses and lab practice are included in the curricula of non-chemical university bachelor/master as well as PhD study programs.

The aim of this poster is to present chemistry subjects that are a part of the curriculum of the 3 specific degree programs in the field of Agronomy, Ecology and Biomass Engineering. Contents and teaching methods will be discussed and the experience from the lab practice where principles of *Sustainable and Green Chemistry* are applied will be presented. As a rule all students start from the Basics of Chemistry where they begin their studies with *Water* as the most familiar and important chemical compound for life on Earth: starting with explaining phases of matter, Lewis structures, polarity of water molecule, unusual water properties, aqueous solutions and solubility, ionic compounds in water, precipitation equilibrium, concentration of solutions, mass-mole-volume calculations, acid-base reaction of water, CO_2 cycle and water hardness, melting/freezing of water and aqueous solutions and then proceeding to chemical energetics, chemical equilibrium, electrochemistry, etc.

ASU also seeks to make safer, greener lab spaces while educating students by applying principles of Green Chemistry in the chemical labs. It is a different way of thinking about how chemistry experiments can be done in the lab. This means focusing on *Greener Experiments* (using alternative safer solvents, less reactive and less toxic reagents, renewable biomass-derived feedstock, or just applying micro-scale techniques), *Making the Lab More Efficient* (efficient usage of energy, water, e.g. proper operation of fume hoods, lab freezers, faucets; using water saving closed-loop cooling systems; economy of distilled water, etc.), *Improving Chemical Waste Procedures* (waste prevention/minimisation by reducing the amounts of chemicals used; recycling and re-use of solvents; proper disposal and treatment of chemical waste; detailed guidelines/instructions about waste disposal procedures; proper labelling of waste beakers/containers; lectures on waste disposal and prevention).

Keywords: Chemistry courses, Non-chemical programs, Laboratory practice, Green chemistry

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POSTER PRESENTATIONS: The contemporary chemistry teachers' education and the long-term professional development of chemistry teachers

PP-2. ***Teachers' learning experience as a key component in their professional training***, Elena Vysotskaya, Svetlana Khrebtova, Iya Rekhtman and Alexander Malin, Psychological Institute of the Russian Academy of Education, Moscow State Pedagogical University, Dept. of Org.Chemistry, Dept. of Science Education, Russian Federation, Introchemist association, USA

PP-3. ***Design of competencial teaching-learning sequences in pre-service secondary science teachers***, Fina Guitart and Marina Castells, University of Barcelona, Spain

PP-4. ***Guests of the chemistry didactics classes - a step towards planning interdisciplinary topics***, Dragica D. Trivic, Vesna D. Milanovic and Milanka Dzinovic, University of Belgrade, Serbia

PP-5. ***Formative and summative assessment in the programme for professional development of chemistry teachers***, Dragica D. Trivic, Biljana I. Tomasevic and Vesna D. Milanovic, University of Belgrade - Faculty of Chemistry, Serbia

PP-6. ***Research-based development of pre-service chemistry teachers' competencies for the implementation of the context-based approach in organic chemistry teaching***, Katarina Putica and Dragica D. Trivic, University of Belgrade - Faculty of Chemistry, Serbia

PP-7. ***Love through the glasses of a chemist: a fruitful topic for the contemporary life science students' and teachers' education?*** Milan R. Nikolić, University of Belgrade – Faculty of Chemistry, Serbia

PP-8. ***Action-research teacher training course for in-service chemistry teachers using a flipped classroom- IBSE approach***, Chiara Schettini, Rossana Galassi, Silvia Zamponi, Daniela Amendola, Donatella Bossoletti and Tiziana Pirani, School of Science and Technology, Chemistry Division, e-learning office, University of Camerino, Liceo scientifico Galilei Ancona, Italy

PP-9. ***Chemistry knowledge structure - views of chemistry teachers***, Aleksandar M. Đorđević¸ Dragica D. Trivic and Vesna D. Milanovic, University of Belgrade - Faculty of Chemistry, Serbia

PP-10. ***Chemistry teacher's in-service course based on student motivational, career-related context based scenarios***, Miia Rannikmäe and Jack Holbrook, University of Tartu, Tartu, Estonia

TEACHERS' LEARNING EXPERIENCE AS A KEY COMPONENT IN THEIR PROFESSIONAL TRAINING

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Teaching an innovative chemistry course is a challenge for any teacher, especially if the course is learner-centered, supports students' initiatives and successive model building, and allows students to plan simple experiments to verify their guesses (Vysotskaya *et al.*, 2015, 2016, 2016a). Both pre-service and in-service teachers need professional training before they can teach students in a new way. The main obstacles are a teacher-centered approach, the only one that is familiar and agrees with personal experience, and a set of basic chemistry concepts memorized in the past without sufficient understanding (Vysotskaya *et al.*, 2015a). We present the features of two training programs for pre-service and in-service chemistry teachers that let them rethink what teaching is about and how understandable chemistry can be. The programs immerse teachers into model building activity at the students' side to let them 1) feel real barriers impacting students' learning; 2) look at chemistry as a purposeful human activity that evolve over the centuries; and 3) realize the logic that stands behind its primary concepts and rules. Such an experience helps teachers to work more confidently and flexibly with all students' guesses, with no fear of wrong students' ideas, and to use even incorrect ones to verify, refine, or revise the model under discussion. After these programs teachers adopt the new way of teaching more easily, more often take next classes to develop their skills, and become mentors in such a program more rapidly. We believe that these long-term effects cover the time and efforts required by the training.

Keywords: Learner-centered approach, Model building, Teachers' training, Developmental instruction, Professional development

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DESIGN OF COMPETENCIAL TEACHING-LEARNING SEQUENCES IN PRE-SERVICE SECONDARY SCIENCE TEACHERS

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One of the challenges and key skills in teacher training is the elaboration of *teaching-learning sequences* (TLS) that students will implement at school in the traineeship.

Research in science teaching and curricula for competencies development has led to new directions in relation to the design of teaching and learning situations. Competency development is tied to functionality and transfer of knowledge (Gilbert *et al.*, 2011). The development of *competencial teaching and learning sequences* (cTLS) requires to decide what students have to learn, why they have to learn it, and how we want them to learn it, considering student characteristics (Couso, 2013).

For those reasons, the key point of cTLS is that they are led by a problem situation to solve, a decision to take or an action to do. In this communication we share, reflect and evaluate the module we have developed to guide pre-service secondary science teachers in the design of cTLS. The module lasted for 12 hours of attendance plus 12 hours of autonomous work. Students have analysed the sequence "The acoustic properties of materials" (Couso, 2009) to inspire them in the design of their own cTLS. In groups, students have created, as a final product, a cTLS shared with other colleagues. The sessions of the module start from the students' ideas, contrast and collectively build the theoretical framework, and work sharing between peers with the role of the teacher as a mentor and guide accompanying the process of change and improvement (Tigchelaar *et al*., 2004; Guitart *et al*., 2009). Methodology has been varied, participative, with individual reflection, discussion and sharing of ideas in small and large groups. It incorporates strategies of self-assessment and co-assessment between groups. Students have been protagonists of their own learning and teachers have helped them to reflect on and take control of the process of design of cTLS.

Evidences of the learning process of future teachers, as well as assessment questionnaire of the module were collected and analysed. The module has helped them in the appropriation of the fundamental ideas about cTLS and how to design and elaborate them.

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GUESTS OF THE CHEMISTRY DIDACTICS CLASSES - A STEP TOWARDS PLANNING INTERDISCIPLINARY TOPICS

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During the previous two decades we established the practice to invite the experts from different fields as guests of the *Chemistry Didactics* classes at the Faculty of Chemistry University of Belgrade. We believed that this practice would help students to develop their communication and collaborative skills with experts from other disciplines. Moreover, it helps them to think from different perspectives about topics that could be relevant for youth education, their future professional orientation, and society, and enables them to better prepare for the planning and realization of interdisciplinary approach in their future classrooms.

In this presentation we will describe a workshop which was realized in cooperation with geographers. This workshop encompassed the students, future chemistry teachers, at their final years of study. The workshop had several parts. An important part related to the production of questions which could be answered through the cooperation of chemists and geographers. After that the importance of these questions was discussed within the framework of individual, societal and vocational relevance (Eilks and Hofstein, 2015) related to the youth education and their future decision-making in everyday life, better integration into society and professional orientation. The final part was associated with the formulation of topic that could be realized by interdisciplinary approach.

This workshop can serve as a model of work for the future chemistry teachers, of how they can involve different specialists in their chemistry classes in order to make their lessons more relevant to youth.

Keywords: Chemistry teachers' education, Interdisciplinary approach, Workshop

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FORMATIVE AND SUMMATIVE ASSESSMENT IN THE PROGRAMME FOR PROFESSIONAL DEVELOPMENT OF CHEMISTRY TEACHERS

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Assessment as the important part of process of teaching and learning was the central theme of the two-day programme for professional development of chemistry teachers that was realized by the Serbian Chemical Society and the Faculty of Chemistry University of Belgrade. In 2016 the programme encompassed 30 chemistry teachers from primary and secondary schools. At the beginning we collected the data from the participants about their attitudes towards assessment and their usual practice by the questionnaire and group interviews (focus group interviews).

During the two days four workshops were organized. The structure of each workshop was the same and they included the introduction, group work and discussion of results of the work in groups. The first workshop was dedicated to the assessment as a support for chemistry learning. The second workshop was dedicated to the issue of how to harmonize the teaching and learning activities, formative and summative assessment, feedback from formative assessment and the criteria by which students are evaluated in the summative assessment. In the framework of the third workshop participants in groups estimated the validity of certain tasks for formative and summative assessment according to the curricula aims and the educational standards. In the fourth workshop the participants developed the tasks for monitoring students' progress towards certain educational standards.

The results of questionnaire and group interviews and the products of chemistry teachers' work in groups will be presented at the Conference.

Keywords: Professional development of chemistry teachers, Formative assessment, Summative assessment

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RESEARCH-BASED DEVELOPMENT OF PRE-SERVICE CHEMISTRY TEACHERS' COMPETENCIES FOR THE IMPLEMENTATION OF THE CONTEXT-BASED APPROACH IN ORGANIC CHEMISTRY TEACHING

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Research has shown that students across the world consider the organic chemistry curriculum to be abstract and difficult to understand (Jimoh, 2005; O'Dwyer and Childs, 2014). Context-based teaching approach represents an effective tool for promoting conceptual understanding and functionalization of organic chemistry knowledge (Schwartz-Bloom *et al*., 2011; Putica and Trivic, 2016), which is why it is important to develop pre-service chemistry teachers' competencies for its implementation in organic chemistry teaching. In accordance with this aim, four pre-service teachers at the Faculty of Chemistry, the University of Belgrade, developed their context-based organic chemistry teaching competencies by means of experimental research. Each pre-service teacher conducted an experiment that compared the effectiveness of the context-based and the traditional teaching approach when it comes to promoting conceptual understanding and functionalization of the selected organic chemistry content. Three of these experiments were conducted in grammar schools, two within the elaboration of the teaching topic *Carboxylic acids and their derivatives*, and the third one within the elaboration of the teaching topic *Alcohols*. The fourth experiment was conducted in an elementary school, within the elaboration of the teaching unit *Alkanes.* Within each of these experiments, the pre-service teachers developed context-based teaching materials for the students in the experimental group, the pre-test and the post-test. Unlike the pre-test which consisted of items that resembled regular textbook items, the post-test, which was used as an instrument for comparing the effectiveness of the two teaching approaches, consisted of items that required deep understanding and the application of the newly acquired organic chemistry knowledge in solving real-life problems. The results of all four experiments confirmed that the context-based teaching approach was more effective than the traditional approach in promoting students' conceptual understanding and functionalization of their knowledge. These findings also confirm that the research-based approach represents an effective tool for developing the pre-service chemistry teachers' competencies for the implementation of the context-based approach in organic chemistry teaching.

Keywords: Conceptual understanding and functionalization of organic chemistry knowledge, Context-based organic chemistry teaching, Research-based development of pre-service chemistry teachers' competencies.

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LOVE THROUGH THE GLASSES OF A CHEMIST: A FRUITFUL TOPIC FOR THE CONTEMPORARY LIFE SCIENCE STUDENTS' AND TEACHERS' EDUCATION?

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Chemistry is often called "the central science" pointing to its importance for other fields of science and everyday life. The author agrees that literally everything can be explained at the molecular level by chemical terms and concepts, even love! The most significant "molecules of love" are busy distinct chemical messengers: phenylethylamine (the Cupid of love), dopamine (the love drug), norepinephrine (the soldier of love), serotonin (the key *hormone of happiness)*, oxytocin (lion tamer), vasopressin (white knight of love) and testosterone (the king of love). Simultaneous changes in their content during the different (interconnected) stages of the relationship between partners (romance, attachment and lust), not only cause well-known symptoms of love "madness", but also prepare body and soul of men for the role of parents. Such comprehensive general content gives the lecturer the freedom to adapt to their listeners, given the differences in age, interests and previous life science knowledge. It allows stressing out a historical/cultural/religion insight into differences in the development and understanding of the term "love/eros": from "A kind of madness given to a man as a gift of God" (Plato) to the "scientific definition" of love as "The imbalance of the signal molecules in specific parts of the brain". Further, this is an exceptionally suitable model system for adopting the principles and concept of signal transduction mechanisms (e.g. importance of specific receptor-ligand interactions, or the interplay between various signal molecules and effectors) as a crucial part of regulation of the biochemical processes and life itself. Finally, the topic cannot be unattractive (who did not fall in love and had not been loved?) and enables full two-way communication in the classroom. If nothing else, it could help to better understand someone's personality and actions, especially in the sensitive period of puberty. From author's personal experiences, the feedback from the chemistry teachers and professionals, high school and bachelor students has so far been very encouraging.

Keywords: Chemistry teachers' education, Chemistry students' education, Interactive teaching strategies, Multidisciplinary approach

ACTION-RESEARCH TEACHER TRAINING COURSE FOR IN-SERVICE CHEMISTRY TEACHERS USING A FLIPPED CLASSROOM- IBSE APPROACH

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As a part of the PLS project (Scientific Degrees National Plan), the UNICAM Chemistry degree course has been holding training courses for the Teaching of Chemistry since 2010. Addressed to High School Science teachers of the Marche Region, the courses are in blended mode, with residential and online training on dedicated Moodle platform.

In the current academic year (2016/17), two Chemistry High School teachers have undertaken an action research experiment on the teaching of some chemical concepts, using the pedagogical model of the Flipped Classroom and the IBSE approach (Inquiry Based Science Education), with emphasis on the 5E Learning Cycle.

At the end of the training period, the teachers have experimented the activities with the students, following the five-phase sequence of Engage, Explore, Explain, Elaborate, Evaluate, making use of original interactive material developed by UNICAM lecturers.

The monitoring and evaluation have been carried out by questionnaires given to teachers and by analysing the products created by both teachers and students. The result analysis shows an overall benefit, both in terms of acquisition of the new teaching practice by teachers and skills acquired by pupils.

Keywords: In-service teachers, Action research, Flipped classroom, IBSE, Chemical concepts

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CHEMISTRY KNOWLEDGE STRUCTURE - VIEWS OF CHEMISTRY TEACHERS

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Modern society is characterized by rapid development in all spheres of human life. The development of education system should contribute to the development of societies and respond to all innovations placed by the industry. School has to adapt to the changeable demands of society and work on the development of positive students' attitudes towards science. In addition, schools should help students to develop effective strategies for science and chemistry learning.

The chemistry teachers are expected to find the easiest and the most effective way in which students could acquire new knowledge and skills. It is important that students have an opportunity to develop understanding of chemistry instead of using the rote learning. In addition, it is necessary that students understand the practical application of the studied content and in this way functional knowledge can be acquired. Thinking about connections between concepts in chemistry and other disciplines could improve students' knowledge and lead to increasing their motivation and finally to the formation of the functional knowledge.

The aim of this presentation is to show the structure of knowledge that chemistry teachers in Serbia expect their students to have when they finish primary or secondary school. In the questionnaire, a total of 120 teachers from primary and secondary schools in Serbia were asked to: 1) display the conceptual maps; 2) identify the most important chemical concepts; 3) point to the links between chemical concepts which they expect their students to learn. The results showed that teachers in primary and secondary schools use a very similar combination of concepts and identify them as key concepts for students' education in chemistry.

Keywords: Chemistry education, Conceptual maps, Chemistry teacher

CHEMISTRY TEACHER'S IN-SERVICE COURSE BASED ON STUDENT MOTIVATIONAL, CAREER-RELATED CONTEXT-BASED SCENARIOS

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A literature review by Potvin and Hasni (2014) has shown that society-oriented, context-based science education increases students' interest to choose science studies and science-related careers. Gilbert et al. (2011) argue that context-based education is meaningful when the context or application is within a real-life situation which is familiar to the students. Issues positively affecting student interest, motivation or attitudes provide role models for science and technology career orientations. Currently, in-service courses focus on developing and evaluating scenarios for chemistry and science in general learning environments where discussions on careers in research and chemical industry (in its wider meaning) are taken to be an integral part of science learning. The theoretical framework is linked with context-based teaching and supported by the theory of interest, motivation and relevance. The central concept is "scenario" which is defined as "a motivational student relevant construct, expressed in words and which might be illustrated/expanded by cartoons, videos, and/or power-point slides" (Holbrook and Rannikmäe, 2017). 56 chemistry and science teachers attend an in-service course in which scenarios developed by educators and students are introduced. In this course, teachers are asked to evaluate the scenarios using an instrument which includes items on knowledge, interest, career awareness and scenario-related attributes (Kotkas *et al*., 2016). Group discussions are conducted to find out the relationship between relevance, interest and motivation based on students' perceptions. Finally, teachers develop scenarios themselves and introduce these to the others during the in-service training. The effectiveness of the in-service course is discussed. This study is supported by the Horizon project, MultiCo.

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POSTER PRESENTATIONS: Use of ICT in the 3rd level of chemistry education

PP-11. ***Use of a touch screen app to increase student engagement in drug design***, Tess Phillips and Mike Edwards, Keele University, United Kingdom

PP-12. ***Jimp 2 software as a teaching tool: understanding orbitals using Fenskee-Hall method***, Dušan Ž. Veljković, Ivana S. Antonijević and Snežana D. Zarić, University of Belgrade - Faculty of Chemistry, Institute for Chemistry, Technology and Metallurgy, University of Belgrade, Serbia, Department of Chemistry, Texas A & M University at Qatar, Qatar

USE OF A TOUCH SCREEN APP TO INCREASE STUDENT ENGAGEMENT IN DRUG DESIGN

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iPad apps are typically intuitive and easy to use, making them student friendly, as students can master the interactions needed very quickly, reducing the level of distraction from employing new technology. Whilst iPad devices are expensive, we have found that using a small set of iPads in group activities provides a portable and effective solution enabling the use of technology in our teaching sessions.

An understanding of molecular properties is vital to the process of drug design, and Lipinski's (Lipinski *et al*., 1997) and Veber's rules (Veber *et al*., 2002) are routinely taught as a core aspect of any medicinal chemistry programme. However, students often have only a vague understanding of how a molecule's structure relates to key properties such as logP and polar surface area.

We have adopted the use of the Asteris app (http://www.asteris-app.com), which provides a visual and structure-based representation of molecular properties, in a series of enquiry led group exercises in our medicinal chemistry teaching. We will describe how we use the app to guide the students through tasks involving the optimisation of activity and pharmacokinetic properties based on molecular structures leading to an assessed open-ended drug design exercise.

We have found that the use of the iPads and Asteris app leads to increased student engagement with our sessions, and we have observed a deeper level of understanding in our students, evidenced by the conversations taking place during the sessions.

Keywords: Technology, iPad, app, Engagement, Group-work

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JIMP 2 SOFTWARE AS A TEACHING TOOL: UNDERSTANDING ORBITALS USING FENSKEE-HALL METHOD

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Teaching molecular orbital concept to undergraduate students is known to be very challenging; analysis of examination data for undergraduate students reveals that they do not have a clear understanding of the concepts of atomic and molecular orbitals (Tsaparlis, 1997). Understanding of the orbital concept has been subject to considerable debate and research (Barradas-Solas and Sánchez Gómez, 2014). One of teaching strategies to deal with this problem is based on usage of different quantum chemical software to calculate shape, energy and to visualize molecular orbitals. The main downside of this approach is the fact that quantum chemical calculations are often very time-consuming, especially in the case of molecules that contain transition metal atoms.

Fenske-Hall method is ab initio method mainly developed for molecular orbitals calculation of transition metal complexes and organometallic compounds (Hall and Fenske, 1972). It was shown that this method is very fast, and very accurate (results are similar to the results obtained by more rigorous and more time-consuming DFT methods).

Here we present a series of computational laboratory exercises using Fenske-Hall method incorporated in Jimp2 software to calculate and visualize both atomic and molecular orbitals. Students will learn how to calculate energy and visualize molecular orbitals of simple molecules. Exercises provide deeper insight into relationship between atomic and molecular orbitals with special emphasis on calculation of contribution of atomic orbitals in particular molecular orbital. Using results of Fenske-Hall calculations, students will construct molecular-orbital diagrams for simple molecules.

Keywords: Orbitals, Fenske-Hall method, Jimp 2

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POSTER PRESENTATIONS: Evaluation of learning outcomes and assessment related problems in HEIs

PP-13. ***Improvement of students' performance in a blended learning organic chemistry course by self-testing of reached study outcomes***, Priksane A., Logins J. and Klimenkovs I., University of Latvia, Latvia

IMPROVEMENT OF STUDENTS' PERFORMANCE IN A BLENDED LEARNING ORGANIC CHEMISTRY COURSE BY SELF-TESTING OF REACHED STUDY OUTCOMES

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Chemistry is an experimental science and often an approach of blended learning is used. In this research an organic chemistry delivery is based on a combination of face-to-face and online teaching and learning. The goal of the used approach is to promote the development of first year students' performance and learning skills by the understanding and evaluation of reached outcomes (Turunen and Byers, 2012). Different aspects of metacognition are incorporated in the study course. M. M. Cooper *et al*. described detailed assessment of metacognition use in chemistry (Cooper *et al*., 2008).

Therefore students are provided 1) with information about successful learning strategies, 2) with organic chemistry materials, where the main learning objectives and detailed outcomes are given for each topic. The corresponding multiple choice self-assessment tests are recommended as homework to follow students' activity and reached results of the selected topic. The objectives and outcomes of several laboratory exercises are developed together with students. Laboratory reports are evaluated as passed/failed, but gained level of knowledge, safety and practical skills are assessed by post-laboratory multiple choice computer tests in the classroom. Other assessment methods during seminars are based on traditional written midterm tests and a final exam.

The parallel groups of chemistry and non-chemistry students are observed. Students' background knowledge in organic chemistry is tested by the adapted methodology. Students' attitude and abilities to learn, quality of available materials and stepwise analyses of outcomes are evaluated using two students' surveys.

Students appreciate the systematic following to the outcomes during organic chemistry study process, involvement in the development of outcomes for laboratory exercises and self-evaluation tests.

Keywords: Organic chemistry, Online tests, Learning skills, Outcome based self-assessment

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POSTER PRESENTATIONS: The role of history of chemistry and philosophy of science in university education

PP-14. ***Understanding the development of teaching chemistry at University in Croatia***, Vanja Flegar, Suzana Inić and Jasna Jablan, Croatian Academy of Sciences and Arts, Croatia

PP-15. ***Development and application of chemical terminology in Croatian university chemistry of the early 20th century***, Vanja Flegar, Suzana Inić and Jasna Jablan, Croatian Academy of Sciences and Arts, Croatia

PP-16. ***Synthesis of students' conceptions about heat and temperature with historical confrontation***, Abdeljalil Métioui, Louis Trudel and Mireille Baulu MacWillie, Université du Québec à Montréal, Université d'Ottawa, Université Sainte-Anne Pointe de l'Église, Canada

PP-17. ***History of chemistry in the pre-service chemistry teachers education***, Dragica D. Trivic and Vesna D. Milanovic, University of Belgrade - Faculty of Chemistry, Serbia

UNDERSTANDING THE DEVELOPMENT OF TEACHING CHEMISTRY AT UNIVERSITY IN CROATIA

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Last year we marked the 140th anniversary of University Chemistry Education in Croatia. In this paper we will investigate the circumstances and the development of teaching chemistry at university level.

In the second half of the 19th century natural sciences in Croatia were developing more intensively than ever before. Chemistry in Croatia was introduced with inclusion of chemistry in the secondary schools curriculum in the middle of the 19th century, but not at higher level. The favourable circumstances in which chemistry in Croatia evolved was the renewal of the University of Zagreb (1874) and the founding of the Yugoslav Academy of Sciences and Arts in Zagreb (1866). The newly founded educational institutions in the year 1866 did not have at the beginning of their activity a sufficient number of teaching experts so scientists from other countries were sought to apply for these positions. So far there has been no detailed and overall study of these circumstances on the Croatian territory.

Our work will examine the circumstances related to the construction of the first Croatian Chemical Institute (Lučbeni zavod) which was used in experimental chemistry classes and also to conduct scientific research. The programs of teaching chemistry at that time at the universities in Europe were under a strong influence of J. Liebig. His teachings gave a special attention to the chemistry exercises during which the students participated in conducting chemical experiments. It will be shown how from its beginning chemistry education was connected with laboratory work and inquiry-based chemistry education was always stressed as a cornerstone of chemical education.

The paper will focus on investigating the first university textbooks and manuals in chemistry written in Croatian language and display the reception and transmission of the knowledge in the field of chemistry which the newly appointed professors passed on to students with a special interest to the periodic table of elements. The presented results of our investigations will give a contribution to understanding the development of European chemistry at the beginning of the nineteenth century since each university has its own specific history.

Keywords: University chemistry education, Inquiry-based chemistry education, University textbooks, Periodic table of elements, Croatia

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DEVELOPMENT AND APPLICATION OF CHEMICAL TERMINOLOGY IN CROATIAN UNIVERSITY CHEMISTRY OF THE EARLY 20th CENTURY

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The paper presents the development of chemical nomenclature in Croatia until the mid-20th century as well as its application in university teaching of chemistry. The base of chemical scientific terminology in Croatia was set by Bogoslav Šulek in his *Croatian-Italian-German dictionary of scientific terminology* (1874 *Hrvatsko-talijansko-njemačkog rječnika znanstvenoga nazivlja*), in which he sought to introduce a national expression for each chemical element or concept. In formulating the Croatian chemical terms Šulek relied on other Slavic nations such as the Czech chemical nomenclature, which had been more developed at that time. Julije Domac, a university professor of pharmacognosy with a doctorate in chemistry, in his high-school textbooks of organic chemistry (1893, sec. Ed. 1899, tr. Ed. 1906) and inorganic chemistry (1901) and in his university handbook of pharmacognosy (1899) along with Croatian nomenclature, accepted and used the international chemical nomenclature as well. Gustav Janeček, a chemistry professor at Zagreb University and the author of the first textbooks of chemistry (1879, 1883, 1890, 1907 and 1919) in his textbooks like Domac uses the Latin nomenclature in accordance with the European practice of that time but he also retains the original folk names of elements and compounds. With these efforts Domac and Janeček made it possible to break from the purely national phase in the development of chemical terminology in Croatia and start to shape a systematically Croatian chemical terminology in university chemistry in the late 19th and early 20th centuries.

Keywords: Croatian university chemistry development, Chemical nomenclature, Chemistry textbooks, Gustav Janeček, Julije Domac

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SYNTHESIS OF STUDENTS' CONCEPTIONS ABOUT HEAT AND TEMPERATURE WITH HISTORICAL CONFRONTATION

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More and more research stresses the need to introduce the history of chemistry in general chemistry courses (Niaz, 2005). Such an approach will value misconceptions developed by the student before teaching to interpret various phenomena related, for example, to the physical and chemical transformations of matter in everyday contexts. Indeed, some of these misconceptions were constructed in the past by well-known scientists. Also, many articles in didactics demonstrate the persistence of certain false conceptions, despite its teaching spread over several years (Chu *et al*., 2012). The aim of this communication is to present our analysis of the different theories related to heat and temperature concepts developed in history. To this end, we are going to illustrate the conceptual basis of these theories and show that they are in discontinuity at the epistemological level as viewed by the historian Kuhn. For example, the ideas developed by Lavoisier (1743-1794) on the material nature of heat (the caloric model) are in discontinuity with those developed by Rumford (1753-1814) where heat is not a material gas but "a kind of movement". It should be noted that Rumford's conception was accepted by the scientific community several years later despite its rationality. Thus, students are not different from scientists; they do not easily abandon their false conceptions despite formal education. In a teaching context, the process of conceptual change can be achieved by confronting students' conceptions with those developed by scientists of different periods.

Keywords: History, Heat, Temperature, Student, Conception

HISTORY OF CHEMISTRY IN THE PRE-SERVICE CHEMISTRY TEACHERS EDUCATION

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History of chemistry could be an important part of the curriculum for pre-service chemistry teachers' education. This allows them the deeper understanding of nature of science and scientific work, as well as to build a base for future planning the contextual approaches through which their school students could learn about nature of science. History of Chemistry is taught in the fourth year within the integrated academic studies curriculum (300 ECTS) for chemistry teachers' education at the Faculty of Chemistry University of Belgrade.

During the last three school years at the very beginning of the course of History of Chemistry the estimation of the knowledge of some historical facts, such as the scientific contribution of Robert Boyle, Henry Cavendish, Joseph Priestley, Antoine Lavoisier, John Dalton, Jöns Jacob Berzelius, Alessandro Volta, Michael Faraday was conducted. These scientists were chosen according to the previous analysis of the syllabuses of different secondary school and university chemistry and physics subjects. In this way, we were able to examine whether students pay attention to the work of scientists when they study various subjects from chemistry and physics domain. In addition, we asked the students whether they read texts from the history of science, what was the most important scientific discovery from their point of view, who was the most significant scientist in their opinion, whether they had a role model among scientists. Also, we asked students to describe an experiment that they knew from the history of science.

The obtained results showed that students, future chemistry teachers, have developed certain attitudes about chemistry as a science, but they possess little knowledge about the scientific work of scientists. These findings are later useful for the lessons and workshops planning within the course of history of chemistry.

Keywords: History of chemistry, Chemistry teacher education, Scientists

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POSTER PRESENTATIONS: Cultural heritage and chemistry education

PP-18. ***Chemical heritage in Sub-Saharan Africa and its significance for chemical education***, Liliana Mammino, University Of Venda, South Africa

CHEMICAL HERITAGE IN SUB-SAHARAN AFRICA AND ITS SIGNIFICANCE FOR CHEMICAL EDUCATION

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The nature of chemistry as the science of substances ensures its presence in all human communities, both in terms of practical usages and in terms of beliefs or interpretations regarding observed phenomena. Therefore, chemical heritage components are present in all cultures. Indigenous chemistry-related activities in Sub-Saharan Africa are numerous, including a variety of household practices (e.g. the brewing of plant materials to produce traditional drinks), the use of natural materials with the roles of paints and dyes, the production of metals from ores, and the broad diverse knowledge embedded in traditional medicine. While the last component is the object of intensive research throughout the continent because of the importance of the search for new biologically active compounds that may be relevant for drug development, other components are investigated less extensively.

The presentation highlights the expected benefits of the inclusion of relevant information about indigenous chemical heritage into chemical education programs in order to emphasize connections between the meaning of chemistry and the learners' cultural roots which may facilitate familiarity perceptions (Marasinghe, 2012; 2016). The discussion is substantiated by a number of illustrative examples, including examples from the chemical practices in the VhaVenda indigenous culture. The significance of learners' active involvement in the investigation of the chemical heritage of their communities is given particular attention, for its potential and verified benefits.

Keywords: African traditional cultures, chemical heritage, chemistry education, indigenous knowledge.

References:

Marasinghe, B. (2012). Presented at *12th Eurasia Conference on Chemical Sciences*, Corfu (Greece).

Marasinghe, B. (2016). Presented at *ICCE 2016*, Kuching (Malaysia).

WORKSHOPS

WS-1. ***How to prepare our students to enter job market?*** Iwona Maciejowska, Pascal Mimero, Faculty of Chemistry, Jagiellonian University, Poland, CESI Engineering School, Centre of Lyon, France

WS-2. ***Team based learning – take an academic, a class of students and scratch cards!*** Natalie Brown, Laura Hancock, Graeme R. Jones, Tess Phillips and Daniela Plana, School of Chemical and Physical Sciences, Lennard-Jones Laboratories, Keele University, United Kingdom

WS-3. ***A student designed curriculum: developing a project-based introductory chemistry laboratory course***, Vasiliki Lykourinou, Alejandro Rovira, Emily Navarette, John de la Parra, Northeastern University, United States

HOW TO PREPARE OUR STUDENTS TO ENTER JOB MARKET?

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"What can I do with my chemistry degree?"– it is a quite popular question among our graduates. More experienced alumni could answer "It is definitely too late to ask about it now". What can we as chemistry faculties do for our students to help them find a job adequate to competences we trained them for? First of all – to know potential employers' requirements (e.g. 21st century skills: Problem solving, Creativity, Analytic thinking, Collaboration, Communication, Ethics, Action, and Accountability [1]), and to share them between university teachers and students.

Fortunately, representations of employers (chemical and related industries, such as: agrochemical, metallurgical, petrochemical, pharmaceutical, plastics and polymers, cosmetics, food, painting & coating, etc. are more and more often invited to participate in various bodies responsible for developing chemistry study programmes. Another issue is a clear set of those competences – learning outcomes. Do our alumni know what they can do / are able to do?

Equally important is widening the horizons – how many of our students (and teachers) know that chemistry degrees would be useful not only in chemistry R&D laboratories or industries, but also in a job such as Chartered certified accountant, Environmental consultant, Higher education lecturer, Nuclear engineer, Patent attorney, Science writer, Secondary school teacher, Quality and Safety Manager, etc… ? [2]

More direct help is based on the preparation to go through the recruitment process (e.g. to know its steps, rules) – assistance provided by the faculty career service, or dedicated courses such as "Communication in Chemistry" (HEA) or "Alumni on the Labour market" (1st and 2nd cycle, Jagiellonian University in Kraków). Looking at the situation after the diploma, during the professional life, usually the Human Resources' Service of a company in charge of assisting the development of their employees; also Chemical Societies, Professional or Sectorial Unions, may also provide training programmes, targeting hard and soft skills.

After the university education graduation (Master 2, Engineer, Ph.D), there is a potential of evolution for chemists to enlarge their own perspectives right after the diploma in order to increase the opportunities on the job market with wider competences; but also after few years of professional activities, where it still could be possible for graduated chemists to reach a new career, entering managerial functions and responsibilities [3,4].

References:

[1] The Critical 21st Century Skills Every Student Needs and Why, by Lee Watanabe-Crockett(2016) https://globaldigitalcitizen.org/21st-century-skills-every-student-needs

[2] PROSPECTS, What can I do with my degree? https://www.prospects.ac.uk/careers-advice/what-can-i-do-with-my-degree/chemistry

[3] CPE Continuing Education Department, professional training programmes, www.cpe.fr

[4] CESI Engineering School, Continuing Education Programme and specialized post graduate masters, www.eicesi.fr& www.cpe-formation.fr

Am I ready to enter the job market? – try it at a workshop

For doctoral students we propose reviewing of their application documents: resume (CV) and letter of intention (related to one of chosen job offers proposed by us), as well as a simulation of job interview associated with that offer. Registration for a limited number of participants of such workshop will be open in the first day (June 28th) at the conference reception/registration desk.

TEAM BASED LEARNING – TAKE AN ACADEMIC, A CLASS OF STUDENTS AND SCRATCH CARDS!

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This workshop provides a hands-on introduction to Team Based Learning (TBL), described by Sweet as "a special form of collaborative learning using a specific sequence of individual work, group work and immediate feedback to create a motivational framework in which students increasingly hold each other accountable for coming to class prepared and contributing to discussion" (http://www.teambasedlearning.org/).

The best way to understand how TBL works is to experience it yourself, so in this session we will give you the opportunity to participate in a Chemistry TBL workshop.

TBL sessions begin with answering a set of multiple choice questions individually, before solving the same problems with your team and receiving immediate feedback on your answers using scratch cards. Finally, we will have you debating an application activity in your teams, which will then be reported simultaneously and discussed as a whole class.

We will end with a discussion of the pros and cons we have encountered using TBL, at Keele and Nanjing Xiaozhuang (China), in two formats; the first replaces both lectures and problem classes entirely (Organic Mechanisms), whilst the second provides a framework for full cohort problem classes (General and Organic Chemistry and Spectroscopy) (Jones and Hancock, 2015).

TBL teaches more than just Chemistry, it develops six of the competencies in the World Economic Forum's list of future skills; complex problem solving, critical thinking, people management, coordinating with others, judgement and decision making and negotiation.

The physical sciences have been late to the TBL party but we aim to demonstrate the power of this teaching method. TBL is an interesting teaching tool which will help develop the questioning and reasoning minds that we all strive for in our students by encouraging them to become active learners who support each other.

Keywords: Team based learning, Active learners

References:

Jones, G.R. and Hancock, L.M. (2015) Team Based Learning – a Scratch Approach to Large Group Problem Classes. *Journal of Academic Development and Education*, *4*, 98-103.

A STUDENT-DESIGNED CURRICULUM: DEVELOPING A PROJECT-BASED *INTRODUCTORY CHEMISTRY LABORATORY COURSE*

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The project, *Creating a student-developed, project-based introductory chemistry laboratory curriculum*, gives undergraduates an active role in their education by providing a setting in which they must design, optimize, and implement their own protocols. Stepping away from the "mix and record" methodology employed across universities for decades, the introductory chemistry laboratory course is designed to make students think critically through team-focused, research-based experimentation. Given only a goal, set materials, and a skeletal procedure, students must work as true scientists to determine testable variables, develop execution strategies, and debate their decisions against those of other teams. While environmental responsibility has been deemed a priority of the scientific community, it is missing from most modern day curricula. To address this gap between theory and practice, research from Northeastern and other universities that employ The Twelve Principles of Green Chemistry (Anastas and Warner, 1998) has been integrated into every learning module. To further reinforce this goal, students are required to apply green chemistry practices in the lab when performing reactions, toxicology, and waste. By overlaying student-created experiments with green chemistry practices, the course is conducive to the creation of a new generation of highly skilled, environmentally aware scientists. The final overarching component of this project is the creation of an organic turnover mechanism, in which students, after course completion, are invited to join the development team so they may further modify the existing curriculum. Students' perspectives, though often overlooked in academics, are a vital resource in the optimization of learning. Their unique viewpoints are crucial in evaluating new methodologies, experiments, and even new course topics. All in all, this project embodies experiential learning and is truly in the vanguard of education research at Northeastern, pushing students to become not only better learners rather than better students, but also to assume an ownership of their edification and that of their peers.

Keywords: Undergraduate chemistry curriculum, Green chemistry, Introductory chemistry

References:

Anastas, P.T. and Warner, J.C. (1998). *Green Chemistry: Theory and Practice*. New York, NY: Oxford University Press.

CHEMISTRY SHOW

CS-1. ***Connection between inquiry-based science education (IBSE) and education for sustainable development (ESD) – resources for science teachers*****,** Stevan Jokić and Ljiljana Jokić, Institute for Nuclear Sciences - Vinča, AKM Edukacija, Serbia

CONNECTION BETWEEN INQUIRY-BASED SCIENCE EDUCATION (IBSE) AND EDUCATION FOR SUSTAINABLE DEVELOPMENT (ESD) – RESOURCES FOR SCIENCE TEACHERS

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The SUSTAIN network (http://www.sustain-europe.eu/) has been created to develop significant connections between IBSE and ESD in order to create classroom activities and professional development resources for teachers and teachers educators presented in booklets Energy, Everyday objects and Food in ESD (translated also into the Serbian language http://rukautestu.vin.bg.ac.rs/?Page_Id=1206). We will present three Material Kits tested with more than 100 teachers of Chemistry and Physics at lower secondary schools and high schools within eight-hour workshops: 1. *What is the role of yeast in bread preparation?* Material: 3 plastic bottles, a plate, a plastic pipe, modelling clay, a matchbox, sugar, salt, water, yeast, a USB microscope. Teachers must show the existence of CO_2 and see yeast cells with a microscope. *2. What you can find in the milk?* Material: Milk, a plate, a hot plate, food colour, plastic dishes, iodine, meal, a USB microscope, water, baby powder, mirrors, a laser pointer… Teachers must show the existence of water and micelles in milk. 3. *Osmosis* Material: Potatoes, salt, physiological solution, water, a knife, a plate. Teachers must show the phenomenon of osmosis and connect it with the conservation of food.

Keywords: IBSE, ESD, Osmosis, Yeast, Milk

INDEX OF AUTHORS