Book of Abstracts

14th European Conference on Research in Chemical Education

2nd – 6th September 2018, Warsaw Poland

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„Educational innovations and teacher needs”

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Division of Chemical Education of European Association of Chemical Molecular Sciences (EuCheMS)

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Welcome to the 14th European Conference on Research in Chemical Education (14th ECRICE) that this time, is in Warsaw, Poland from September 2nd to September 6th 2018.

This event has been organized by Faculty of Chemistry University of Warsaw together with the Division of Chemical Education of European Association of Chemical Molecular Sciences (EuCheMS). Futhermore it sponsored by the Marshal of the Mazowieckie Voivodeship in Warsaw.

Current European Conference on Research in Chemical Education in Warsaw is a continuation of successful meetings in Barcelona (Spain, 2016), Jyväskylä, (Finland, 2014), Rome (Italy, 2012), Krakow (Poland 2010) and Istanbul, (Turkey, 2008) at top touristic places. We hope that Warsaw, lying in the heart of Poland, is picturesque enough to be considered as an attractive place to visit. Chemical Education is permanently undergoing developments which are also related to the changing role of Chemistry in today Society as well as the way this branch of science is noticed. Our goal has been to bring together scientists, teachers and students of different backgrounds that are active in various aspects of chemical education at every level of it – from primary school to postgraducate and PhD studies, as well as exchange experience in research in chemical education, promoting lifelong learning and enthusiasm for chemistry.

The ECRICE conference includes both invited and contributed papers on all aspects of chemistry education. Our goal has been to maintain high scientific standards of the European Conference on Research in Chemical Education series and, therefore, we are proud to have in Warsaw scientists who have distinguished themselves in their fields.

On behalf of the Conference Organizers I thank you for your attendant in the Conference

Enjoy your stay in Warsaw

Krzysztof Miecznikowski

Monday, September 3th, 2018

Phosphate Recovery as a Topic for Formal and Non-Formal Chemistry Education

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Phosphate rock is a resource of high economic importance and supply risk [1]. Phosphate has an essential role for plant growth and is used in nearly every fertilizer. The supply risk can be referred to the distribution of world's phosphate. Today, about three-quarters of the world's reserves are located in Morocco and in the areas of Western Sahara annexed by Morocco [2], and thus in an area of potential political unrest. Although the European Commission in 2014 announced phosphate rock in their list of critical raw materials, phosphates are a barely treated topic in chemistry education. In addition, almost all natural phosphate deposits are contaminated by heavy metals (e.g. cadmium or uranium). So, in recent years increasing attempts were made to close the phosphate cycle to protect the environment and to avoid potential occurring problems.

The poster describes a three-step educational initiative. First, learners at school explore the importance of phosphates via a digital learning environment created with the Prezi™ software. The learners then visit a non-formal university laboratory. Students get engaged with qualitative and quantitative analyses on phosphates. The students experience how phosphate can be recovered from wastewater and sludge. Experiments are adapted from real recovery processes currently under development in environmental technology. The learners compare the yields in recovery and decide which process works best. Back in school, the Prezi™ environment can be used to finally discuss the topic from a societal perspective. The learners are made familiar with the economic and geo-political aspects of this socio-scientific issue. The learning initiative aims at learners from secondary schools, student teachers, and vocational trainees in chemistry related professions.

The evaluation shows that the students like the learning environments, both the digital media and the laboratory program. Feedback indicates that they feel to have learned a lot on phosphate. The approach seems to be suitable for bringing this relevant and important topic into a broader public view.

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Session Teaching of Fundamentals in Chemistry

Studying Ordinary Teaching Practices about the Introduction of Chemical Formulas to Determine Teachers' Needs

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The symbolic language is considered as a meta level of knowledge [1]. It enables both to represent the model register and the reality-as-idealised [2, 3] and to act as a bridge between the macroscopic and submicroscopic levels [4]. We study the teaching of the introduction of chemical formulas in grade 8 in France to characterize what could be considered as ordinary teaching practices of the language of chemistry. Two volunteer teachers were filmed in their classroom and then were interviewed. First, we examined their teaching plan and their action logic to look for commonalities and differences, then we looked for the relationships the teachers made between the empirical register, the model register and the symbolic register in the taught content and in their discourses. Following the double didactic and ergonomic approach [5], we explored the cognitive and the mediative components of their practices. Therefore, in each session we noted the chemical contents taught, the work organisation (who does what? When? How?). Then we analysed their discourses regarding the registers of chemistry, the macroscopic and submicroscopic levels and examined whether the level of the symbolic language they used was specified. Finally, the interviews gave information enabling us to document the institutional, social and personal determinants of the practices [5]. During both sessions, the teachers made similar choices regarding the chemical contents taught and the work organisation. To justify the chemical formulas proposed to the students they relied on ball and stick models and seemed to be unable to provide any other justification. The submicroscopic model was the only register to be explicitly linked to the symbolic register. The discourse content did not enable the students to explicitly associate chemical names and formulas to both macroscopic and submicroscopic levels.

These teaching sessions can be considered as ordinary ones because the observed regularities are consistent with the institutional constraints and with the students' difficulties about using and interpreting the symbolic language previously noticed [1]. The institutional constraints and the lack of knowledge of some students' difficulties seem to be the source of the teachers' similar choices. We think that the observed teaching cannot enable the students to establish proper links between the different registers and levels of chemistry. From the interviews we assume that the teachers lack didactical tools. We designed a didactical tool dedicated to the teaching of this topic, which seems necessary.

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Teaching Chromatography in a Comprehensive Approach Which Lead to Operationnal Competencies

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Depending of the future position of chemistry students, analytical expert or occasional user, knowledge, skills and abilities in gas and liquid chromatographic techniques will differ a lot. So, pedagogical strategies can be very different and directed to one of the three extreme situations in relation to specific competencies:

- an application oriented approach, which consist to apply already defined methods
- a technological oriented approach dedicated to instrumentation maintenance
- a phenomenological oriented approach required to develop separation methods.

Of course, each scenario will never be exclusive, and curricula will be built with equilibrium between these three extreme situations depending of the targeted trainees, and skills to be developed. Whatever the position, it will always be necessary to adjust chromatographic methods to obtain a better separation, and in such situation, student will be facing an optimization problem.

The main issue encountered by students in the optimization process is related to the apparent multiplicity of relations/equations introduced during chromatographic lectures. These relations do not give clearly the casual links between operating parameters and quality parameters such as resolution and analysis time. If these links are necessary to efficiently optimize chromatographic separation, the way to build these links is a very difficult task to perform during the learning process. From 2009, we used a pedagogical approach based on “concept maps” and “cause and effect diagrams” in order to promote the development of skills related to chromatographic optimization. This strategy will be presented starting from the classical relationship of chromatography, reformulated by students in a global diagram. From this diagram, simulation of chromatography was built by the students and chromatograms can be visualized immediately to anticipate the effects of HPLC parameters. In such a way, optimization competencies were dramatically enhanced.

Experimental Cycles as Alternative Approach to Teaching the Topic Chemical Reactions

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The topic Chemical Reactions belongs to both the key and critical ones within the learning content at the lower secondary school level. As a solution, we proposed to include chemical experimental cycles into the instruction reflecting valid legislative documents and real teacher´s conditions. The experimental cycles are created as sets of simple, easily conducted experiments based on mutual change of chemical matters. Initial matter is a final product of the experimental cycle which; the cycle includes various types of chemical reactions (acid-base reactions, precipitating reactions etc.). The cycles are simple, or consisting from two or more separated ones. Various factors should be considered within the process of designing the cycles, colourful changes of the matters, which is the reason why cycles exploiting copper are so favourite. Other popular one are as follows: 1. Reaction of copper and nitric acid resulting in copper nitrate, 2. Reaction of cooper nitrate and sodium hydroxide resulting in cupric hydroxide, 3. Thermal dissociation of cupric hydroxide into cupric oxide, 4. Reaction of cupric oxide and sulphuric acid into copper sulphate, 5. Reaction of copper sulphate and zinc resulting in copper and zinc sulphate. However, some of these experiments do not meet safety requirements under the school conditions, which must be taken into consideration before conducting the experiments. Reflecting these pre-conditions, we proposed the calcium cycle, which is not accompanied by clear colourful changes but supported by single tests documenting the process of reaction. The calcium cycle consists of following steps: 1. Thermal decomposition of calcium carbonate resulting in calcium oxide, 2. Reaction of calcium oxide and water resulting in calcium hydroxide, 3. Reaction of calcium hydroxide and hydrochloric acid resulting in calcium chloride and 4. Reaction of calcium chloride and sodium carbonate resulting in calcium carbonate as the final product.

This experimental cycle works as a contribution to learning chemical transformations of matters reflecting lower safety risks. In conclusion, we would emphasize that except of the cycles representing chemical changes of inorganic matters, there exist cycles focusing on organic ones, or recycling wastes etc.

The proposed calcium cycle will be evaluated from the view of its exploitation in teaching practice reflecting the main intention – researching critical and key topics of the learning content in lower secondary chemistry curriculum.

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Principles of Semiotics Applied to the Analysis of Use and Interpretation of Lewis Structures by Chemistry Majors

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Chemistry is extraordinarily visual not only in the observation of phenomena but also in its use of a complex symbolic language. Chemical formulas or structures placed in chemical equations following basic, common syntactic rules convey vast amounts of information and, in fact, enable chemists to "see" what happens in a reaction vessel (even if hypothetically). Lewis structures [1] are the simplest model to get students started in the use of atoms and bonds—the basic semantic units of the chemical symbolic language—to efficiently communicate chemical information. Thus, competence in their use is essential to progress in the study of chemistry, much like competence in the language of instruction should be. Although proposals on how to teach/learn inert rules abound, [2,3] very scant research has been conducted in relation to Lewis structures. [4,5] Thus, experience shows Lewis structures are often taught similar to foreign languages where grammar rules void of meaning and application are memorised to never enable the learner to compose a simple sentence. The work presented here is part of a larger project that investigates the conceptualisation and use of Lewis Structures by novices and experts. The presumption is this knowledge will serve as platform to design instruction that will more effectively develop student competence in Lewis structures. This study analysed responses from more than 150 students from different levels to open-ended questions (textural evidence) aimed at elucidating their conceptualisation of Lewis structures. Additionally, they probed student perspectives on the role and use of Lewis structures in the practise of chemistry. This work aims at informing a pedagogical proposal to mediate the understanding and effective learning of Lewis structures based on research findings.

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The Concept of Chemical Reaction in Lower Secondary-School Chemistry

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It is known that the particle nature and atomic and molecular structure of matter cause great conceptual difficulties for students, leading to poor understanding [1]. To resolve these difficulties, Johnstone proposed the chemical triad (the chemistry triangle) for the teaching and learning of chemistry [2], which has served as a theoretical framework guiding research and practice in chemistry teaching. On the other hand, it is supported that the understanding of the concepts of chemical substance, chemical element, chemical compound, mixture, solution and chemical reaction cannot be effective without the use of particle models of matter [3, 4].

In this communication, we investigated whether (Greek) 8th-grade students had understood the concept of the chemical reaction. The main research questions were: (1) To what extent are students able to formulate definitions for chemical reactions? (2) Can they distinguish and justify on the basis of particulate models the concepts of chemical element, chemical compound, and mixture of elements and/or compounds? (3) Can they write down a chemical equation in symbolic form or with their atomic and molecular representation? (4) Can they understand and explain what happens during chemical reactions? (5) Do they understand the stoichiometry of chemical reactions? In addition, we investigated the effect of a teaching intervention, in which chemical reactions were taught after the introduction of the concepts of atoms, molecules, and their symbolism.

Regardless of the teaching intervention, the performance of students in a relevant test was low (35.6%), with the majority of students lacking an understansing of the concept of reaction. With respect to the teaching intervention, no statistically significant difference was detected in the test for the total sample between experimental and control group; however, further research and especially larger scale didactic interventions are needed to explore the issue of the teaching order.

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Challenging High Achieving Chemistry Students in New Zealand High Schools

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In 2004, the National Certificate for Education Achievement (NCEA), was introduced as the main national qualification for New Zealand High School students. The qualification is based on assessment standards, known as achievement standard, that each have a defined credit value. These standards describe what students must know or do to achieve credits. They are used to assess different areas of knowledge and skills at the three levels of NCEA. Achievement standards are either assessed internally by teachers during the year or the standard is assessed externally, generally through an examination at the end of the year. For each standard, there are three possible levels of achievement, achieved, merit and excellence. [1] In a subject such as Chemistry, the taxonomy of “describe, explain, apply” is mostly used to differentiate the three levels of achievement.[2] In external examinations, around 12% of students will gain achievement with excellence. In the early days of the new qualification, teaching for excellence was particularly challenging for chemistry teachers as previous examinations had mostly focused on short answer questions. Alongside the new qualification, high achieving students were also given the option to take examinations for the New Zealand Scholarship with top candidates receiving monetary rewards. In most subjects, including Chemistry, this involves a three hour examination assessed against a ‘scholarship standard’. While the syllabus for this examination is the same as for NCEA, scholarship candidates are expected to demonstrate “high-level critical thinking, abstraction and generalisation, and to integrate, synthesise and apply knowledge, skills, understanding and ideas to complex situations”. [3] Writing examination questions and preparing students for such an examination has been particularly challenging in chemistry, where students need to develop and use skills beyond those expected for their NCEA assessments, while not extending their knowledge base. As a result, a unique style of examination has evolved resulting in new opportunities to challenge and extend the skills of our top students.

This presentation will share some of the challenges of this examination for examiners, teachers and students.

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Language-Related Difficulties and Quantum Chemistry Learning

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Language is the most fundamental communication tool. Inadequate language mastery limits communication efficiency. When the inadequacies are serious, communication may fail its purpose. Teaching and learning rely primarily on communication and their efficiency and quality decrease with decrease in language mastery. Many studies have been devoted to the importance of language mastery in the teaching and learning process [e.g. 1,2] and to the additional difficulties inherent in second language instruction [e.g., 3].

The presentation focuses on the limitations that inadequate language mastery poses to conceptual understanding within a quantum chemistry course. The conceptual demands of this course require good language mastery levels and, therefore, the impact of inadequate language mastery is particularly heavy. A specific study was carried out within the quantum chemistry course (first year of postgraduate level) at the University of Venda. Due to historical and sociological reason, most students experience heavy challenges with language mastery, whose impact is enormously increased by the second-language-instruction situation. The study utilized students' works as primary source of information, complemented by in-class interactions and by occasional informal interviews. Error analysis was selected as the main investigation approach, with the objective of identifying language-related causes or components in students' errors. The study was repeated for many year, as it was primarily meant to enable better addressing of students' difficulties within the course, according to an action research perspective. The observations show decreasing efficiency of the learning process as the learners' language mastery level kept decreasing from year to year. The results thus confirm the essential role of language mastery for effective learning, and point to the need of interventions aimed at ensuring adequate development of learners' language mastery since early stages of instruction. Furthermore, the results highlight the specific difficulties of second language instruction in relation to conceptually demanding areas, thus contributing to stress the importance of mother tongue instruction for effective science learning.

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Novel Teaching Methods

Identification of Strategies Used by Lower-secondary School Students Solving Chemistry Problem-tasks

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The paper represents selected results of a qualitative study focused on the strategies used by lower secondary school students when solving chemistry problem tasks. Altogether 157 9th graders from four different elementary schools in Prague were given a test consisting of a set of chemistry problem tasks taken from Educational Standards [1] - an appendix to the national curriculum. Out of these students, 16 were selected for the study based on their test results (average results). These students were individually given a second set of problem tasks of a similar difficulty and were asked to solve them. A researcher using the Think Aloud method [2] was present.

The results show that some results can be categorized as "false positive". In case only correct answers supported by logical thinking and knowledge were taken into account, the results of the tests would be considerably lower. This study enables characterization of so called "supporting strategies" as well as "limiting strategies". Focusing on these in education when working with learning tasks (opposite to the testing tasks) could lead to improvement of students problem-solving skills. This work therefore contributes to a very interesting field with respect to scientific literacy and overall school success.

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Gamification at Lectures on General Chemistry

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Traditionally, lectures and labs dominate teaching in chemistry at the university level. However, the use of traditional lectures carries with it 2 dangers. The first is that the lectures are limited in their effectiveness of conveying knowledge, since students are passive participants. For some students the lecture may be too easy so they bored. However, for some students the lecture may be too difficult - which discourages them from further learning. To transform lectures of chemical into an active learning environment, we can change the form of the lectures [1], and we can offer the students new methods to learning. During the classes, students used computer simulations to understand problems and they used games to practice practical skills. The element of gamification was also used to exam the students'. This is in line with the contemporary trends in the use of gamification and simulation in university education [2, 3, 4]. The final version of the general and analytical chemistry lecture for students of the "Biology with chemistry teaching" course was developed in the academic year 2016/2017. The lecture contained elements of gamification and was largely based on students' independent work. At the end of a series of lectures, in 2017, the test was conducted that evaluated the new method of teaching. The results obtained were compared with the results of the surveyed students from 2014, when the analogous lecture was conducted using traditional methods. Both groups answered 4 questions (Likert scale). To the question: Lectures were too difficult for me (1) ... for easy (5) average of the experimental group's response was 3.3 and the control group was 2.4. To the question: Lectures were too fast (1) ... too slow (5) average of the experimental group's response was 3.1 and the control group was 2.3. To the question: I understood in the class: nothing (1) ... all (5) average of the experimental group's response was 3.9 and the control group was 3.0. General assessment of classes (1-5) was also better in experimental group (4.3) then control class (3.6) All students from the experimental group stated that they prefer a lecture containing elements of gamification, even though such a form of lecture requires them to be more active. Thus, it can be stated that the change of the traditional lecture into active classes containing elements of the game was successful.

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Detective Story – a Way of Motivation in Chemistry Laboratory Course?

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Recently, in the Czech Republic, chemistry education suffers from lack of interest of primary as well as secondary school students and chemistry as subject belongs to the least favorite subjects at all. There are many reasons for this situation, for example overly theoretical lessons, lack of laboratory courses and practical work, in some cases negative attitudes of society to chemistry and, to some extent, the nature of chemistry which is considered to be abstract and complex science. As a result, chemistry is sometimes presented and consequently considered to be non-useful and/or dangerous field. Hence, to support the chemistry education, it is necessary to show the pupils that chemistry is very important and useful for themselves and the society as well through an implementation of motivating elements into the educational process (didactic sequence). Suitable motivation can simplify the educational process, it can involve pupils in studied phenomena, support the knowledge retention, etc. Basic knowledge related to motivation in case of some specific areas of education can help to make education more effective and interesting. However, there is a question which motivating elements can be beneficial having an appropriate motivational effect. With respect to that, a simple application "Cases of detective Kulich", which combines some selected educational content with motivational elements, has been developed in cooperation with Science in agency for Android-based 10" tablets and it is available in Czech Google Play store. The possible motivation is implemented through a "mystery" of detective story of a murder of Mr. Urvinitka. Pupil acts as an assistant of despotic investigator Kulich, who does not believe in modern forensic methods of investigation and relies more on his own experience. During narration of the story, the pupil-assistant presents to detective Kulich seven scientific methods (conductivity measurement, fingerprints collection, blood detection and blood groups identification, spectroscopy measurements, isolation and detection of DNA and evidence of smokers) and the theories behind to reveal the murderer from selection of suspects. The story should show to pupils that chemistry is the key factor in solution of the case to emphasize its importance.

In this contribution, we focus on evaluation of motivational orientations of pupils participating in a lab course conducted by the mentioned application. To evaluate the motivational orientations of students in the laboratory course, we used two questionnaires filled in by pupils based on two tools: (i) Motivated Strategies for Learning Questionnaire (MSLQ) and (ii) Intrinsic Motivation Inventory (IMI). The results showed that the story provided motivational effect, especially for pupils with lower intrinsic motivation, which demonstrates suitability of implementation of "mysterious" motivational elements in chemistry education and quality of the story and approach employed for development of the application.

Chemistry in a Primary School: Storytelling and Hand-On Activities about Water

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The combination of hands-on activities and storytelling has been considered a successful way to help young children to elaborate meaningful links between the theoretical knowledge and empirical evidence [1]. Based on a book we wrote, "Storytelling with chemistry" [2] we developed a set of activities aimed to introduce primary students to chemistry. The activities involved 38 primary students from a school in the North of Portugal. All their answers and notes were taken in a kind of lab notebook. We used a free association task to collect at least three words or ideas that they associated to water before and after the story has been told. Using props the story "Aitch-two-o: a drop of water" which revolves about the properties and the chemical composition of the water was told. Then, we carried out six hands-on activities in which water had a central role tied with the story: pH indicators, surface tension, supersaturated solution, flammable liquids, humidity, redox reaction. During the hands-on activities students were asked to take note about what they were observing, doing and thinking. They were challenged to make predictions, compare them with the results and explain the phenomena that they observed. Preliminary results revealed that representations evolved after listening to the story. Before the storytelling, words reported in the association task referred by three or more participants were linked to the liquid state of water in the nature (rivers, sea) and physiological needs (drinking and thirst), one exception being the reference to the chemical formula of water. After the storytelling, words reported to the three states of water in a reified way (ice, vapor, clouds and hail) but also to their scientific names (solid, gaseous and liquid). They also referred chemical elements: oxygen and hydrogen. Only a few words were evoked both before and after the storytelling (rivers, rain and liquid). Students were highly engaged in the hands-on activities(e.g., using the dropper and counting aloud the drops), showing surprise when they saw changes of colour and states. Nonetheless, some issues were observed. In the surface tension activity, students failed to predict what would happen to the aluminum rings dropped on the water, being questionable if they realized the differences between surface tension and buoyancy. In the supersaturated solution activity, 47% of students did not correctly integrate dissonant tactile and visual observations. In the flammable liquids activity, 16% of students thought that were actually observing "burning water" and after listening to the scientific explanation still 26% did not correctly understand the phenomenon. Students' oral participation suggested that they could not easily identify the causal relationship among the colour change, humidity and temperature. In the redox reaction activity, issues about the differentiation between water and aqueous solutions came up, as only 10% of students thought the mixture used in the experiment contained water. This ongoing research emphasizes the need to further improve the storytelling and the activities in order to better communicate chemistry to a young audience attending not only their cognitive skills, social representations, context but also to the very own specificities of this science.

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Application Interactive Methods and Technologies of Teaching Chemistry at the ISCED 2

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The current chemistry education is solving problems related to determining the subject matter and education strategy that would correspond to the current educational demands. The main demands are that the subject matter should be current, connected to practice, environmentalism and other aspects of the current life, and it should also activate educational strategies related to the interest and motivation of the students [1]. One of the options fulfilling these requirements is the application of different interactive methods related to the use of Information and Communication Technology (ICT).

Therefore, our goal is to create and verify an interactive chemistry course for lower secondary schools based on the characteristics of interactive, ICT-connected education. This work is topical because of the current shortage of interactive chemistry courses.

The first stage of our work consisted of an analysis of educational content. The review of interactive methods of teaching, possibilities and practical value of these methods in the educational system are considered in works [2-5]. Currently, ICT is able to increase motivation, promote personalized learning and stimulate interaction between teachers and students [6-7]. We have presented some of the developed methodological options, which illustrate the ability to use interactive methods to increase cognitive activity of students and the effectiveness of the learning process using ICT.

In the second stage of our work, we developed interactive teaching materials for chemistry lessons with embedded interactive training methods for lower secondary schools.

In the next stage, all prepared materials will be verified and eventually adapted into the final form for use in chemistry teaching at ISCED 2.

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Flipped Learning as a New Approach for University Organic Chemistry

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Flipped learning approaches have emerged since the beginning of the 21st century to make students' learning environments more active and thereby improve learning outcomes as well as student engagement [1]. In the US, several flipped projects have focused on university chemistry courses, normally the student groups are large, from hundreds up to thousands of students [2], while some research also is found on smaller groups [3]. Here we study an organic chemistry university course both quantitatively and qualitatively during two years when changing from a more traditional teaching method to a new pedagogical approach (i.e., flipped learning), for empirical data see Table 1. In Sweden, flipped learning approaches are uncommon compared to the US and a Swedish university chemistry department had intentions improve students' learning outcomes and increase students' engagement in chemistry. The organic course has been perceived difficult and, according to previous course evaluations, also been ascribed as having bad quality in general. Therefore, a change was requested both from students and teachers.

Table 1. Empirical data in the study.

	Year 1	Year 2
Students (n)	36	35
Survey 1 – 2 – 3 (n)	33 – 23 – 20	32 – 25 – 26
Interviews (n)	7	11
Observations (n)	5	4

From the empirical data we will elaborate on students' opinions when meeting a new teaching and learning approach. Students' challenges with the organic chemistry course are discussed relating to their opinions about chemistry in general and flipped learning in specific. How students used the different learning material and how they made use of each other through peer interaction when solving problems in class will be discussed according to both constructivist and socio-cultural perspectives. Furthermore, students' own perception of how they used the course material related to an exact analysis of how the material actually was adapted will be presented together to explore how flipped learning have been applied within the course.

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The Effectiveness of Implementing Career-Related and Scenario-Driven Teaching Modules in Teaching Chemistry

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The lack of students' interest towards science careers is a well-known problem worldwide. Research has shown that students' awareness about science-related careers is insufficient.This proposal is targeted towards the use of contexts and related scenarios, which interest young people and are intended to orient them towards science studies as well as raising awareness of science-related careers. A scenario is defined as "a motivational, student relevant construct, expressed in words and which might be illustrated/expanded by cartoons, videos, and/or power-point. The scenario is intended as a motivational start for the learning, whilst further learning includes discussions on careers in research and industry -in the science education. The theoretical framework is linked with context-based teaching and supported by theories of interest, motivation and relevance. The classroom environment is heavily built on social constructivism, appearing at two levels; learning and teaching. Within the EC project MultiCo, students and educators from 5 countries (Finland, Estonia, Germany, Cyprus, United Kingdom) developed student relevant scenarios, which were evaluated by lower secondary students. The evaluation instrument included items on knowledge and value triggered interest, career awareness, scenario-related attributes and open-ended questions, to establish the relationship between relevance, interest and motivation from the students' perspective. Based on students' answers, findings indicated that students feel it is difficult to link motivational scenarios with acquiring new science knowledge and therefore scenarios, even those of interest to students, cannot stand alone. Teacher's guidance to change students' perception to learn is also needed. However, students liked scenarios which were created by themselves, although they evaluated teacher-created scenarios to be easier to follow and gain career-related aspects. Students` answers varied between the participating countries, but tended to be similar within a country.

74 grade 7 students, from 3 schools from Estonia, participated in this longitudinal study over a 2,5 year intervention period. During the intervention, 4 scenarios, highly evaluated by students, were used as the initiator for chemistry learning. Students` chemistry learning took place during the following 4-5 lessons, designed by chemistry teachers to meet the curriculum goals. Chemistry teachers met on a regular basis, prior to the classroom intervention, enabling them to follow the same design of the lessons. Besides practical activities in the classroom and meeting with experts from different careers, students' chemistry learning included visits to a famous international beer and soft drinks factory, where they were introduced to the process by which lemonade and beer was produced, starting from the raw products, development of the economic technologies, quality control and advertising new products to the public. Students were encouraged to ask any questions they wished and make personal contacts with employees of the factory during the visit and, if necessary, afterwards. The effectiveness of the longitudinal study was determined using four types of instruments which determined: a) students awareness about science related careers, their future career aspirations and attitudes towards chemistry/ science learning as pre and post questionnaire; b) students opinions about each scenario and teaching after every intervention; c) cognitive test in chemistry, reflecting curriculum content-related learning; d) students` interviews to validate outcomes.

Analytical procedures used were Correlation and factor analysis. Models describing students` learning in chemistry and its relationship with students' careers awareness were created. The outcomes were validated using international experts.

Teaching Students with Special Needs

The Unique Role of National and International Chemistry Olympiads in Chemistry Education

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In order to optimize the effectiveness of chemistry teaching, various methods of education have been proposed for several last decades. In spite of that, for 64 years in Poland and for 50 years at the international level, Chemistry Olympiads are being organized as the most powerful method of finding and developing young talents among the secondary school students. The intellectual ability of those students significantly exceeds that of regular ones. In consequence, the Olympiads develop the exclusive circle of young, talented people who expect highest standards of teaching and professional knowledge from their mentors. In the presentation, the history of Polish and International Chemistry Olympiads will be outlined and it will be shown that the general concept of the competition did not essentially changed during these years, while the level of difficulty of the tasks increased enormously. Thus, Chemistry Olympiads appear to be both traditional and very stable method of creative teaching at the highest and icreasing essential level. The genius of the idea of the Chemistry Olympiad, of course, applies to all subject Olympiads.

Young Chemist University-Filling the Gap Between Secondary School and University

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No doubt, there is a significant gap between the secondary school and university chemical education. Most of the first-year students find that their college courses are fundamentally different from their high school projects. Education on an academic level requires from the students far more independence, creativity, activity, hard literature work, capabilities of designing and performing experiments, analysis and interpretation of results, drawing logical conclusions based on evidences and solving complex chemical problems. University chemical education is also associated with finding a balance between individuality and the team work, between leadership and subordination. Most of the above problems are hardly addressed at the secondary schools so pupils very often choose academic education without adequate prior knowledge of academical expectations and practices. In order to change this, at the Faculty of Chemistry of the University of Warsaw we have launched an „Young Chemist University" programme, within which secondary school pupils perform small research projects at the Faculty of Chemistry. The aim of his project is to improve acquaintance of secondary school pupils with university activities at the Faculty of Chemistry and to bring the university chemistry into the school pupils' lives. „The Young Chemist University" (in Polish UMC) programme is addressed to young chemistry enthusiasts, those pupils who are ready to actively participate in theoretical and experimental chemical courses and those who want to connect their professional future with this field of science. We offer students an opportunity to perform individual research projects which had been designed by active researchers from the Faculty. Our offer consists of ca. 50 projects created on the basis of scientific research currently conducted in our laboratories. The projects are related to a vast range of topics ranging from biochemistry and chemical synthesis, through projects related to physical chemistry and structural analysis, up to research in quantum chemistry. Pupils have a chance to participate in real research activities, learn its components and see real departmental life. We have also successfully applied to the National Centre for Research and Development in order to get financial support for the project entitled: "Young Chemist University" (grant application number: POWR.03.01.00-00-U150/17). In fact the application contains several activities aiming at the primary and secondary school pupils. In this contribution details of our project including the project idea and organization, pupils recruiting procedure, examples of projects accomplished, details of reporting and closure of the first edition of UMC will be presented. The participants of this programme have the opportunity to develop their passions and expand their knowledge under the guidance of outstanding chemists and their PhD students. We will also present details of our activities enumerated in our successful grant application. Like all transitional levels, the project poses challenges of learning new things which may not be rooted in prior instructions or learning experience.

Understanding the Special Needs of First Year University Students

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Students making the transition from high school to university have challenges to face on a number of different levels. For many they are living away from home for the first time, the style of teaching, learning expectations and assessments are different and there is much more freedom of choice about how to divide their time between study and other activities. The biggest challenge anticipated by students in our institution is about how they will manage their time. The pattern of attendance at lectures and other non-compulsory classes during the teaching weeks tends to reflect poor time management skills

In order to gather information about student learning behaviour in our first year chemistry classes, we collected data from a number of different sources. We have monitored lecture attendance, we have surveyed students about their chemistry learning activities and their perception of how these affect their learning gains, we have surveyed students about their lecture expectations, attendance and attitude, and we have looked at the data from the learning management system about student engagement with resources over time. As patterns of student behaviour emerge, we are be able to make better informed choices about the timing and nature of the assessment tasks. Student choice of learning resources, alongside survey and focus group comments provides insight into the transition from high school to university learning expectations.

Transition pedagogy principles for first year of university study (Kift, Nelson & Clarke,ZS 2010) suggest that curriculum design should take into account students' background, needs and patterns of study. At high school, patterns of study are developed in response to the National assessment regime that dominates teaching and learning at this stage of schooling. By investigating patterns of student behaviour throughout the first year of university study, we will better understand the way they go about their learning and hence be able to design curricula to facilitate successful transition through their first year of study.

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On Developing the Research Capabilities of Youth - Pilot Chemical Classes for Students Aged 11-12 at the Faculty of Chemistry of the University of Warsaw

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Since 70 years, students in Poland have started to study chemistry at the age of 13-14 years old [1], when the direction of their interests is usually quite clear, as indicated by the analysis [2], [3]. These studies have led us to try to answer the following questions: Would it be possible to carry out chemical classes corresponding to the initial chemistry teaching program with younger students than 13 years old? At what students' age invite them to participate in classes? How should these activities look like? How would those activities affect students' interests?

In 2017/2018 school year a pilot program entitled "We Discover Chemistry Paths Like Maria Skłodowska - Curie" (polish: Odkrywamy Ścieżki Chemii jak Maria Skłodowska - Curie) (see Project logo - Fig. 1) was conducted for nearly one hundred students aged 11-12 from Warsaw (project co-financed by Warsaw Education Office).

Fig. 1.Project logo

Classes were held on Saturdays and lasted 25 hours (5 consecutive Saturdays for 5 hours). At the very beginning of the project students became chemical elements during the classes, signing their symbols. They actively participated in lectures with a demonstration of experiments, laboratory classes and chemical games. Students wrote short tests of knowledge and chemical skills on each class. The whole cycle ended with the presentation of the properties of the above mentioned selected element. The students were very eager to participate in the classes, and the parents were surprised and delighted with the interest shown by their children.

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How Can We Prepare Our Students for Work with Disabled Teenage at Primary and High School?

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Many aspects of functioning of a teenage with disabilities at primary and high school should be discussed with students during the lectures at universities. Appropriate approach to this teenage is a prerequisite for successful learning. The psychological knowledge, understanding the mechanisms of behavior of a single student and their interaction in a peer group is as important as the chemical knowledge. The chemists are not the psychologists and the question is how to give them useful and efficient tools to work with adolescent?

The presentation will be devoted to the characterization (from teachers point of view) of problematic situations among young people e.g. exclusion form peer group. Particular emphasis will be placed on disabled teenager and the education of our master students to open their minds on new solutions for the well-known chemical experiments. How can we prepare in the most effective way our students for solving scientific problems during working with the visually impaired and the blind?

During the "Practices in psychology" our students adapt the educational materials to the needs of visually impaired students and carry out the chemical experiments themselves with switching off the sense of sight. They have to solve typical chemical problems using standard chemical methods like preparation of the salts solutions, weighting of the salts, volumetric measurements, heating, precipitating of the deposit, filtrating. The special attention during the experimental chemistry lesson is paid to the safety.

After the series of introductory meetings, our students assist the blind high school students in carrying out the chemical experiments. A summary on the effectiveness of these activities will be presented at the end of the presentation.

Symposium in Memory of Professor Alex H. Johnstone

Organizer: Georgios Tsaparlis

Alex Johnstone's Stars to Steer by in Chemistry Education

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Alex H. Johnstone laid the foundations for chemistry education both in terms of its subject matter and of research methodologies [1], so he is quite rightly considered to be one of the 'founding fathers' of the field of chemistry education research. For Johnstone, harmonization of a logical approach to the subject matter with a psychological one was necessary and this could only be provided through educational research. Johnstone's famous triangle distinguishing macroscopic, submicroscopic, and symbolic chemistry has had, and continues to have, a great influence on chemistry education. In addition, he has made great contributions through his work on: (i) the effect of working memory and information processing on students' science problem solving, (ii) student and teacher assessment and (iii) laboratory work. Finally, he put his ideas and knowledge about chemistry curricula and learning to the test, by co-authoring two unique and outstanding books, one for university and one for school level. The contributors to this symposium are all connected in different ways with Johnstone and his work.

Norman Reid did his PhD with Johnstone and was his closest associate and successor as director of the Centre of Science Education at the University of Glasgow. Unfortunately, he is unable to attend this conference, so his presentation will be in video format highlighting Johnstone's great contributions, and, as he states the video is "not designed as simply history".

Tina Overton will review her team's research that has been particularly influenced by Alex's work in the area of problem solving. In particular, she will discuss algorithmic, conceptual and open-ended problems in a chemistry context and how various cognitive factors influence success and consider "the journey from novice to expert problem solver".

Dimitris Stamovlasis will initiate us into a methodological perspective for education research, which is based on the theory of Complex Dynamical Systems (CDS), where nonlinearity is a likely behavioral feature. Sudden changes, such as unexpected failures, for instance in chemistry problem solving, can be captured and understood by a catastrophe model. He has applied this approach to consider empirical data that can be interpreted using Johnstone's working-memory overload phenomenon.

David Read never actually met Alex, but Johnstone's work has had an immense impact on him, and over the last few years, he has been working hard to raise awareness of Johnstone's innovations amongst schoolteachers, so they are able to provide better support to students struggling to make sense of chemistry.

Finally, I had the privilege, in 1990, to spend a sabbatical semester with Alex in Glasgow. This led on to an invaluable collaboration with him ever since, and a very large number of my own studies have been influenced by his three-level structure of chemistry and his information processing model of problem solving. In the symposium, I will review some of these studies.

A Tribute to Professor Alex H Johnstone

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The aim of this presentation is to give a very brief overview of the career of the late Professor Alex H Johnstone (1930-2017) who taught inorganic chemistry at the University of Glasgow and was the Director of the Centre for Science Education at that university. His international impact in the field of chemistry education is perhaps unparalleled and many of the modern developments seen today owe much to his brilliant research as well as his great skill as a teacher and communicator.

He started his career in the 1950s with over a decade of school teaching but, during this time, he contributed considerably to a new chemistry curriculum at school level which transformed Scottish chemistry education. Following the publication of a set of school textbooks, he moved to the University of Glasgow to undertake rigorous research to explore how this highly successful new curriculum was developing and to identify any problems that learners were experiencing.

He supervised large numbers of PhD students who followed up his initial findings. This led in due course to the great breakthrough in the early 1980s which laid the foundations of our entire understanding on how learners come to understand conceptual ideas. Later students then applied the findings, bringing about transformations in lecture learning, laboratory learning and group work problem solving. As part of this, he led a team in the university in setting up a new first year undergraduate course, based on the research findings. Later research revealed the quite remarkable benefits for the students who followed this course.

His greatest contributions relate to the way we now understand the key role of working memory in all learning, his development of simple models to guide teachers (including his famous triangle model and his problem-solving analysis), a vast range of publications in primary journals as well as numerous monographs and reviews. He co-wrote a remarkable university text on introductory thermodynamics (now in English and Italian), much based on his research findings as well as his deep empathy for learners. He also made enormous contributions in the field of assessment as well as co-authoring a new chemistry text-book for school level which was overtly based on his research findings.

At an international level, he was a much sought-after conference speaker well as receiving numerous awards and medals from various countries for his work in chemistry education. He was a quite brilliant teacher and his research was always related to the students he taught week after week. He loved chemistry, especially in the areas of inorganic and analytic chemistry. His goal was always to transmit something of the excitement and fun of chemistry to future students. He wanted chemistry to become meaningful and to be perceived as directly relevant to modern living. He simply brought chemistry to life.

Alongside his brilliant teaching career, he set standards for educational research that just challenge us all. His work was characterised by rigour, creativity and a deep sensitivity to the realities of the learners. In this, he has left a legacy of findings for future generations. However, he has also given an agenda for researchers today as, together, we seek to make the discipline of chemistry meaningful and exciting for future generations.

The presentation will made in video format and is not designed as simply history. The goal will be to highlight the great contribution that he made as well as pointing to the agenda for us in the future, this identifying key areas for enquiry. A handout will provide the key central references which have a longer-term significance for us today.

Problem Solving: Strategies, Solutions, and Success

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Alex Johnstone's work in the area of problem solving used the information processing model and the concept of working memory to understand students' difficulties in solving problems in chemistry. His categorization of problem types enables teachers to better understand what they are asking students ti do. This presentation will review our research that has been influenced by Alex's work in this are. The differences between algorithmic, conceptual and open-ended problems in a chemistry context will be discussed as well as how various cognitive factors may influence success. The different approaches used by students from various STEM disciplines will be discussed as well as the journey from novice to expert problem solver.

The Genius of Johnstone: From Research into Practice

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It is unquestionable that chemistry is one of the most challenging subjects taught at school. Alex Johnstone helped to shed light on why this is the case, using his gift of empathy with learners to circumvent the 'curse of knowledge' that often afflicts those struggling to convey the subject through their teaching. By doing this, Johnstone provided a plethora of insights that can help teachers to break down the barriers faced by students in getting to grips with chemistry.

Given the impact of Johnstone's work, as evidenced by the vast number of citations his works have received, one might expect that chemistry teachers would be familiar with his research and that they would routinely incorporate its findings into their practice. This presentation will include evidence garnered from teachers in the UK regarding their knowledge of Johnstone's work, and will outline suggestions for how this knowledge base might be expanded in the future. One aim will be to prompt the audience to consider how they might act as advocates for Johnstone's teachings, helping teachers everywhere to improve their practice and, hopefully, to enhance student learning.

Room for Thought about Chemistry Education

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Alex Johnstone has exerted a great influence on my research and me, ever since I had the privilege of spending a sabbatical semester with him in Glasgow in 1990. In one of my early research studies [1], I proposed a three-cycle method for teaching lower secondary school chemistry, which went separately over the macroscopic, the symbolic and the submicroscopic levels of chemistry. Closely following Johnstone's ideas, I later proposed a novel introductory lower-secondary chemistry course for the 8th grade that sought to apply the theories of science education to support conceptual/meaningful learning and to develop a teaching methodology that encourages active and inquiry forms of learning [2]. Special emphasis was paid in this program to the careful introduction of the concepts of molecule and atom, which were delayed until the last two units of the course.

With regard to problem solving, Johnstone's predictive model focuses on the working memory (WM) overload hypothesis, stating that a student is likely to be successful in solving a problem if it has a mental demand (M-demand) which is less than or equal to the student's WM capacity ($M \leq WM$). In one of my studies on problem solving, I examined the limitations of the model and identified the conditions that needed to be fulfilled in order for it to be valid. In a follow-up study, I studied simple organic chemical-synthesis problems, with a simple logical structure but varying M-demand [3]. The data demonstrated the expected pattern with a sudden drop in performance (in accordance with Johnstone's model). The effect was more pronounced in the case of students without previous training in this kind of (real) problem solving. Finally, the effect of disembedding ability was made evident in a correlation study on non-algorithmic quantitative problem solving in university physical chemistry [5].

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Nonlinear Dynamics And Catastrophe Theory Models Explaining Students' Failure in Chemistry Problem Solving

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This paper presents a methodological perspective for chemistry education research, which is based on the theory of Complex Dynamical Systems (CDS). In this framework, the processes of teaching and learning chemistry are considered as CDS, where *nonlinearity* is a likely behavioral feature [1]. Sudden changes, such as unexpected failures, for instance in chemistry problem solving can be captured by a catastrophe model and be understood by CDS epistemological framework. Nonlinear phenomena have been reported explicitly or implicitly decades ago from scholars investigating students' unexpected failure in solving chemistry problems and models have formulated, i.e. the Johnstone-El-Banna model, in order to explain empirical observations [2]. Within the Neo-Piagetian framework and/or by means of information processing models, empirical data were interpreted using the working-memory (WM) overload phenomenon. The limited WM capacity was the principle variable examined along with variable acting as moderators, such as disembedding ability [3]. The involvement of more than one variable was broadly acknowledged; cognitive variables such as logical thinking and field-dependence independence were shown to be also potential predictors of student performance, however the mode of their interaction remained unexplored. The present research extents the above mentioned series of investigation by introducing nonlinear modeling based cusp catastrophe [1]. Students' achievement in chemistry is described by two control variables: The asymmetry factor (a) and the bifurcation factor (b), which for the present applications were the information processing capacity and field-dependence independence respectively. The mathematical formalism involves the equation: $\delta f(y)/\delta y= -y^3+by+a$, where the role of bifurcation factor suggests that beyond a threshold value the system splits into two modes of behavior (high and low performance). In that region sudden transitions between success and failure are expected. This dynamic behavior is pronounced in cases of no-algorithmic problem solving, such as organic synthesis [4-5]. The implications for theory and practice are discussed.

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Engaging Children, Youth and Teachers in Chemistry through Non-Formal Education in the Finnish LUMA Ecosystem

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Non-formal education is a novel way to engage children, youth and teacher in chemistry in Finland. Some examples of the popular LUMA activities in the context of non-formal education are presented, and the use of design-based research method as a tool for pedagogical innovations. The aim of LUMA Centre Finland (http://www.luma.fi/news) is to inspire and motivate 3-19 years old children and youth into mathematics, science and technology through the latest methods and activities of math, science and technology education. The aim is also to support the life-long learning of teachers working on levels of education from early childhood to universities, and strengthen the development of research-based teaching. LUMA Centre Finland is an umbrella organization for the collaboration of schools, 12 Finnish universities and the business sector.

Curriculum Design and Educational Policy

A Longitudinal Chemistry Enhancement Programme

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The issue of the numbers of students choosing to study chemistry and the background characteristics of such students is one that has been high on the policy agenda. The under-representation of certain groups is a concern and occurs with respect to a number of factors including social class, gender, ethnicity and disability. In the UK, national datasets have been used [1] to quantify the extent to which both participation and attainment in science are stratified by socio-economic status. Students from poorer families are less likely to take sciences than many other subjects. Very few young people (approximately 15%) aspire to become a scientist [2]. This percentage remains stable as students age from 10 to 14 years, is markedly lower than aspirations for many other careers and is despite the fact that most young people report liking school science, report positive views of scientists and say that their parents think it is important for them to learn science.

Funded by the Royal Society of Chemistry (RSC), the project called 'Chemistry for all' aims to widen student participation in chemistry by providing interventions for students aged 12 – 16 over a five year period. Each of 3 participating universities works with 6 schools where the student population has below average attainment, and where there are high numbers of disadvantaged students. To determine the impact of these interventions research is undertaken to see whether participation in chemistry increases both post-16 and at university. This paper reports on student interviews and observations relating to one of the universities. The events take place in the university as 'laboratory days' where the students undertake inquiry, e.g. forensic science. School outreach activities include drama events, careers talks and engaging chemistry lessons, using a range of strategies and resources. Interviews are conducted on an annual basis with six students from each of two intervention schools.

Analysis shows that science is valued by all students, but seen as more important for those who would pursue science-related careers; a utilitarian view in terms of science education for a job predominates, and a limited view of how science might be relevant to a range of careers. Most students do not know what career they might follow or whether science would be useful to them. Students tend to judge their own performance in science according to target-setting assessments. Most have no experience of science outside of school. Students could recall science activities they had undertaken in as Chemistry for all, there was an increasing value put on science and broadening awareness of how it could be useful, plus an increased awareness of what chemistry is. Chemistry is valued and of interest, but only one of the 12 students intends to take it further post-16. More focus on self-efficacy is needed.

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Chemistry-Related Career Choices of Learners in Cross and Longitudinal Section

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Due to the rather negative image of science and an imminent shortage of skilled workers, numerous institutions request an increased implementation of career orientation in science education. Furthermore, students need to recognize the relevance of science for their everyday life. In their relevance model [1] point out the vocational dimension as one of three dimensions of relevance in science education.

As part of the job-oriented mobile environmental laboratory Chem-Trucking, students and their current state of their vocational orientation and factors influencing students' expectations concerning their professional orientation - especially in the field of chemistry - were evaluated. In spring 2015, 1113 students from the eight and eleventh grade of various types of schools in the region of Siegen in Germany were surveyed. With the help of factor analysis and multiple linear regression, a model for each grade was developed, in which the students' vocational orientation is described in relation to self-concept, self-to-prototype-matching and image of school chemistry lessons and chemistry in general [2].

The results of the survey, the reported high impact of the image of chemistry lessons and the prototype of chemists on chemistry-related career orientation were taken into consideration to develop the intervention project "Chem-Trucking"[3].

In 2017, three years after the first study, several of the eight grade students were surveyed again as part of a longitudinal study. In addition, students of a MINT camp, who are certainly interested in natural sciences, will be interviewed in the summer of 2018 regarding a possible choice of chemistry or science-related occupations. First results of both studies will be presented.

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Teachers Co-Designing and Implementing a Career-Related Instruction in Chemistry Education

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Chemistry education does not provide students with adequate awareness of careers related with chemistry. Therefore, innovative instructions regarding the problem needs to be designed. In co-designing, teachers create new or adapt existing curricular activities in collaboration with peers, experts and career professionals with up-to-date insights, and other stakeholders and students' ideas [1, 2]. During this interaction, teachers can reflect their positioning about ownership, sense-making, and agency in relation to the designed instruction and concrete teaching material [3]. In this case study, two teachers, researcher, and a scientific professional co-designed a career-based scenario named "Coal to the teeth" starting a chemistry instruction dealing with activated carbon. Teachers' viewpoints about co-designing and implementing the career-related instruction in chemistry education are examined.

The context of the study is the EU project MultiCO. The project's aim is to promote scientific career awareness and engagement in science learning using career-based scenarios. Two female chemistry teachers co-designed the career-related instruction in audio-recorded planning meeting. Based on teachers' ideas, researcher with the help of a dentist designed the career-based scenario. Teachers re-designed the scenario and instruction before its implementation. During the implementation, teachers and researcher had short discussions after each lesson. Teachers were interviewed afterwards to get more detailed information about their perceptions. All data was transcript and analysed by content analysis.

Discussing about the new carbon toothpaste with their students inspired teachers to create this new chemistry instruction. Teachers explained how difficult it is to integrate careers in chemistry education. Therefore, they wanted to involve real professional in designing the instruction combining chemistry knowledge with the career of a dentist and her explanations about the chemistry issues with teeth. Teachers highlighted the visual and informative appearance of the co-designed scenario and agreed that the virtual and personal contact with the dentist through video engaged students in following chemistry inquiries. Teachers perceived that it was easy to implement the scenario even though they were not involved in every phase of designing it. In addition, teachers appreciated that the whole instruction was relevant and interesting for the students, professional of the field was involved, and they were free to implement the co-designed scenario and instruction in their own way. We conclude that teachers has to support the ideas of the innovative instruction, and feel the change necessary, and only then, co-designing career-related chemistry instruction succeeds.

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Citizen Science – a Way of Keeping Amateurs in Touch with Professionals

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European Union has been facing the common challenges such as early school leaving or lifelong learning for years. They belong to main targets that remain on the agenda and all good practice examples are welcome. Citizen science belongs to the approaches that seem to have a great potential to draw a wide group of people to science in a popular way. The phenomenon of citizen science is a civic engagement that expects the active role of the public in the science: amateur scientists (nonprofessionals) conduct a scientific research often arranged by professionals. The passive design known from the first projects moves to active design where users of specific applications collect the data that are sent to creators of the applications, researchers. The results that are widely collected all over the world can, therefore, be analyzed and interpreted deeper because of its number, heterogeneity, and authenticity. People can easily become a part of a scientific team and contribute to a research that would hardly be carried out by one few-headed team. Lots of citizen science researchers deal with issues that are attractive for people because of their usefulness or arrangement of application (gathering the ticks, taking photographs of surroundings) and/or because of accessibility of the data (typical for biological issues). This aspect also supports bridging the gap between citizens-amateurs and scientists-professionalists, as well as lifelong learning.
The contribution will present an overview of citizen science projects in the Czech Republic and the potential that citizen science has in the chemistry issues (environment, nourishment). The Department of chemistry education, Charles University (Prague), has an experience with specific groups of citizens (retired people, high school students) and wants to develop broaden cooperation in order to encourage citizens to participate in chemistry science.

Counsellors Support in Promoting Students Scientific Career Awareness

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Europe faces a shortfall in science-knowledgeable people at all levels of society including chemical industry. Knowledge about careers may increase the interest to choose scientific careers particularly when students are interested in science and careers match their interests and abilities [1]. Moreover, secondary school students need counselling support in the areas of social values, learning skills and of vocational guidance, too [2]. This study focuses on school counsellors' viewpoint of their possibilities in advancing secondary school students' scientific career awareness.

The context of the study is the EU project MultiCO. The aim in the project is to stimulate students' engagement in science learning through the use, of career-based scenarios and at the same time raise students' awareness and interest in career paths that involve science. In Finland, lower secondary schools (grades 7-9) have counsellors whose task among others is to help students in their further study and career choices. For this study, data was collected through focus group discussions with eight school counsellors. Discussions about science education and scientific careers were audio recorded and analysed using content analysis.

The counsellors discussed more about science-related careers than scientific careers and were aware of skills needed in these careers, however they hesitated to take responsibility of presenting these careers to the students. On the other side, they described how they have discussed with students about technological field encouraging students to think its importance. Counsellors felt that science teachers are better experts to present scientific or science-related careers. Further, they suggested that 'The Introductory Periods in Workplaces' which belong to the schools' activities could, in some cases, focus more on scientific careers. Counsellors perceived that career-based scenario is an appropriate way to link careers to science content. They were able to list lot of scientific or science-related current and future careers, and suggested contexts to the career-based scenarios. The counsellors told about their experiences on the factors influencing students' science study and career choices and highlighted science teachers' role and the role of the place where the students live. Counsellors' perceptions support the idea to promote scientific career awareness through career-based scenarios and further the impact on science study and career choices. It also would be beneficial that science teachers collaborate with counsellors in introducing scientific careers.

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Outcomes of Learning from Future Secondary Chemistry Teachers in the Design of Teaching-Learning Sequences with Competencial Approach

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The secondary school curricula which aims to evaluate both competences and the impact of PISA tests [1] are promoting a transformation of teaching that considers the development of students as persons prepared to act in the world, more than to gain knowledges disconnected from the real world. Furthermore, a context-based-science education approach, which make content meaningful and allows students to transfer constructed knowledge in one context to other real-world situations [2] seems increasingly advised.

The topic of this communication is related to the need to adapt teacher training of future chemistry teachers to new educational trends and nowadays professional challenges, empowering them to design teaching-learning sequences fitting with competencial approach (cTLS) that students face in front a meaningful action or decision in a relevant context, that ask them to construct or use the big ideas of scientific knowledge [3].

A teacher training module has been designed and implemented with the aim to empower future chemistry teachers in the design of cTLS. Through a 12 h presencial time module, theoretical framework and opportunities to practice and plan cTLS were provided, and the cTLS designed by students were shared, discussed and co-evaluated. The methodology used in this module was based on reflective practice adapted to the initial teacher training [4].

A qualitative research which had the aim of providing an improvement in the educational process was carried out. The objectives were to identify the initial ideas about TLS, to assess the progress in learning from the analysis of the characteristics of cTLS, and to analyse students'perception regarding the contribution of the module in the process of developing cTLS. The study sample were 23 students, the data collection tools were an activity to detect initial ideas, 3 versions of cTLS per student, and an assessment questionnaire of the module. The analysis tools were the same ones used in qualitative research such as categorization of open questions regarding at students' answers and the main features of the cTLS.

The results and conclusions show the progress in the learning. The students take ownership of the sTLS model, the elements of its design, and the basic ideas for the sequencing of activities. The analysis of the assessment questionnaire informs that students consider it adequate and useful, about the difficulties detected, and possible improvements.

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Current Problems and Challenges of Chemistry Curriculum at Lower Secondary Education in the Czech Republic

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In the contribution we deal with the research project results focuses on the identification of key, critical and dynamic points of chemistry education on the lower secondary school level through building the cooperation environment between teachers and teachers´ educators in Czech Republic. Methodology of research is based mainly on semi-structured interview with chemistry teachers (n = 40) identifying key, critical and dynamic points in the current curriculum. All points are classifying from the view of:

- importance within the subject paradigm (setting the key points and relation to key concepts),
- demandingness for learners by teacher´s self-assessment of teaching process (identification of critical points) and
- the current development of the subject (discussion about dynamic points of the curriculum).

The obtained results present problems with cognition overload of the pupils and the necessity to improve the content, particularly to build stronger connection to everyday life and forming of science literacy. The results tend to verify the expected critical fields of the early chemistry curriculum, i.e. mainly chemical calculations, chemical reactions, field of electro-chemistry, chemical nomenclature and professional communication. The results also show more attention should be paid to areas, in which chemistry teachers from the praxis can contribute substantially towards improvement of teacher's education and chemistry curriculum on their teaching level. Next steps of the project are oriented to defining the methodological processes and strategies to teaching/learning elected critical and key points of the curriculum, including their optimization and verification by the action research of connected teachers.

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From the Analysis of Chemistry in Beauty Blogs towards Curriculum Innovation

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Cosmetics play an important role in our everyday lives. However, the variety of different products and brands appear confusing to consumers. Products vary from basic, indispensable, everyday items such as soaps, shower gels and shampoos, to decorative cosmetics and high-end skin creams with specific, ‘innovative’ ingredients for every skin type imaginable. When choosing a product, German girls and women between 14 and 29 often rely on online beauty blogs, digital diaries which are written by authors who rarely have a scientific background. Often such blogs reach a readership of several million users per month. But which role do chemical aspects play in beauty blog texts?

Relevant chemistry education should cover a broad range of goals, including preparation to live an individual, responsible, and self-determined life in the society [1]. Acting and participating in society requires skills for dealing with the media offers surrounding us. This encompasses understanding and reacting to scientific aspects presented by the media [2]. While research on traditional media, such as newspapers, is quite prevalent in science education [3], research on new types of media remains quite spotty although a broader coverage of media education in science education has already been highlighted [4].

This presentation describes a qualitative content analysis of 60 recent posts from six popular English-language beauty blogs. The texts were coded according to categories such as the number of chemistry-related terms, supporting information for such terms, positive and negative claims regarding chemical aspects, references to studies etc. Based on the distribution of the categories, two main types of blogs could be distinguished: The “trustworthy scientific type” and “the non-scientific type”. By color-coding the different categories, a difference between these types can be easily depicted. The presentation will discuss first findings and ideas on how to make use of corresponding analysis of beauty blogs for the teaching of chemistry.

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Research in Chemistry Education – Teachers Centered

Bridging the Gap between Science Education Theory and Practice: Teachers' Knowledge of Science Education Research

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The problem: Many scientific attempts are made to expand our theoretical understanding of science education, especially chemistry education. These efforts usually result with considerable and meaningful outcomes that can benefit science education. However, these scientific outcomes are not readily accessible to teachers to learn from. Teachers, as practitioners, are often not involved in the scientific process, resulting with some of the studies being not well adapted to classroom setting. In addition, even when teachers are exposed to research in chemistry education they do not tend to implement it nor to change their teaching. The current study was design to deal with the gap between research and practice in chemistry education by designing a course about research in science education for in-service chemistry teachers.

Significance of the study: The study allows insight into the course design, in which teachers were exposed to the of research in chemistry education research, learned the language of field and acted as review board in chemistry education research journal. having the role of reviewers, the teachers had the opportunity to critique research papers in chemistry education however they need to provide evidence for their comments. This process supported a bridge between the two body of expertise practitioners and researchers in chemistry education.

The objective of this study is to assess the contribution of the course to teachers' knowledge and attitudes toward chemistry education research.

Methods: The course, was provided in the framework of the "Rothschild-Weizmann"[1] Master's Program in Science Education, spanned over 14 2-hour meetings. Five experienced chemistry teacher participated. The analysis was qualitative and included, discourse analysis, evaluation of research writing assignment, assessing knowledge assimilation through classroom exercises and analysis of meetings transcripts for additional attitudinal information. Data analysis will be conducted in accordance with the qualitative-constructivist approach [2].

Results: Results suggest that participating teachers were able to change their science education research discourse and use terminology that was not used before. In particular, they were able to generate a research questionnaire and analyze it. Analysis of attitudes suggested that participating teachers were more willing to partake in science education research following the course and are more ready to apply conclusions and methods driven from science education research in their chemistry teaching.

Discussion and Conclusion: The results demonstrate that a greater involvement of teachers in chemistry education research can promote better engagement of teachers in this field. Consequently, this can lead to the betterment of chemistry education research, since teachers are practitioners that can contribute meaningful insights into the research process. This can bridge the gap between science education theory and practice and even lead to "Research–practice partnerships" (RPP) [3] in which teachers and researchers are partners in chemistry education research that provide answers to problems that are raised by the educational field.

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Changes of Teachers' Knowledge, Beliefs and Attitudes Regarding IBL in the Framework of a Professional Development Program

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Austrian educational policy has strived for reforming curricula and frameworks for science education towards inquiry-based learning (IBL) for almost 20 years. Although substantial changes have been made at the legislative level [1], teaching practice has changed only marginally so far [2]. One reason for this is that education policy neglected to consider the teachers' existing practices, beliefs and attitudes when realizing the reformed curricula. Consequently, there has been a mismatch between what education policy expects teachers to do and what they are willing and able to do in their daily practices [3].

This is also reflected in the teachers' feedback concerning a four-part workshop-series regarding IBL. Even after this workshop-series, the participating teachers stated to feel not confident enough to implement IBL on their own [4]. On the contrary, they named various obstacles (such as lacking resources or students' insufficient knowledge and skills) to implement IBL and expressed the need of specific methodological knowledge and skills [1]. To meet this demand, we designed a professional development program (PDP), which aimed to support the teachers in extending and deepening their knowledge and skills in the field of IBL. By planning, applying and reflecting IBL collaboratively with colleagues and researchers, the teachers had the opportunity to gather ideas together and obtain materials, as well as to exchange the experiences they had gained when implementing IBL in their own classes.

In order to make the processes and development the teachers underwent during the PDP visible, data were collected at two different timepoints. Previous to the PDP, a group discussion (N=5) was conducted and at the end of the PDP, individual interviews (N=3) took place in order to investigate the participating teachers' knowledge, beliefs and attitudes regarding IBL. The group discussion was analyzed by applying qualitative content analysis [5], which resulted in an elaborated system of categories. This category system was applied on the individual interviews as well to contrast these results with those from the group discussion.

In our presentation, we will provide an insight into the data from both collection timepoints and additionally, we will demonstrate how far the participating teachers' knowledge, beliefs and attitudes regarding IBL have changed over the period of the PDP.

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Application of Systemic Three-Tier Diagnostic Instrument for Assessing Chemistry Student Teachers' Conceptual Understanding of Organic Chemistry Reactions

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The aim of this study was to develop and apply up to now unexamined systemic three-tier diagnostic instrument in order to be administrated to 15 chemistry student teachers' who were in the final forth year of education towards bachelor's chemistry degree, in the Faculty of Sciences, Republic of Serbia. The instrument consisted of five questions, and each of them had three tiers: (i) Systemic multiple choice question with three graphical options (according to Fahmy [1]), (ii) student teachers' explanation of the selected option in the first tier, and (iii) confident tier. After each question, student teachers' were asked to choose one of the seven options in the Likert scale, in order to estimate the difficulty of the question. In addition, the time needed to solve each question was also measured. Three variables (student teachers' performances in the first and the second tiers, subjective mental effort, and the time) were used to estimate the student teachers' efficiency (E) of solving systemic questions. The obtained results indicated that student teachers showed positive efficiency in solving three of five systemic questions. However, obtained positive E values were significantly and highly correlated with the student teachers' confidence in the provided answers only within two systemic questions. According to this, small percentage of student teachers who had conceptual understanding of organic chemistry reactions was found. Additionally, several serious misunderstandings appeared within their answers.

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Teaching Science: Challenges Encountered when Teaching an Area Outside Science Specialism

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Integrated Science is taught in the first two years of secondary school in Malta and includes topics from Physics, Chemistry and Biology. Within many secondary schools, the role of the science teacher is a multifaceted one, with teachers being required to take on the role of ‘subject specialists’ when teaching the separate science disciplines as well as a more ‘generalist’ role when teaching Integrated Science. Most science teachers are likely to have a degree level qualification in only one science subject but when teaching Integrated Science they need to teach several science topics that they might not have studied beforehand. When teaching outside one’s science specialism one will be teaching a subject/s that one has not studied at Degree or at Advanced level. Teaching outside area of expertise offers considerable challenges [1] [2] as has been found in various studies.

This study was carried out in order to explore the main challenges that Maltese science teachers, who are non-chemistry specialists, encounter when teaching chemistry-based topics from the Integrated Science syllabus. A professional learning programme was developed to support the participant teachers when teaching outside their area of specialism. Following a qualitative methodological approach data was gathered mainly through individual interviews, focus group interviews and classroom observations when the science teachers participated in a professional development programme. The results are presented by selecting three case studies of participant teachers who narrate their experiences when planning and teaching chemistry topics and the various difficulties they encounter. They recount how teaching a subject that they may not feel confident in affects their self–efficacy and their identity as science teachers. Furthermore the teachers describe how they deal with such challenges and how they seek to improve their practices. Based upon the outcomes of this research recommendations are provided with regards to how such teachers can be supported to facilitate teaching outside an area of science specialism.

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Research in Chemistry Education – Students Centered

An Analysis of the Visual Representation of Redox Reactions in Secondary Chemistry Textbooks from Different Chinese Communities

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Redox reactions belong to the central concepts taught in secondary school chemistry [1]. A central concept of explaining common difficulties in chemistry teaching and learning was suggested already in 1991 by Johnstone. Johnstone's idea concerns a permanent shift in chemical thinking between its three representational levels, namely the macroscopic, submicroscopic, and symbolic levels. It is important for teachers to know how to deal with and how to connect the different representational levels in chemistry, and how to use different representations of redox reaction content [2]. It is also suggested that visualization can offer help in better dealing with the different representational levels [3]. Since chemistry textbooks are the mediator between the chemistry and the learner [4], it is suggested that, it is important to ensure that visual representations are carefully prepared and integrated into the textbook.

The purpose of the current study is to describe how grade-10 chemistry textbooks from different Chinese communities, namely the People's Republic of China, Hong Kong, Taiwan, and the Chinese minority in Malaysia, represent content related to redox reactions. The focus of the study is not to indicate eventual conceptual errors, but rather to characterize how the textbooks adapt visual representations related to redox reaction content. We found representations of textbooks from the People's Republic of China mostly focus on the macro and macro-symbolic levels and indicate some everyday life as well as industry and technology orientation. The findings show that the textbook from Taiwan uses more intense multiple macroscopic, submicroscopic, and symbolic representations to illustrate the redox reaction concept in a more comprehensible way. The textbook from Hong Kong has a strong structure-of-discipline orientation with mostly macro level representations. The textbook from the Chinese minority in Malaysia follows a strong structure-of-discipline orientation with limited visual support.

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Five Graders' Succes in Solving Problem Tasks in Relation to their Attitude toward Science in School

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The paper presents the results of a survey focused on the ability of 5th graders to solve problem tasks. At the same time, the attitudes of these pupils toward science at school were also investigated. The six problem tasks released from the TIMSS international survey of 2007 and 2011 were selected. The tasks required pupils to use knowledge and reasoning skills. Selected tasks were thematically focused on the implementation of the experiment. Pupil's attitudes toward science in school was found out via items taken from the TIMSS survey pupil's questionnaire. Pupils expressed their opinion on each questionnaire item. 160 pupils from six classes were involved in the research. The success of the solving the problem tasks was compared with the success of the pupils of the Czech Republic, who participated in the international survey TIMSS in 2007 and 2011. The results were comparable in two tasks. The selected pupils were significantly more successful than the national selection for the TIMSS survey in solving of four tasks. Differences in success can be due to the sample size surveyed - more than nine thousand pupils participated in the TIMSS survey in the Czech Republic in 2007. The relationship between pupils' attitudes towards science at school and their success in solving problem tasks has been partially demonstrated. In some cases, a pupil who has a rather negative attitude towards science at school has achieved comparable success with pupils with positive attitudes towards science at school. Explanation can be found in a different way of thinking when solving problem tasks that "suit" the pupil with a rather negative attitude to school science.

Students' Argumentation Skills Expressed in the Context of the History of Chemistry

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The development of students' abilities to formulate arguments, reason and think critically in scientific context is one of the goals of science education [1]. Episodes from the history of chemistry can serve as that scientific context. The research was conducted with the aim of examining students' ability to apply the newly acquired knowledge about composition, structure and general properties of organic compounds to formulating arguments for and against the views of the scientists who had contributed to the development of organic chemistry in the 19th century. A total of 43 students aged 14 participated in this research in the school year 2017/18. Firstly, the students individually read the text about the composition, structure and general properties of organic compounds and how these compounds are different from inorganic compounds. After that, they listened to audio-voice recordings in which the views of scientists who are given the credit for the development of organic chemistry were interpreted (Jons Jacob Berzelius, Friedrich Wohler, Antoine - Laurent de Lavoisier, Friedrich August Kekule von Stradonitz and Archibald Scott Couper). After each recording, students were expected to individually estimate whether the presented views of the scientists would be acceptable today or not and to write arguments for and against. The students were given the opportunity to use the text they had previously read as the source of information for formulating arguments. In this approach the students were in a position to apply the acquired knowledge in order to estimate the views of the scientists, and to improve their high-order cognitive skills.

A conclusion supported by at least one justification was labelled as an argument in the analysis of students' answers in this research. The structure and contents of arguments were evaluated jointly on a 0-to-5 scale according to the modified version of the methodology described in the literature [2]. One third of the total number of produced arguments contains a conclusion, justification and additional explanation of the justification. At the same time, this kind of argument is the most frequent. Based on the obtained results it can be concluded that the episodes from the history of chemistry in combination with some other sources of information can serve as a fruitful context for formulating arguments and stimulating high-order cognitive skills.

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Professional Development of Chemistry Teachers: from Theory to Practice

Organizer: Avi Hofstein

The Development of Ownership and Leadership Amongst Chemistry Teachers

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We are operating in science education in general and in chemistry teaching and learning in an era of new content and pedagogical standards. These new standards are in fact a call for rethinking the way we prepare chemistry teachers for these challenges. One way to make progress toward these goals is to treat teachers as equal partners in decision-making regarding research and development. In cases in which this is done, teachers will have to play a greater role in providing key leadership at all levels of the educational system [1]. One of the initial stages in the development of leadership amongst the chemistry teachers is to enhance their sense of ownership [2]. It is suggested, that in order to develop a sense of ownership among teachers, it is vital to develop the teachers as learners and as practitioners in their classroom. In other words, the goal should be to equip the teachers with the relevant chemistry content knowledge its' aligned PCK (pedagogical content knowledge). What specific roles of teacher leader are we interested in developing? The three main abilities one should aim in developing are the following:

- **Teacher development**: We expect leading teachers to be involved in initiating, facilitating, planning, and conducting professional development initiatives for chemistry teachers in their schools and/or in their region.
- **Teachers as curriculum developers**: We expect participants in professional development of leading chemistry teachers to be able to develop chemistry curricula, innovative instructional and pedagogical techniques, and new approaches to assessment aligned with these pedagogies
- **Teachers as active participants:** Participants should be able to create effective, school-based learning environment that will involve communities of practice and networking to improve school-based pedagogy. They should also be able to support new teachers in their initial years of practice in the chemistry classroom.

In the symposium, we shall present and discuss a model for the development of these professional skills and abilities and its related research and assessment.

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Evidence-Based Professional Development of Chemistry Teachers

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In chemistry education new standards are emerging regarding the content and pedagogy of teaching and learning. This necessitates a change in the way we professionalize the chemistry teachers. In Israel, inquiry-type experiences are provided to students in the chemistry laboratory [1], [2]. An evidence-based continuous professional development (CPD) program for chemistry teachers was developed and implemented. In this study, our main goal was to explore the teachers' development and growth, over time. Seven high-school chemistry teachers participated in a year-long workshop. Information regarding their beliefs, their professional growth, and behavior was gathered using video-tape recordings, oral interviews, and in-depth discussions during the year-long workshop. We found that video-tape recordings provided reliable and valid evidence regarding the changes that the teachers underwent. The combination of in-depth discussions, assessment of the video-tapes at the workshop, as well as the interviews held with the teachers, provided us with an explicit and clear understanding of teachers' professional development and growth. In addition, the workshop served as a platform for presenting and discussing the evidence brought by the teachers from their classrooms, and gave them an opportunity for reflection [3].

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Roles of Action Research in the Professional Development of Chemistry Teachers

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Action research in science education aims the cyclical transformation of classroom practices through the action research cycle of innovation, research, reflection, and further improvement of the changed teaching approach [1]. In the same time, action research is suggested to be one of the most promising strategies for the continuing professional development of teachers in chemistry education [2]. The talk will present three cases of how action research can be used for the professional development of chemistry teachers. The first case concerns a long-term participatory approach of a network of chemistry teachers working for many years on the joint research and innovation of their classroom practices, e.g. how to teach the particulate nature of matter by a changed curriculum approach [3]. The second case is a teacher-centred action research on how to teach chemical bonding in a remote environment supported by external advisors via synchronous and asynchronous online communication [4]. The third case deals with the innovation of pre-service teacher education in a partnership approach of teacher educators, e.g. with a focus on keeping teacher education courses on the use of ICT in chemistry education up-to-date with changes and improvements in technology [5]. The three cases will be reflected and directions for a stronger inclusion of action research in the professional development of chemistry teachers (pre- and in-service) will be given as they are currently under development in the project Action Research To Innovate Science Teaching (ARTIST) [6].

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Workshops I

Chemical Escape Room Workshop: Fun and Flow in the High-School Chemistry Classroom

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In (chemistry) education we constantly seek new, creative ways to teach our students chemistry by applying innovative activities related to their daily life. In a project conducted by the National Chemistry Teachers' Center at the Weizmann Institute of Science in Israel, we designed a Chemistry Escape Room (CER) based on the principles of the popular game “escape room”. In ECRICE 2018, we will invite the participants to experience the CER activities and actually feel the flow. This will be followed by a discussion regarding the design, the mode of operation, and students' and teachers' responses.

Escape rooms are a form of live-action team-based game in which participants are given a fixed amount of time to find clues, solve puzzles, complete tasks, and escape from a locked room [1]. Escape room games require group work, intellectual challenges, and a bit of luck to create an enticing activity. The popularity of escape rooms in many countries is immense, as reflected by the number of searches for the term "escape room", which has increased tenfold in the last years [2]. It is this enthusiasm that we try to harness in the classroom in the form of a mobile chemical escape room. When designing the CER, we decided that it had to be as fun as any commercial escape room, but in addition, it had to comply with several additional design constraints to be suitable for the classroom: (1) The activity must comply with the high school chemistry curriculum. (2) It must accommodate large groups of about 20 at a time (a full class). (3) It should be mobile in order to reach a maximum number of students. (4) Materials must be inexpensive to allow for considerable wear and tear. (5) Chemical knowledge is essential to solve the puzzles and the tasks.

The result is a kit that teachers can borrow and operate in their schools with their own students. The reaction from the participants was overwhelming. As we approach the second year of operation, over 350 teachers and more than 1500 students have so far experienced one or more of the escape room activities. According to this model of operation, it is the teachers who are in charge of operating the room activities. We tried to comprehend the high popularity of the escape room by interviewing teachers and by administering a student questionnaire; the findings will be shared in the workshop. The workshop will allow participants to not only experience the magic of the "Chemical Escape" activity, but also to learn about how to turn a popular genre into a successful chemistry education activity.

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The Chemistry Teacher International

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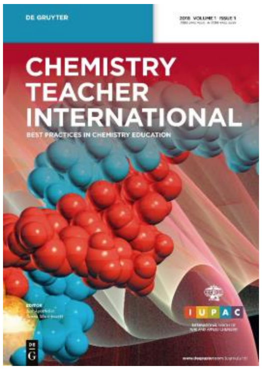

Chemistry Teacher International (ISSN 2569-3263) is a new online Open Access journal launched in a collaboration between IUPAC's Committee on Chemistry Education (CCE) and De Gruyter. Articles will be available in HTML and PDF formats. The Editors-in-Chief of the journal are the chair of the CCE, Jan Apotheker, and the chair of the Division of Chemical Education of EuCheMS, Iwona Maciejowska.

The journal aims to publish good practice examples of education from around the world. Activities presented at conferences, such as NICE in Asia, ACRICE in Africa, and ECRICE in Europe, will be sources of material for the journal. Instead of publishing a proceedings book, a special issue of the journal can be published, containing a wealth of material presented at the conference. Of course, activities at ICCE conferences will also be presented. Organizers of Science Olympiads, such as the International Junior Science Olympiad, the European Science Olympiad, and the International Chemistry Olympiad, are strongly invited to discuss the exams from their final rounds in the journal.

In 2012 Marcy Towns and Adam Kraft [1] published an article in which they identified a number of journals focusing on chemistry and science education.

The journals mentioned above are all journals that focus mainly on Chemistry education research or more broadly on science education research.

Chemistry Teacher International aims to focus on good practices in education, bridging a gap between research and education. It will be open access and available through: https://www.degruyter.com/view/j/cti

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Wednesday, September 5th, 2018

Reform of First Year Chemistry Studies

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The talk will focus on the reform of first year chemistry studies at the Department of Chemistry, University of Jyväskylä, Finland. A new model for chemistry studies is presented, which take into account recent chemistry education research on chemistry learning, research-based and active-learning approaches, as well as supports students' wellbeing and include enhanced, target-oriented study councelling and support to develop academic study skills.

All these factors have resulted to a holistic approach that has renowed the way chemistry is taught, the way curriculum has been modified and the way studies are supported and learning assessed. Simultaneously, the Department has reacted to new learning demands by infrastructure and personnel modifications along with constant small collaborative, research-based pedagogical development projects within the framework of first year chemistry studies.

So far, the holistic first year chemistry education reform has resulted to students with increasing motivations towards their studies, better throughput in courses and increased learning achievements. Especially, the first year drop-out rate has diminished significantly.

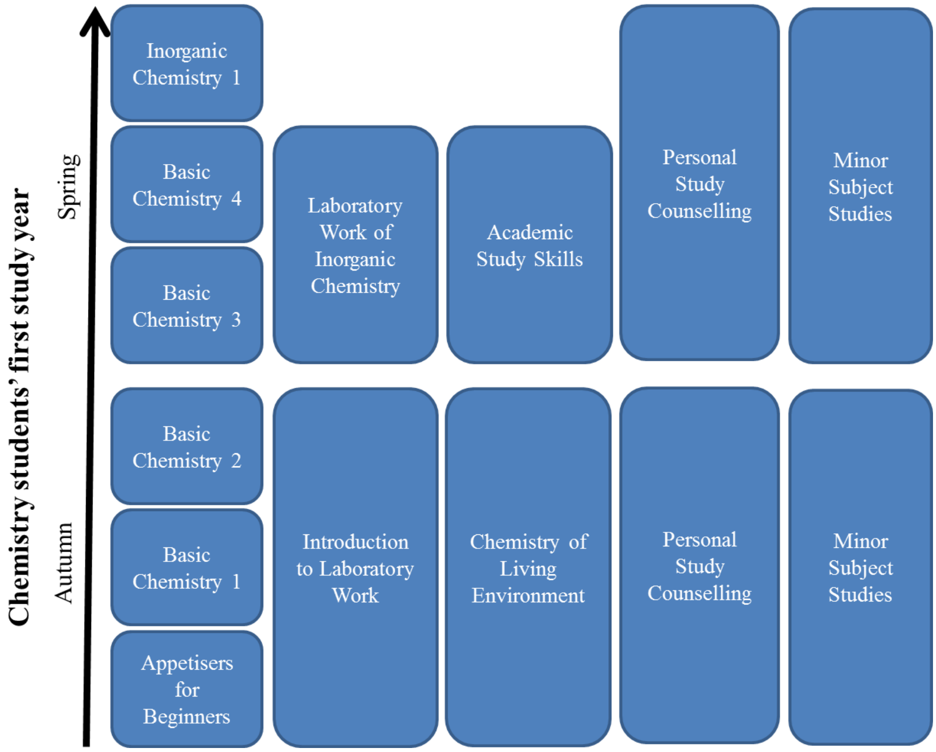

Figure 1. Chemistry students' first study year courses.

Pre-Service Teachers Training

Investigating the Effectiveness of a Teacher Education Programme that Promotes Inclusive STEM Education

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According to the EU framework for key competences, mathematics and science are among the eight key prerequisites for active participation in society [1]. However, across the EU, 17% of 15-year-olds underachieve in science and this underachievement is prevalent among students with low socioeconomic backgrounds [2]. Changing societies, increased migration and changes in students' needs together with changes in the aims of STEM education give rise to an urgent need for inclusive education that promotes learning in students of different competence levels and diverse cultural backgrounds.

MaSDiV (Supporting Mathematics and Science teachers in addressing Diversity and promoting fundamental Values) is an ERASMUS+ project aimed at addressing current challenges in STEM education: the underachievement of particular student populations; linking mathematics and science competences with social and civic competences and effectively supporting teachers as they face increasing social, cultural and competence-related diversity in their classrooms. These needs were addressed through the development of a professional development programme for teachers, to support teachers in the use of inquiry-based learning as an approach for addressing achievement-related diversity through real-life, relevant contexts and as a tool for intercultural learning.

In Malta, two parallel programmes were developed; one for professional development leaders and one for teachers. The programme designs, based on MaSDiV professional development modules, drew on social constructivist and socio-cultural theories of learning, where participants learn with and from others by participating in social practices through ongoing active engagement. Participants discussed pedagogical issues and engaged reflectively about their practice.

Towards the end of the course classroom observations and interviews with teachers provided information about the effectiveness of the course. These were part of case studies intended to answer the following questions: (1) How do teachers use IBL to address achievement-related diversity? What are their experiences related in this regard? (2) How do teachers use contexts relevant to students and society in their lessons? What are their experiences in this regard? (3) To what extent did the professional development programme support teachers? The results presented in this paper will focus on science teachers' and in particular chemistry teachers' experience of the course and their attempts to address diversity and promote fundamental values through STEM education.

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Using Participatory Action Research for Developing University Chemistry Teacher Training

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The Participatory Action Research (PAR) model by Eilks and Ralle [1] is very well known in science education. Over the years many teaching and learning materials were developed and implemented in German secondary schools using this model [e.g. 2]. The success of the model encouraged us to adapt it for the university level in order to develop university chemistry education courses. In most of the seminars, the topic was dealing with growing heterogeneity and diversity in chemistry classes. However, in order to do this, we met and conquered some challenges which benefited the work in the original model.

The present paper is based on an advanced model of Participatory Action Research for developing university chemistry teachers training. For an advanced model the focus is strongly on the extended development team which contains different person which were not the part of the team in the first place (e.g. scholars from language department, special need education etc.). The role of the student teachers changes as well. They are part of the development process and a part of the development team as well.

The adapted cyclical model starts with the problem from the seminar or school. Further, the development team has to be put together based on the initial problem and the competencies or skills which are needed to solve the problem. Therefore, team construction represents a main part of the advanced model. After the formation of the team, development of the teaching module, the materials, and the cyclical development routine begins (development of the seminars, testing in practice, evaluation, reflection and revision). The result of the development process is new teaching materials, media, and methods for university lessons, but materials for school can also arise. The problem from the seminar has been reduced or eliminated, which begins the developmental process again. An addition, the group wins many documented and reflected experiences from teaching at the university.

The developed model will be presented in detail and an example of a development process from the practice will be given.

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Pre-service Chemistry Teachers' Ability to Analyze Lessons: A Multiple Case Study

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Teacher's ability to analyze educational situations is crucial not only for their decision about future practice but also for their own feedback. Teachers' development and their lesson observation skills are a cultivating element during their pre-service training. Prospective teachers generally do not have sufficiently developed observation competencies. The main focus remains in the content orientation whereas the pedagogical knowledge [1], observation skills included, remains secondary.

Our team has decided to determine the quality of chemistry student teachers observation skills [2]. It was assessed in their 4th year at university on specific case studies. The student teachers underwent their in-school orientation practice as well as other practice and, in addition, they have completed the first teaching practice. Students gradually followed chemistry lessons at basic school (lower-secondary), grammar school and non-chemical secondary vocational school. After each observation, they wrote a reflection. By monitoring the depth of their reflection, changes in their ability to reflect a lesson can be observed. In the final interviews, interference effects [3] such as provided observation sheet [4], colloquium immediately after the lessons and the teaching practice itself were identified. The results show significant differences in the students' ability to reflect lessons. The effect could dwell in their teaching (analyzing) talent, verbalization skills but also in the extent to which the pre-service training was efficient.

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An Investigation of Pre-Service Chemistry Teachers' Pedagogical Content Knowledge through Reports of Supervised Internship

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In Brazil, all of university teacher preparation programs require a supervised internship in a school. This stage allows the student to participate in a completely teaching process, from the lesson plan to teach and to reflect on their practice. It is important to verify if the teacher training programs are contributing to the development of pedagogical content knowledge (PCK), considered the central component of teachers' professional knowledge [1].

In this way, the aim of this study was to investigate the pre-service chemistry teachers´ PCK manifestations during a supervised internship, on the subject of redox reactions. This content was chosen because it is one of the most difficult topics, both to learn and to teach [2].

The rubric used consists of nine elements that are independent to represent subject matter and instructional strategies through three different moments: planning, implementation and reflection [3]. Each element was rated in limited, basic, proficient or exemplary. Two researchers analyzed nine internship final reports, related to the redox content (k = 0,92).

Of the three phases, the subjects presented a lower performance (limited) in the first one (planning). This is because students generally did not take into account students' prior knowledge, they did not integrate it into instructional strategies, and they did not try to adopt new teaching strategies. Among the nine pre-service teachers, two of them presented most of the elements of PCK categorized as basic and just one element categorized as proficient, in the phase of reflection. This is because they choose the strategies according to the difficulties and the prior knowledge of the students. In addition, they gave attention to the students' understanding, students' difficulties and misconceptions after the lesson.

It appears that final internship reports can be a good data for analyze components of PCK because in the report, there is a description of the planning, application and reflections of the pre-service teachers. Considering that the internship is the last phase of the initial formation of the teacher, it is expected that pre-service teachers already show a deeper knowledge on planning. Hence, teaching education programs should be designed to expand PCK.

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Capturing Preservice Chemistry Teachers' Understanding of Precipitation Reactions through their Storyboards and Animations

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Understanding of chemistry concepts requires an ability to move across three levels of representations, namely, macroscopic, particulate, and symbolic [1]. To promote students' understanding of chemistry concepts, students should engage in the process of interpreting macroscopic evidences and developing mental representations of the phenomenon at the particulate level based on the evidences [2]. In line with teaching, while assessing students' understanding, students should represent their understandings in multiple forms (e.g., verbal/visual or static/dynamic) as they transfer their macroscopic observations to particulate representations. Thus, the purpose of this study was to identify preservice chemistry teachers' understanding of precipitation reactions through storyboards and animations that they generated after viewing the experimental video of a precipitation reaction.

A total of 27 preservice chemistry teachers, who were enrolled in their final year of teacher education program, participated in this study. The participants first viewed a 3-minute long experimental video, showing the reaction between copper(II) sulfate and sodium hydroxide, and then they identified the experimental evidences associated with this precipitation (ppt) reaction. Afterwards, they were asked to draw a storyboard to show the reaction process at the particulate level. The storyboarding is followed by generating particulate animations of the same reaction process by using ChemSense [3]. The data were first coded by using open coding, and then the emerged codes were narrowed down into four categories of understandings, called fully structured, moderately structured, weakly structured, and alternative. Based on the storyboarding data, only two participants showed fully structured understanding of ppt. reactions, five students indicated moderately structured (not kept the number of particles the same), and 11 participants exhibited weakly structured understanding of ppt. reactions (additionally not shown water movement). Five participants showed alternative understanding by representing at least one specific alternative conception in their drawings. Based on the animation data, 15 participants indicated alternative understanding, and seven participants showed weakly structured understanding of ppt. reactions. However, only three participants exhibited fully structured understanding of ppt. reactions. Based on the data, dynamic representations appeared to be more useful for identifying the participants' alternative conceptions. In addition, instructors may put more emphasis on connecting macroscopic evidence with particulate representations, and generating storyboards and animations can be used as assessment tools for capturing learners' understanding of various chemical concepts.

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Kitchen Chemistry Course for Chemistry Education Students: Influences on Chemistry Teacher Students, Visiting Pupils and their Teachers

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This study introduces the Kitchen Chemistry (KC) course and its influences on teacher students and visiting student groups (pupils and their teachers). The KC course is an optional course in advanced studies for chemistry teacher students in the Department of Chemistry at the University of Jyväskylä.

KC is considered to be a life-relevant learning environment that engages learners in science through the pursuit of personally relevant and meaningful goals [1]. KC, as a form of interdisciplinary learning, aims to develop boundary-crossing skills and to support the development of pupils' scientific thinking [2]. When students are able to see how laboratory work relates to their real life, they are likely to be more motivated in the area of science they are investigating [3].

The purpose of this research was to determine the following: (a) What kind of opportunities does context-based teaching allow the KC course? (b) What does KC offer chemistry teaching?

This study is significant because it will help develop the KC course for the future. This year, 15 teacher students attended the course. The visiting groups consisted of 51 pupils and three teachers. The data were collected through questionnaires (Likert scale and open questions) and interviews. The data were analyzed quantitatively as well as qualitatively.

We found that KC is viewed as an interesting subject which has a strong connection to the content of chemistry. KC gave pupils the opportunity to understand the phenomenon in a familiar context. Chemistry education students reported real-world connections to chemistry concepts and contexts. They also found KC as an interesting form of teaching chemistry. Teachers of visiting groups saw that motivation is the challenge: pupils often see the subjects of chemistry and home economics as separate entities. The two KC course teachers were enthusiastic about teaching the subject, and they wanted to offer to students the best possible opportunity to learn. The heterogeneity of the teacher students' knowledge was considered the biggest challenge in the course.

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Validating an Instrument for Assessing the PCK of Galvanic Cells

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The desire to enhance teacher performance has driven PCK research since the construct was proposed by Shulman [1]. The first period of the PCK research is marked by a qualitative approach, aiming to assess the nature of teacher's knowledge. Currently, researchers have increased their focus on quantitative approach in order to reaching a more generalizable conclusion. On that sense, this study aims to propose a valid and reliable instrument to measure chemistry teachers' PCK, following Mavhunga's TSPCK Model [2], which consists of five components: learner prior knowledge (LPK), curricular saliency (CSL), difficulty to teach (DFT), representations (REP), and conceptual teaching strategies (CTS).

The proposed instrument is a modified version of Ndlovu Electrochemistry Instrument [3]. The main modifications were: a) removal of items on electrolytic cells, to focus only in galvanic cells; b) reduction in the number of items, to shorten the test accomplishment time. The final modified version has seven items with the following distribution: two items about LPK, two about CSL, one about DFT, one about REP, and one about CTS.

A psychometric analysis was conducted through a Rasch Partial Credit Model [4] with 58 Brazilian pre-service and in-service chemistry teachers. To investigate whether the proposed test fit the Rasch model, mean-square and z-standardized outfit statistics (MNSQ and ZSTD, respectively) related to the items' difficulty and the persons' ability were analyzed. Reliability indices such as person reliability and item reliability were analyzed as well.

For all items and persons, the outfit indices are in the expected interval (values <1.5 to MNSQ or between -2 and +2 to ZSTD) [4] and therefore show a productive measurement. The item and person reliability indices also presented good values [4]: 0.94 and 0.81 respectively. The mean of the persons' ability in PCK (-1.82 ± 1.31) is lower than the mean of the items difficulty (0.00 ± 0.79), what it is expected, given the topic difficulty.

Rasch fit statistics and reliability indices suggest that modified test measures a single overall variable: the PCK of Galvanic Cell. In the future, this test might be administered to assess chemistry teachers PCK, mainly in the Brazilian context.

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Digital Tools in Chemistry Education - Virtual/Augmented Reality & Gamification

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Today there is a digital boom within education, in Sweden all school curricula are re-written where use of digital tools has been added as mandatory in all subject syllabi from the autumn of 2018. This has made teachers, as well as educational researchers, interested to find relevant digital tools where students enhance their learning, not only finding them fun and exciting. In this presentation, the role of technologies as Virtual Reality (VR), Augmented Reality (AR) and gamification is explored to study how students learn chemistry, both regarding affective as well as cognitive aspects of learning [1]. Students' perceived interest and value are studied using Krapp and Prenzel's framework of interest [2] and Wenger and colleagues framework of value creation in communities and networks [3]. Part of the interest in VR technology has to do with the availability when a smartphone can be converted to a VR headset at a very low cost. AR technology is much more complicated and expensive, however, the multiple sensory modalities makes it interesting [4]. Gamification in the classroom, where application of game-design in learning processes, has recently attracted a lot of attention [5]. The main aim with gamification is to enhance students' internal motivation through for example clues and possibilities to "level-up".

To explore how digital tools influence students learning, we will present two projects. The first is a university organic chemistry course where students practice their spatial competence using VR as a tool to visualise stereochemistry. The students study stereoisomers (for example simple molecules as 2-chlorobutane and more complex stereoisomers as muscarine and nicotine) and we have studied their perceived interest and value of the digital tools using a survey, interviews and observations. In the second project, engineering students have developed a teaching module for upper secondary chemistry using gamification, VR and AR as a way to motivate school students to learn about the protein synthesis. Here, we have conducted a survey and interviews with both the engineering students who developed the module, as well with the school students and teachers who have used the module. In the presentation, possibilities and challenges with the digital tools will be discussed, and examples for practice will be demonstrated.

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(Mis)conceptions and (Mis)understanding in Chemistry

Individualised Teaching Using Digital Instruments in Chemical Education

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With the publication of the strategic concept "Education in the Digital World" in Germany in 2016, learning with and about digital media becomes mandatory at all German schools [1]. At the same time, the digitisation offers great potential for teaching highly heterogeneous learning groups individually and comprehensively [2, pp.1-5]. In order to implement digital media in teaching successfully, it is necessary to (I) generate profound knowledge about the effectiveness of digital learning environments regarding heterogeneous learning groups [3] and (II) to professionalise teachers for digitisation [4]. Against this background, we are working on the following two projects:

(I) In the first project, we develop and evaluate a digital learning environment for lower secondary classrooms. For this, we designed an interactive iBook as well as equivalent paper-pencil-material in order to compare the effect on the students' learning behaviour and learning outcomes. Regarding the design of the teaching unit, we follow the concept of Universal Design for Learning (UDL) [6], which represents a model for joint learning of learners with and without special needs.

(II) The second project aims to develop and evaluate a university seminar that prepares prospective chemistry teachers for implementing digital tools in their lessons effectively and adequately. The study is an intervention study that tests the interventions' effects by using a pre-post-follow-up-design. Based on the adapted evaluation steps by Kirkpatrick (1979), this seminar is evaluated on the four levels *attractiveness*, *cognitive changes, practical implementation,* and *effect on the students* [5]. The first results of the pilot study will be presented and discussed.

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Can Self-Efficacy Compensate for a Lack in Chemistry Knowledge?

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The construct of self-efficacy has gained much interest in the science education community. Introduced by Albert Bandura, self-efficacy has been described as an individual's beliefs about their capability to accomplish certain tasks and achieve intended results [1]. Self-efficacy is also task-specific; for example, a student's perception of their ability to perform at a certain level in a chemistry course would depend only upon their chemistry self-efficacy. Indeed, studies have shown that self-efficacy can be a good predictor of problem-solving behavior and achievement in introductory chemistry courses [2-3]. However, are performance gains resulting from high self-efficacy large enough to offset a lack of prior chemistry knowledge, arguable the strongest predictor of performance in an introductory chemistry course [4-5]? This contribution expands upon that question by including prior chemistry knowledge as a potential moderating variable in the ability of self-efficacy to predict performance in general chemistry courses. Students enrolled in an introductory chemistry course were rated on their self-efficacy for chemistry according to their responses on selected questions in the Motivated Strategies for Learning Questionnaire (MSLQ). Their prior knowledge was assessed early in the course by completing the Toledo Chemistry Placement Examination. Scores from their first chemistry exam were collected from each General Chemistry instructor after the course was completed. Self-efficacy for chemistry and prior knowledge were positively linearly correlated with exam scores, and there was a difference in exam scores between students of low and high self-efficacy, suggesting that self-efficacy may partially compensate for a deficit in a cognitive variable in determining achievement in chemistry courses. This result has broad implications for the classroom, as developing interventions to increase student self-efficacy could potentially close the achievement gap between students of high and low prior knowledge in introductory chemistry courses.

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Convergent-Divergent Thinking of Primary and Secondary School Students Associated with Open-Ended Chemistry Problems

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A lot of chemistry teachers express their concern regarding the thinking levels their students use. They wonder how to improve the higher level thinking skills of their students. Teachers are usually satisfied with the students' convergent thinking during the problem solving, i.e. when they apply the main chemistry ideas logically and produce one correct answer. The key problem of this research is the divergent thinking of primary and secondary school students when they solve open-ended designed chemistry problems, with the contribution of logical, critical and evaluative thinking. Divergent thinking is defined using indicators such as: (i) fluency – the ability to think of many ideas or many possible solutions to a problem, and (ii) flexibility – the ability to use ideas in a new, different, and unusual way [1].

The first examination was conducted with primary school students aged 14 in the school year 2016/2017. The obtained results have shown that 30% of students were able to formulate more acceptable responses to the given open-ended chemistry problems, i.e. the fluency and flexibility of students' answers were indicated. This finding is important because the students from this sample had not had this kind of experience and demands in their previous education. In addition, the primary school students showed that they could combine the previously acquired knowledge of chemistry, connect it with everyday life, and thus find original answers.

The second examination was conducted with secondary school students aged 16 in the school year 2017/2018. It was shown that about 30% of the secondary school students were able to produce different responses in the items which did not require chemical calculations. As far as stoichiometric calculations are concerned, the percentage of students who were able to formulate more acceptable responses to the given open-ended chemistry problems was less than 10%.

The results of these studies can be used to further develop the approaches which support the divergent thinking of primary and secondary school students in teaching chemistry, as well as to monitor and evaluate the effects of such work by evaluating students' achievements in open-ended problems.

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Diagnosing Students’ Misconceptions in General Chemistry using Four-Tier Multiple-Choice Test

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Researchers in the field of science education have reported many techniques for diagnosing students’ misconceptions. Recently, four-tier multiple-choice tests started to gain more interest among researchers [1-3]. These instruments represent modified two-tier instruments, which besides content and reason tiers, contain additional two tiers with confidence rating scales, thus providing more reliable results on students’ misconceptions and conceptual understanding.

This study reports on the development and application of the four-tier instrument as a tool for identification of students’ misconceptions in general chemistry. The instrument consisted of 10 questions designed in a four-tier format which covered topics in high school general chemistry. The test was administrated to freshman students majoring in chemistry, biochemistry, quality control and environmental protection at the Faculty of Sciences, University of Novi Sad, Serbia, right after they enrolled in studies. The instrument was first checked for reliability and validity and then used for misconception identification. Additionally, based on the confidence rating with which a misconception is expressed by students, all identified misconceptions were further categorized as spurious, moderate or strong [1].

In the presentation, the designed instrument will be discussed, and the first results comprising some interesting collected misconceptions will be shown.

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How Chemistry Teachers May Help in Fighting Conspiracy Theories and Hoaxes

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Every day we are faced with many fake news, conspiracy theories and hoaxes. Popular new term even speaks about "alternative truth". People, used to believe to anything that is published in any media, feel upset. They are not accustomed to reading lies and accusations and frequently they are not able to identify among "alternative truths" the right one.

Many frequently disseminated conspiracy theories concern processes in nature or in society, the basis of which lies in science – or they are linked with physical phenomena or chemical properties of substances. Several of them present real threat to health or life of people that believe in them. Chemistry teachers should introduce explanation of conspiracy theories with chemical nature in their lessons. This presentation introduces several "chemical conspiracy theories" and tries to bring scientific explanation of them. Particularly we mention "chemtrails" in the sky, vaccination of children, food additives (with E-numbers), homeopathy, and genetically modified organisms. [1]

Involvement of chemical conspiracy theories and hoaxes in future chemistry teachers' education may lead to preparation of teachers who would become ready to engage students in real problems that people meet in everyday life. Discussion of controversial topics and conspiracy theories may support science literacy and enhance decision making skills of young people. [2]

Non-formal Education and Science Communication and Consumer Chemistry are two subjects of chemistry teachers' education at Trnava University where controversial socio-scientific issues and chemical conspiracy theories have been incorporated. [3]

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Textbooks as Source for Conceptional Confusion in Chemistry Teaching and Learning in School

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To become scientifically literate, building up a well-founded knowledge of the conceptual relationships among scientific ideas and the deeper structures connecting these ideas is crucial. Chi et al. [1] describe this as "effective organization of knowledge with meaningful relations among related elements". Learners often have problems with drawing conceptual interconnections between the big ideas of a topic (e.g. 'acids & bases') because their knowledge is a fragmented accumulation of bits and pieces containing conflicting and naïve notions.

One of the many factors that influence students' conceptual learning are textbooks. On the one hand, textbooks are used by students for learning in class and at home. On the other hand, and even more importantly, many teachers use them for lesson preparation and rely on them to "define both what and how they teach" [2]. For this reason, it is crucial but not sufficient that textbooks present the scientific content in a correct and, for the target group, appropriate way. They also have to support students' learning in perceiving and understanding the conceptual relationships between the big ideas of the respective topic in order to use the knowledge and competences for reasoning and decision making in scientific contexts.

Within the framework of a design-based research project at the Austrian Educational Competence Centre Chemistry (AECC Chemistry) at the University of Vienna, we analysed selected textbooks for primary and secondary science/chemistry education focusing on the topic 'acids & bases'. One of the research questions is: "To what extend do Austrian chemistry textbooks for secondary classes present the big ideas of the topic 'acids & bases' in a conceptually coherent and scientifically adequate way?" Starting with discussing and formulating the big ideas of 'acids & bases', our next steps were to develop a conceptual coherence map [2]. This map is used for analysing the secondary textbooks based on a priorly developed and refined set of encoding rules.

The talk thus gives insight into selected outcomes from the textbook analysis and discusses the value of these findings to explain teachers' and students' widespread confusions and misconceptions within the topic 'acids & bases'.

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What SCIENCE Is? Survey on Students' Opinions

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It is extremely important to understand that despite the inherent tentativeness or uncertainty of scientific explanations (and perhaps to a lesser extent, descriptive "facts") SCIENTIFIC KNOWLEDGE IS THE MOST RELIABLE KNOWLEDGE we can have about the NATURAL world and how it works. This is because scientists have developed a methodology for learning based on principles of CRITICAL THINKING that can enhance or increase greatly the reliability of scientific knowledge [1].

Is the above statement obvious for students representing various science disciplines? Do age, gender or other factors influence students' definitions on science? Which words are used by them to define What SCIENCE is? Does the form of language used by a particular group of students at different ISCED levels affect their perception of SCIENCE meanings?

All these questions were taken into account during presented survey. Almost one thousand students (ISCED 2, 3, 6-8) were assessed. Some of the results of our investigations are unexpected and allowed us to create the students' version of SCIENCE definition.

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Workshops II

3D Notes from Chemistry Lessons

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Molecular modeling kits are widely used in chemistry classrooms across a wide range of student ages. Unfortunately, in all cases, resources (the number of different pieces) in those kits are limited. The user can build a model, but after use has to deconstruct it and put elements back into the kit for another use. From the school perspective, students cannot take models home and use them later.

The solution can be 3D printing technology, that can provide an exclusive model for each student. Some may say that using classical 3D printers is expensive, time-consuming and require designing and technical skills. Using small, hand-held 3D printers (3D pens) can solve all those problems. There are already known attempts to use 3D printing pens for modeling in chemical education. Dean, Ewan, and McIndoe [1] designed a system for visualization geometry according to VSEPR (valence shell electron pair repulsion) theory. Authors also identified the main problem using this technology: “Novices to the 3D printing pen find it difficult to manipulate the pen accurately in three dimensions, and even experts usually generate 3D models by drawing 2D sections and assembling them together to make the final model”. For that reason, their system is based on 2D templates printed on paper sheets. Users cover templates using printing pen and in this way get 2D sections that can be later combined into a 3D model.

During the presentation, a modular modeling kit for drawing chemical molecules using hand-held 3D printing technology that allows drawing models of chemical molecules directly in 3D will be introduced. The presented solution is Authors’ original, patent protected, invention [2].

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Teachers' Professional Learning Communities (PLCs)

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Creating teachers' professional learning communities (PLCs) is an effective bottom-up way of bringing innovation into the science curriculum and professional development. The models of PLCs are based on principles of learning that emphasize the co-construction of knowledge by learners, who in this case are the teachers themselves. Teachers in a professional learning community meet regularly to explore their practices and the learning outcomes of their students, analyze their teaching and their students' learning processes, draw conclusions, and make changes in order to improve their teaching and the learning of their students. PLC workshops for chemistry teachers were initiated two years ago in Israel, at the Weizmann Institute of Science. The workshops operate as a cascade model: A leading team of researchers guides a group of teachers who will lead regional communities of teachers (communities close to home). So far, there are eight regional communities of chemistry teachers in Israel, consisting of Jewish and Arab high school teachers. The main goal of the PLCs is developing trust among the teachers in order to enable them to get acquainted with "The other", who has a different culture [1]; to search together for strategies referring the education for sustainable development (EDS); to deal with curriculum topics; to discuss environmental issues, and to develop socio-scientific issues [2]; During the workshops, the teachers reflect upon their teaching methods, and discuss how to use different strategies in order to change the social views of students in the mixed society, as well as coping with their learning difficulties. Based on interviews with teachers who participate in the PLCs, we may conclude, that such a community has an impact on teaching practices, and may serve as a perfect environment for preparing and encouraging teachers to conduct changes. The changes should be in the curriculum as well in their pedagogical content knowledge, regarding important issues in education, such as preparation of the future citizen in a mixed cultural society. Examples of activities will be enacted in the workshop.

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Lessons that Chemistry Education Can Take from Nanotechnology

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This year chemists around the world will be celebrating 150 years since the periodic table was introduced by Mendeleev. Other basic chemistry concepts and topics were also discovered a long time ago. However, John Dewey[1] stated: "If we teach today's students as we taught yesterday's, we rob our children of tomorrow." Dewey's well-known statement poses a challenge for chemistry educators. This challenge can be addressed by learning chemistry through contemporary research. According to this approach, contemporary research and cutting-edge knowledge should be part of the school science curriculum[2]; thus, finding important insertion points for the topic under investigation is essential[3]. Learning science by integrating contemporary research provides students with an opportunity to receive up-to-date information regarding today's most notable and popular science topics. Students readily realize that current research concerns real people who share similar norms and interests. They also learn about the open nature of scientific queries that await a research-based solution. The nature of scientific questions involves an epistemological belief that incorporates numerous information tools and sources of knowledge. Here I focus on one example of contemporary scientific research – nanotechnology [4]. I will therefore examine how different aspects of nano-scale science and technology influence chemistry education. Different aspects of chemistry education will be addressed, as well as the advantages and challenges that come with introducing contemporary nanotechnology research in chemistry education.

Jonathan Osbrorn wrote that "just as those teaching literature would never dream of attempting to cover the whole body of extant literature, choosing rather a range of examples to illustrate the different ways in which good literature can be produced, has the time not come to recognize that it is our responsibility to select a few of the major 'explanatory stories' that [chemistry] sciences offer?" ([5] p. 9). Here I stress that integrating nanotechnology into the chemistry curriculum could serve as a major pedagogical 'explanatory story' for chemistry class.

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Multimedia and New Technologies in Chemistry Education

„A Day of Noah“ - Anchored Instruction and Digital Media in Science Classes

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In our days learning with digital media is one of the main goals in science classes. However, there is a lack of concepts which bases on didactically developed theories and ideas. This study has an attempt to show an example and gives a direction in closing this gap.

Following the model of Participative Action Research [1] teachers and science educators developed, tested and evaluated a new, video-based concept for science classes. The topic of the lesson plan was “Clothes – my second skin”. A modified anchored instruction [2] was developed, which uses interactive videos as anchors and generates a problem-based and situated learning. The self-produced video uses a continuous storyline through all teaching unit (last 10 hours), which focuses on different topics from the science curriculum. Such story-based learning leads to enthusiasm and interest [3]. Here, the students can interact with the story while making decisions on problems in the videos as well. To make a decision, students need to use scientific knowledge, talk about the problem in a group and communicate it to the character (via text message, email, etc.). These interactivity is a game-based element, which can lead to an increased motivation and meaningful learning [4-5].

The lesson plan was tested with overall 106 students. The evaluation is based on a triangular research design with students, teachers and science educators. The results show students` increased motivation and - for the teachers surprisingly - good learning outcome. The students were interested, curious of the story and discussed very agile. They identified with the main character and had fun helping him with his problems. The developed lesson plan is to be seen as successful and opens a meaningful and promising opportunity to use digital media in science lessons. The idea and the concept can also be used for different topics, subjects and age groups. Further results of the study and details from the lesson will be presented and discussed.

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Multimedia Learning Environments for Heterogeneous Learning Groups in Chemistry Education

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To comply with the UN Convention on the Rights of Persons with Disabilities [1], teaching units have to be universally accessible to all students. The Universal Design for Learning (UDL) offers one possible way of creating an inclusive teaching unit that is accessible for every student. New Technologies and media are very suitable for providing flexible materials and are therefore of particular importance to the UDL [2]. We developed a learning software according to the UDL for two 90 min courses to investigate the effect of a digital learning environment on students with and without special educational needs (SEN). In order to evaluate the developed digital learning environment, we formulated the following research questions.

Q1: Is the learning software suitable for increasing the level of expertise?

Q2: Do the students regard learning with the learning software as attractive?

Q3: Do the students use the learning software and its functions adequately?

In this project, an evaluation study [3, pp. 976-977] is carried out in which the learning environment is examined in the field with N = 89 students at the age of 13-14, including n = 16 SEN-students. We used a multiple-choice test [4] (24 items), an attitude test (30 items, 5-point-Likert-scale, ranging from 1 as positive to 5 as negative) after the first and the second part of the learning unit. Furthermore, the activities on the screens of six selected learners were recorded. Additionally, we interviewed teachers about their thoughts on the learning software since their opinion as experts is very important.

The content knowledge concerning chemical reactions has significantly increased from Mpre = .28 to Mpost = .47 (n = 66, who participated in the two courses as well as in the pre- and post-test). The students (n = 72, who participated in the two courses) evaluated the attractiveness of the learning software positively with M = 1.79 for the first part and M = 1.81 for the second part.

The results of the study suggest that the digital learning unit is suitable for learning about chemical reactions. The analysis of the videos shows that students with and without SEN use functions of the software mostly adequately.

These are the first results and further analysis will follow. Furthermore, correlations between the results of the content knowledge test and the videos will be explored to discover reasons for the learning success.

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How to Teach Chemistry Concepts using Technology: Pre-Service Chemistry Teachers' Technological Pedagogical Content Knowledge

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As technology rapidly improves, classrooms are equipped with lots of technological tools (computers, projectors, tablets). If implemented properly, technology-supported instruction enhances students' understanding [1]. However, it has been reported that teachers do not integrate technology frequently and efficiently in their classrooms [2]. A technological pedagogical content knowledge (TPACK) framework that explains knowledge types has been suggested as a requirement for effective technology integration [3]. In TPACK framework, there are three domains -technology, content and pedagogy- and interactions between and among these domains. This study investigated the development of the pre-service chemistry teachers' TPACK using varied technologies to teach chemistry considering gender.

A single-group pre- and post-test poor experimental design was used and 17 pre-service chemistry teachers participated in the study (14 weeks, weekly two class-hours theoretical and two class-hours in computer lab). The Survey of Preservice Teachers' Knowledge of Teaching and Technology developed by [4] was administered as a pre- and post-test. The purpose of the course was to discuss about simulations, animations, instructional games, data-logging, virtual labs and virtual field trip considering chemistry instruction. During the lab sections, the pre-service chemistry teachers discussed the pros and cons of the educational technologies in designing lessons in terms of chemistry concepts, teaching strategies, prerequisite knowledge, and alternative conceptions. Mixed between-within subjects ANOVA gave the results of the teachers' TPACK at two time periods considering also gender factor. When mean scores were compared considering gender it was found that there was a significant difference between scores, Wilks' Lambda=.56, $F(1,15)=11.54$, $p<.005$, partial eta square=.43. But, the interaction effect [$F(1,15)=.152$, $p=.70$] did not reach statistical significance.

The findings of this study revealed that the pre-service chemistry teachers' TPACK improved at the end of the study. Based on these findings, the development of pre-service and in-service chemistry teachers' TPACK is essential for teaching and learning chemistry and teachers should realize the potential of technology in the real-world classroom environment.

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Enhancement of Physics Teaching for Chemistry Students in General Physics 2: Electricity and Magnetism Using Peer Instruction with I-clickers

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Research in Physics and Chemistry Education has showed that classical ways of lecturing allow a statistical student to retain only ca. 10 % of the lectured material [1]. Thus, there is a substantial drive to develop and promote novel teaching methods and pedagogies with the aim to involve the student within the lecturing process before, during, and after the lecture. One of the methods to involve and motivate the student to learn during the actual lecture is Peer Instruction (PI) [1]. Research in this teaching pedagogy for a period of 10 years at Harvard University in the case of teaching Physics for Natural Science students (Chemistry students involved) has showed an almost 100 % increase in knowledge retention, when PI was used in comparison with traditional lectures. PI involves enhancing the lecturing material by short questions directed to students during the lecture and being directly related to a taught material. The students have to think and answer those questions first by themselves and then again after discussion with their peers nearby. Then, the lecturer discusses how to get a proper answer. The student may receive extra credit for proper answers. PI promotes both quiet critical thinking as well as collaboration with others. The groups of students may also compete against one another. Thus, through an increased number of stimuli, the students remember much better the taught material than in the case of passive listening. PI method can be also facilitated with the usage of i-Clickers (PIiC), which are RF transmitters, whose signals are collected by the RF base and analyzed in real time using a small custom program.

During my talk I will show the results of my implementation of PIiC done in a Spring semester of 2018 for a group of 18 students enrolled in the “General Physics 2: Electricity and Magnetism” (GP2) and taught by me for a second semester students of Chemistry at University of Warsaw. According to my knowledge this has been the first PIiC implementation at University of Warsaw, and quite likely first in Poland. The chosen group of the students was selected in such a way that the discussed implementation of PIiC was not a major language hurdle, since they were introduced by me into Physics in English during their 1st semester at Chemisty UW via the course “General Physics I: Mechanics”. I will discuss particular teaching pedagogies of PIiC I have chosen and the resulting students attitudes. I will also discuss the results of the prior and post-teaching BEMA test (Brief Electricity and Magnetism Assessment) [2], which I have conducted among GP2 students to compare their knowledge retention with respective American students. I will conclude with my remarks about proposed improvements and changes for the next iterations of GP2 with PliC for Chemistry Students as well as implementations of PIiC to other Chemistry subjects.

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Using flipped videos to improve GCSE Student Performance and Confidence in Answering Exam Questions on Required Practicals

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With the recent changes in GCSE (14-16-year-old) and A-level (16-18-year-old) specifications, there is a greater emphasis on students applying knowledge of experiments students in class to a new novel context. Assessment of practical chemistry skill has changed from coursework to written examination format. This research seeks to identify whether flipped learning videos presented on the Edpuzzle webpage (www.edpuzzle.com) develop students confidence in answering exam style questions on practical chemistry.

Over recent years flipped classroom has received significant attention as a tool which can be used to improve student performance and attitudes [1,2]. In high schools. digital badges have been shown to improve student attitudes towards practical chemistry [3]. This research seeks to identify whether learning gains and improvements in students' attitudes is observed with students in compulsory science education at secondary school.

In this research a mixed methods approach was used to collect data. Likert scales and short answer questionnaires (n=15) were used to highlight starting point for student confidence in answering questions on practical chemistry. Coding was used to identify rends in student responses. Before students conducted the practical they watched a "how to" video on the practical which had been prepared by the examination awarding body. These videos were hosted on the platform Edpuzzle (www.edpuzzle.com). The advantage of this platform is it allowed for multiple choice, short answer and extended answer questions to be imbedded into the video. Students responses to these questions were collated in advance of the lesson to act as a prompt for teacher support in advance of completing the practical.

During the process of this research project student performance in a formal mock examination were analyzed. This mock included practical and theory questions and students' comparative performance on practical style questions was reviewed. At the end of the project students answered a second questionnaire (n=7) using a Likert scale format to review their confidence in answering questions on practical chemistry.

This project identifies that students felt significantly less confident about questions assessing practical skill compared to non-practical theory questions. Justifications included that students felt less confident around identifying distinct variables such as controls, a skill which would have been expected in old practical course-works.

After two required practicals. students were asked to give feedback on the flipped material and justify their thought process and identified clear examples as positive features of the videos but also highlighted a frustration that the practicals reviewed in example flipped material were not consistent with questions in example sample assessment material.

Analysis of mock exams showed that students performed better in the majority all theory topics except for mole calculations, with average scores on these questions ranging from 70-90% compared with an average score of 66% in practical questions. Final questionnaires showed that although students felt more confident about answering questions on practical questions, they remained less confident compared to questions on chemical concepts.

In conclusion the flipped classroom resource did not significantly improve students' confidence in approaching exam style questions on practical chemistry. Lower student participation (n=7) in a second questionnaire made any conclusions made more muted. The timing of this research project may have adversely impacted the findings. Further research is required to review the impact of flipped teaching on larger cohorts of GCSE students.

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Understanding Precipitation Reactions through Critiquing Animations in Variance

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Learning chemistry involves understanding chemical phenomena at macroscopic, symbolic and particulate levels, as well as transferring information from one level to the other [1]. Understanding chemical reactions at the particulate level has been challenging for many students because they might have difficulty in making connections among these levels. It can be suggested that students might better conceptualize chemical phenomena if they are engaged with particulate level visualizations referring to observable processes. If this engagement includes watching, creating, critiquing and reflecting, their mental models might be improved.

This study aimed to investigate the effects of watching and critiquing two conceptually varying animations on pre-service teachers' mental models of precipitation reactions. Twenty preservice chemistry teachers first watched a 3-minutes video of a precipitation reaction, then prepared a particulate level representation of this reaction through storyboarding and generating animations. One week later, they watched two animations with varying conceptual accuracy. More specifically, one of the animations was conceptually accurate and the other one was conceptually inaccurate. Half of the preservice teachers watched the correct animation first, and half did the opposite. After they watched the animations they critiqued them according to their accuracy, important features, the features supported and refuted by experimental evidence. Finally, they regenerated storyboards and animations.

Data were coded with respect to the emerged themes and categories. The mental models of preservice teachers fell in to four categories; fully structured, moderately structured, weakly structured, and alternative. Before critiquing the animations, initially, it was observed that the majority of the preservice chemistry teachers had mostly moderately and weakly structured, and a few of them had fully structured mental models. When they critiqued the animations, only one student fully identified the inaccurate features in the animation, twelve of them identified one aspect of the inaccurate animation, and seven of them thought that the inaccurate animation was correct. The majority of them had hard time in connecting the particulate level representations to experimental evidences shown in the video. When they were asked to regenerate the storyboards and animations, it was observed that their mental models were said to be improved due to inclusion of some of the features into their revised representations. All in all, active involvement of students through critiquing animations in variance and modeling particles as they make connection between macroscopic and particulate levels may help students better conceptualize chemical processes.

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Posters

The Influence of Metacognitive Awareness on Preservice Chemistry Teachers' Understanding of Gas Behavior

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Metacognitive awareness plays a key role in student learning, more specifically in conceptual change, by helping students to notice the inconsistencies between their alternative and scientific conceptions [1]. Drawing upon the crucial role of metacognitive awareness in science learning, this study intended to explore how the level of metacognitive awareness of preservice chemistry teachers affect their understanding of gas behavior before and after the multirepresentational (MR) instruction on gas behavior.

This mixed method study adopted a quasi-experimental comparison group design with a pre- and posttest. A total of 34 preservice chemistry teachers participated into the study. The data was collected through a five-point likert-type metacognitive awareness (MA) survey [2] and an open-ended questionnaire, including 16 items about gas behavior. The participants took the MA survey only before the instruction but provided written responses to the questions on the open-ended questionnaire before and after the instruction. All participants received the 12-class-hour long MR instruction on gas behavior. The data was analyzed by both quantitative and qualitative methods. First, based on their MA survey scores, the participants were divided into two groups as high-MA and low MA, then their verbal responses about gas behavior on the pre and posttest were coded in two forms. By using numerical data, t-test was conducted on the pre and posttest scores. Before the instruction, the t-test results indicated a statistically significant difference across the groups in favor of high-MA group in terms of understanding gas behavior. However, after the instruction, t-test results showed no statistically significant difference across the groups in terms of understanding gas behavior. For qualitative analysis, the descriptive codes emerged from the data were narrowed down into six categories of understandings, ranging from scientific to alternative. On the pretest, no students in both groups showed full scientific understanding of gas behavior. Yet, 60% of high-MA students showed understandings of either scientific fragments or scientific with alternative fragments. Only 20% of low-MA students exhibited the same types of understandings as their peers in high-MA group, but about 80% of low-MA students held understandings of either alternative with scientific fragments or alternative. On the posttest, the distribution of types of conceptual understandings were similar and mostly scientific in both groups, and no students in each group exhibited mostly nonscientific understandings. Findings showed that the high-MA students held more scientific understandings of gas behavior compared to low-MA group before the instruction, but it appeared that the MR instruction on gas behavior served equally well for both high-MA and low-MA group in terms of promoting their scientific understandings of gas behavior.

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Motivating students of health sciences to study science through scientific projects

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Lack of interest in science is a problem faced by first-year non-disciplinary teachers such as nursing, occupational therapy, medical technology, nutrition and dietetics, etc. The factors that influence the motivation of students towards the study of science can be related to (i) notice a connection between what is learned and daily life, (ii) value the importance in their future carrier, (iii) students self-appreciation about their knowledge in science, (iv) methodologies used by teachers.

In this work, we present a science motivational experience with nursing and occupational therapy students, who have taken a course called “Funny Science” as a part of their elective curricular activities. The program includes activities in order to encourage student for experimental science, starting with a class of biosecurity and basic laboratory material manipulations. Once the proposed practical activities are finished, the students had three weeks to present their own scientific projects what were presented in a vulnerable school as a science fair. They are not given a particular problem. It is up to them to find one, dealing with chemistry, biology, microbiology, or cosmetology.

The results indicate that this type of course is useful to place science in context and integrate different disciplines more than in a traditional laboratory course. Then, some of those experiments and methodologies will be incorporated to regular courses of chemistry, biology, microbiology, organic chemistry, biochemistry and others.

The cognitive, procedural and attitudinal competences were evaluated through rubric throughout the course, including the scientific fair. In addition, a final survey was applied to students to know their perception of science in an academic and daily context.

In general, there was a positive evaluation in aspects such as a greater integration of several scientific disciplines such as biology, chemistry and microbiology.

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Going Digital in the First Year University Chemistry Laboratory

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In order to provide a greater variety of digital learning experiences for our first year students we moved to digital delivery of our laboratory courses. We had a small number of iPads available in the laboratory that we were using with data loggers and we invested in more so as to have one available for every two students. We then shifted from using a printed laboratory manual by creating a series of pdf files for each experiment that are made available to students through the learning management system as well as being accessed on the iPads during the laboratory sessions. The iPads made it possible to introduce a range of useful resources to support the different types of experiments carried out, including links to data tables, videos for out new techniques, notes to support processing of data and animations and simulations to enhance understanding. On-line submission of laboratory reports has been incorporated, and extended to include other assessment item. Establishing the digital platform for the laboratory programme has allowed the development of a different style of laboratory learning with more guided inquiry or problem solving opportunities and greater links to the lecture content. Students and staff have responded favourably to this new regime and there have been unanticipated benefits associated with the on-line assessment submission. We report on the development of the digital delivery process, student and staff evaluations and the potential for new learning opportunities now available in the laboratory component of our courses. [1]

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Design and First Use of a History of Science-Based Resource to Introduce Basic Concepts of Chemistry

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The symbolic language of chemistry is viewed as a bridge between the macroscopic and submicroscopic levels [1] and thus constitutes a meta level of knowledge [2]. We assume that the symbolic language, the concepts of submicroscopic and macroscopic models, of the empirical register should be taught in a dialectical way to encourage the students to make links between the different registers and levels. We designed a resource to put this hypothesis to the test. We followed a method close to that of the Model of Educational Reconstruction [3]: clarification of the content, elicitation of the students' difficulties, determination of the teachers' needs, building of a pilot resource, appropriation and use of this resource by volunteer teachers, analysis of the implementation in the classroom, modification of the pilot resource. In this presentation we set out the design of the resource and its evolution. From controversies identified in the history of science, we worked out a pilot resource on the introduction of chemical formulas for grade 8 students in France. In the first part, the students are told to choose between different symbols proposed by chemists (Hassenfratz and Adet, Dalton, Berzelius) to realise that the language of chemistry is a human construction subject to evolution [4]. In a second stage, some Dalton's and Gaudin's texts are presented to the students to work out the reasons that enabled chemists to construct the formulas of water, oxygen and hydrogen. The resource was submitted to two teachers who both rejected the second part considered too complicated. We studied the implementation of the first part by one of them, who had been observed the previous year in an ordinary teaching session. We noted that his class management was unchanged, the terms used regarding the macroscopic empirical level and the submicroscopic model were still imprecise, the tasks had more varied goals, the students proposed a wider range of writing chemical formulas (e.g. OCO, COO, OOC) which were accepted by the teacher. The post-session interview showed he still did not grasp the meta level role of the symbolic language and did not see the need to justify the chemical formulas. After this first implementation, we totally modified the second part of the resource and decided to focus on the opposition between Dalton's ideas and those of atomist organic chemists such as Kekulé. To make this controversy more accessible to the students, we replaced the historical texts by dialogues between fictional characters. This second version has just been tested by a teacher, the analysis of the teaching sessions is going on.

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Improvement of Teachers' Understanding about Redox Reactions in a CPD

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Redox reactions (RR) have been identified as one of the most difficult subjects for both learning and teaching [1]. Many studies report students' difficulties related to this content. Some of these difficulties have been attributed to failures in teacher training [2]. In this sense, it is important to promote continuous professional development (CPD) programs about RR, not only for an updating of the teachers, but also to supplement possible deficiencies in the initial training courses. The purpose of this study was to evaluate if a CPD program contributed to improve the understanding of fundamental concepts of RR.

This study is the result of a research based on data collected over a forty-hour course, with theory and experimentation, for a group of twenty-one secondary chemistry teachers. Data were collected through a test, with 18 open questions, before and after the course. To assure trustworthy, a rubric was developed for all questions and two researchers codified the answers. The answers were analyzed through a Rasch analysis [3]. To verify the influence of the CPD program in the teachers it was used stacking data method [4]. A paired samples t-test was conducted to verify the significance of the change in teachers' knowledge.

In the stacked data, the outfit z-standardized values for all questions and for most of the teachers were within the expected range of -2 and +2 [4]. The questions separation and reliability indices were 3.52 and 0.93, respectively, and the person separation and reliability indices were 2.40 and 0.85, respectively. These Rasch fit statistics mean that the stacked data showed an adequate fit to Rasch Model. In relation to the improvement of teachers understanding, 20 of 21 teachers increased their knowledge measure. The mean pre-test knowledge measure was -0,43 and the mean post-test was 1,24. According to the t-test, the post-test measures were higher than the pre-test ($|t| = 7{,}06$, $p < .0001$).

From the analysis, it is possible to infer that the participation in CPD program improve significantly teachers understanding about RR. However, it is important to investigate these teachers after a long period of the end of the course to verify retention of the content.

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The Effect of Educational Games on Student Motivation and Achievement in Science

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For educators, the important goal is to figure out the way how students learn effectively and retain knowledge. While students construct the new knowledge, they are active through tasks through self-talk, inner speech, guided-participation, scaffolding, apprenticeships, and peer-interaction. Educational games are entertaining and increase engagement in classroom environment, hence could promote motivation in science learning [1]. In addition to cognitive perspective of learning process, affective perspective of learning process should also be taken into account such as attitudinal or motivational process [2]. Therefore, the purpose of this study was to investigate whether there was a significant effect of educational games and gender on student motivation and achievement in science education.

Twenty-one 7th grade students took part into the study. The independent variables were groups and gender, and the dependent variables were motivation in science and achievement in the science course (GPA). The Motivated Strategies for Learning Questionnaire (MSLQ) was used to measure students' motivation in science learning. A quasi-experimental design that takes account of already existing groups [3] is used as an experimental design in this study. The students in the experimental group constructed educational games integrating science concepts (such as periodic table, particulate nature of matter, etc.). On the other hand, in the control group the students were taught science in teacher-centered manner. A mixed between-within subjects multivariate analysis of variance was conducted to assess the impact of two different interventions (educational game and non-educational game groups) and gender on students' motivation across two periods (pre-MSLQ and post-MSLQ) and student achievement across two periods (pre-GPA and post-GPA). There was a significant interaction between groups and gender on student motivation indicating girls in the non-educational games group scored higher motivation in science, but boys enrolling the educational games group revealed more increase on motivation in science than whom not enrolling. In addition, there was a significant interaction between student motivation and achievement indicating when student motivation was nearly the same, science achievement did not much differ; but when student motivation differed, science achievement was positively affected.

Therefore, the results of this study revealed that educational games effected on student motivation and achievement in science, but gender was deterministic variable. In addition, increased motivation promoted higher achievement in science. Other instructional strategies that increase girls' motivation and achievement in science should be also investigated.

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Philosophically about Matter – from Antiquity to Present Day – How Do I Teach Students With Special Needs the Atomic Theory

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In the education system, autism and Asperger Syndrome are recognized as a disability requiring a special organization of learning and working methods.

In our school each particular lesson has to be constructed in such a way to help students shape soft skills such as: preparing independent written or oral statements, student self-reflection, searching for information, perseverance and patience in the task being done, independent learning, cooperation with others, solving of problems on their own, constructive criticism, drawing conclusions and reasoning.

Stories are the way we store information in the brain. If teachers fill their students' brains with miscellaneous facts and data without any connection, the brain becomes like a catchall closet into which items are tossed and hopelessly lost [2]. A lesson should then tell a story to attract attention of students with special needs. The lesson about the constitution of matter starts with a short introduction to logic and logical consequence (entailment). Then, to stimulate the imagination of students (ISCED 2 level) I use short popular science texts concerning philosophers and scientists views on the constitution of matter, available on site of the National Center for Nuclear Research [2]. A worksheet for students help them draw reflections about different tools available for the theories verification. Students imagine how is matter build according to Leukippos, Democritus, Epicurus, Galileo Galilei, Pierre Gassendi, Platon, Aristotle, William of Conches, Nicolas of Autercourt, Robert Boyle, Isaac Newton, Ruder Josip Bošković, John Dalton, Joseph John Thomson, Ernest Rutherford, Gilbert Newton Lewis, Niels Bohr, Arnold Johannes and Wilhelm Sommerfeld. After the short discussion about each theory students try to draw models of atoms elaborated by: Democritus, Epicurus, Thomson, Rutherford, Bohr as well as the quantum model.

The lesson construction as well as exemplary students' worksheets will be presented.

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A Journey into the Land of the Chemical Elements – Storytelling During Chemistry Classes for Students with Special Needs

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Pupils with special educational needs are not always taught in an integration and special classes and schools. However, they always have the right to special organization of educational conditions, adapted to their difficulties and deficits, and to include them in the necessary forms of therapy [1]. In the education system, autism and Asperger Syndrome are recognized as a disability requiring a special organization of learning and working methods.

Even students with low motivation and weak academic skills are more likely to listen, read, write, and work hard in the context of storytelling [2]. Because class members and teachers are emotionally involved with and usually enjoy storytelling, it can help students develop a positive attitude toward the learning process. It also produces a sense of joy in language and words that is so often missing in the classroom setting. [3].

Classes were conducted for students ISCED 2 level with special educational needs (Asperger Syndrome, aphasia, ADHD, vision problems). In order to attract students' attention and become interested in the topic of the structure of the periodic table and the properties of chemical elements, I used the texts from the book by Peter William Atkins: The periodic kingdom – a journey into the land of the chemical elements, detailing the geography, history and governing of this imaginary landscape [4]. Each of the students received their blank periodic table to complete, periodic table of elements with basic information, and then during my story telling and reading the excerpts of the book was to fill the empty periodic table with information. The students' task was to transform text into images that tell a story (a map of the Periodic Kingdom)

The lesson plan as well as exemplary students' works will be presented.

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Sorting out Chemistry Concept Inventories on a Collaborative, Dynamic and Low-Maintenance Infrastructure

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Since the publication of the Force Concept Inventory [1], back in 1992, and, in chemistry, the presentation of the Chemistry Concepts Inventory in 2004 [2], many chemistry education researchers and chemical educators have developed instruments of this type to characterize learners' understanding of different topics. While concept inventories are a good way to diagnose students' prior ideas and many of these exist, it is usually hard for educators to find the instruments and enough data to evaluate the quality of a specific questionnaire.

Although the authors are aware of previous efforts in cataloguing and making a database to ease finding and evaluating these tools either in chemistry or more generally in science, only a project in physics, PhysPort [3], seems to be currently active. Hence an easy way to access the concept inventories in chemistry, is still missing

This poster will present a simple project to build a collaborative infrastructure to organize and make accessible the chemistry inventories designed and tested by the chem-ed community. This infrastructure, currently at https://tinyurl.com/chemcidb, pursues the following objectives:

- be easy to maintain and easy to contribute,
- use dynamic-generated content as much as possible (calling webservices or using links to the web),
- have its data open.

Its initial and current design is based on two Google sheets, one for the database and second one for the interface. Help is more than welcome!

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InChI Open Education Resource

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This poster will describe an Open Education Resource (OER) designed to help chemists, educators and students find information on, and applications of, the IUPAC International Chemical Identifier (InChI) [1]. InChI is a machine readable semantic identifier based on layered line notation for the representation of chemical structures that was developed by IUPAC and NIST. InChI is an open and freely available identifier, used in many chemical data bases and other open cheminformatics tools. The standard InChI and its correlative hashed key arguably being the new nomenclature of the digital area, enabling a wide variety of 21st century semantic web applications and activities that should be utilized in chemical education and the practice of chemistry.

Usage of the World Wide Web has become ubiquitous by practicing chemists in the pursuit of science, and yet few take advantage of semantic features that advances such as InChI enable, for instance connecting data collections, instead navigating the web the same way they would a book, browsing from one webpage to another. In 2017 the InChI Trust initiated a working group to tackle issues related to the adoption of InChI by the greater practicing community of chemists, and the InChI OER is the first project of this working group.

Using the InChI OER, chemists, educators and students can find resources on InChI. This will include downloadable classroom and reference materials such as modifiable documents and spreadsheets. This poster will describe the InChI Open Education Resource designed to help chemists, educators and students find information about and applications based on the InChI standard.

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Using Eye-Tracking Approach to Explain Students' Achievements in Solving the Task about Burning by Applying Chemistry Triplet

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Applying macro-, submicro- and symbolic levels of chemical concepts representations (chemistry triplet) at all levels of education is an essential part of chemistry teaching and learning. It is significant to understand how students are able to translate the chemistry triplet in solving specific problem. Chemical reaction is one of the fundamental concepts in chemical education and burning as one of the specific example. Eye-tracking technology can offer possibilities to monitor cognitive processes due to the links between eye movements and cognition [1]. The duration and the frequency of fixations are associated with the ongoing mental processes related to the fixated information [2]. Research [3] also indicate, that students who select inaccurate animation of chemical reaction are often enticed by a model that is easier to explain and fits with their understanding of reaction equations.

The research problem was to explore students' achievements in solving chemistry triplet and context-based task about chemical reaction, more specifically burning. The objective is to determine the differences between students who selected the correct chemical equation presenting burning of methane (G1) and those who had not (G2) in absolute total fixation durations (TFDs) and fixation counts (FCs) on macro and dynamic 3D animation of particles (SMR) representing burning of methane at the submicro level.

Forty nine students participated in this research (average aged 16 and 23 years). Questionnaires, tests and the eye-tracking (the screen based EyeLink 1000) with computer-displayed task was used to gather the data. Participants were divided into two groups according to their selection of the chemical equation. The differences in pre-knowledge, motivation, formal-reasoning and visualization abilities, general intelligence and working memory capacity, between the two groups are not significant.

Results show that TFDs on the SMR for G1 (Md=2.0s; IQR .5-5.0s) were significantly lower than for G2 (Md=14.0s; IQR 1.7-27.0s; Mann-Whitney U=163.0; p=.022). Similar results were obtained for FCs on the SMR (G1: Md=9; IQR 3-12; G2: Md=50; IQR 4.5-68.5; Mann-Whitney U=171.5; p=.034). TFDs on the chemical equation for G1 (Md=19.5s; IQR 11.4-26.7s) were significantly higher than for G2 (Md=5.7s; IQR 3.6-28.1s; Mann-Whitney U=165.0; p=.025). Similar results were obtained also for FCs on the chemical equation (G1: Md=63.5; IQR 47.3-97.3; G2: Md=20; IQR 16.5-87.0; Mann-Whitney U=162.0; p=.021).

The significance of this research is to understand how important different levels of chemistry triplet are for students in solving specific problems. It can be concluded that students who selected the correct chemical equation spend less time processing 3D animation of methane burning. However, more successful students spend more time on the correct chemical equation mentally analysing it without seeking much information at macro- or submicrolevel.

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Fourteen Years Old Slovenian Students' Understanding of Atmospheric Pollution

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In addressing environmental issues, it is imperative to begin with the young generations as they are the ones who will inherit and safeguard the survival of the Earth [1]. The primary school is the natural place to introduce children to environmental education, since at this level they instinctively have a holistic view of the environment; they have not yet been trained to compartmentalize their learning into separate subjects [2]. Therefore, our aim was to identify 14-years-old student's understanding of factors that influence air pollution.

Altogether, 1012 primary school students grade 9, average age 14 years, from 24 schools (5.3% of all primary schools) in 11 different regions of Slovenia, participated in the study. A three-tier atmospheric pollution phenomena diagnostic test (APPDiT), to identify primary school students understanding of acid rain (AR), global warming (GW), ozone layer depletion (OLD) and photochemical fog (PHF) was applied. The APPDiT comprises fifteen tasks. Each task testing an understanding of a different atmospheric pollution phenomenon and has two separate parts. In the first part participants had to answer the question about knowledge of atmospheric pollution phenomena. In the second part they had to identify the right explanation for it. The construct validity of the instrument was confirmed by six independent experts in chemical and environmental education. The design of the research was non-experimental, descriptive and cross-sectional. The research was conducted in April 2017. The instrument was applied anonymously and all the participants had the same conditions for completing the questionnaire and they spent on average 45 minutes to fulfil it.

The results showed general misunderstandings on atmospheric pollution with the overall success rate of only around 40.0 %. It was found that around 36.7 %, 5.1 %, 42.8 % and 19.1 % of students recognise and understand the reasons of the AR, the GW, the OLD and the PCF, respectively. From here, it is clear that students overall knowledge on the particular atmospheric phenomena is low with the lowest understanding on GW. However, students expressed the highest levels of understanding the OLD.

It can be concluded that the average primary school students' (grade 9) score on the APPDiT is not sufficient and more emphasis should be placed on developing the understanding of atmospheric pollution factors. Since we found specific environmental topics about air composition and pollution already in curricula for 5th and 7th grades and not anymore in the later grades, it is reasonable to assume that students tend to forget basic concepts on this topic. It is also important to emphasize, that teachers should present GW more clearly to the students, due to the fact that this atmospheric pollution phenomena is the most important one in the last decade, and students' knowledge about it, the weakest.

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A new concept of teaching basic chemical principles in primary school, with particular emphasis on the concept of a mole

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In the age of information flood, factual teaching has completely lost its value. Modern man, who in a fraction of a second can reach almost any information, needs also tools that will allow him to critically evaluate its correctness and credibility. Chemistry is one of those school subjects that cannot be taught only with transfer of knowledge (facts), but first and foremost it requires grasping and understanding the connections between them, and so - it teaches logical thinking. Unfortunately, this huge potential of chemistry as an exact science is only used to a small extent at school.

A negative example of this is the way of introducing the concept of an atom at school. The current core curriculum is structured in such a way that it obliges the teacher to introduce atomic theory in the first months of learning chemistry in primary school. For every well-educated chemist, an atom is a real and completely understandable concept. However, for the student who first hears about it, it is a completely abstract construct, because of its invisibility and immeasurability. As part of my master's thesis, I developed a new, original way of teaching basic chemical principles in a primary school based on a mole - a concept perceptible better than an abstract atom.

The chemistry curriculum I have developed assumes that the concept of an atom will be introduced only after familiarizing students with the basic, and not so abstract, concepts and laws of chemistry. In my plan, the program puts a lot of emphasis on independent discovery of chemical laws (mass conservation law, law of definite proportions, then atomistic theory) and self-performed (during the lesson) determination of many constants and characteristic quantities (density, compound composition, molar mass, molar volume, atomic mass, empirical formula, molecular formula). As a result, instead of (current) traditional teaching about chemical formulas and equations, chemical knowledge will be passed in such a way as to be an school subject on which the student learns to study the world, observe, weigh, measure, construct hypotheses and verify them.

In my thesis I also describe a set of appropriate laboratory experiments to be done by students or a teacher during the lesson.

Action Research to Innovate Science Teaching - an ERASMUS+ Capacity Building Action in Science Teacher Education

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The focus of the Action Research to Innovate Science Teaching project (ARTIST) is to innovate science education through classroom-based and teacher-driven action research [1]. Action research aims the cyclical transformation of authentic practices through the action research cycle of innovation, research, reflection, and further improvement of the innovation approach [2].

Action research is a valuable and broadly applied strategy for innovations and continuing professional development of teachers in science education [2]. Beyond the interest of concrete change and innovation, action research aims for the generation of knowledge and best practice strategies, serving as patterns for innovations in the field of interest in general, but also in contributing to the continuous professional development of the acting practitioners [3]. ARTIST considers action research to be one of the most promising strategies for innovating science education and creating evidence-based classroom practices in domain-specific educational studies.

ARTIST aims and capacity building in the participating countries by innovating science teacher education, doing action research case studies in networks of HEIs, schools and industry, and by providing resources for implementing action research into teacher education. One part of ARTIST is also to establish a new forum for exchange and presentation of action research and innovation studies, namely the international journal Action Research and Innovation in Science Education (ARISE).

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Summary of the Project Entitled: Frequently Unasked Questions in College Chemistry (FuAQ)

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Active participation of students during lecture time may be negatively impacted by factors such as sense of inadequacy, shyness, fear of public speaking, negative pass experiences and other reasons that might prevent students' spontaneous participation. The proposed FuAQ strategy pursues channeling all these unspoken questions to:

1. Create an anonymously friendly vehicle to voice out all these questions in real time using a smart device application
2. Utilize FuAQ as a tool to diagnose cracks and flaws on the instructional process
3. Improve instructors, coaches and tutors effectiveness in addressing the real academic needs of our students
4. Utilize technology to support BCC's (Bronx Community College) efforts to provide the best and more fruitful academic experience for our students
5. Make the learning process more dynamic , interactive, productive and fun

Applications specially crafted for smart devices have become in a reliable tool to speed up a given process without having to waste time navigating the web to find answers for our questions. The objective of the proposed application is collecting questions in real time from attending/face to face or online students that otherwise would not feel comfortable to publicly ask them during lecture time and giving them answers timely.
Finally, the educational instruction runs the risk of becoming a dull process at some point because, unresolved questions will piled up and escalate progressively into a total disengagement of the affected student population if instructors, tutors, coaches do not have the right tools to timely detect problems and offer effective solutions, so we can retain our students and increase the rate of graduation of our programs.

Remote Experimentation in Science Teaching: Perceptions of Undergraduate Students and Teaching Professionals

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Different technological resources are available for science teaching and have been studied in recent decades. Among these, the use of remote laboratories (RL) has shown a growth in the last decade because it is characterized as a hybrid teaching proposal and that allows the development of competences aimed at student autonomy [1]. Understanding the impacts of the use of this resource on teacher training and real teaching environments is necessary and the objective of this work was to develop a RL and investigate its use in two different real contexts: in a postgraduate course for teachers of sciences and an undergraduate course in chemistry, aiming to understand the perceptions regarding of the use of RL.

An RL was built with an Arduino UNO board, associated with an ESP8266 board (with integrated WiFi) and using the Moodle platform as a way of linking the video system. The experiments were the Briggs-Rausher reaction and an experiment to determine the reaction order of the thiosulfate ion in reaction with hydrochloric acid. Data collection was done from a open-ended questionnaire about the participants' perceptions regarding the positive and negative aspects of RL use. Content analysis was performed for the responses [2]. In relation to the answers obtained, it was possible to construct categories for positives and / or benefits and categories for negative aspects and / or losses presented in table 1.

Categorias encontradas para pós-graduandos em ensino (18 respostas)		Categorias encontradas para alunos da graduação em química (42 respostas)
CP 1. Possibility / accessibility to practical / experimental activities even with lack of resources (10 replies)		CE1. Contributions to learning and use in low-resource environments (16 replies).
CP 2. Contributions to the professional practice of teachers (8 replies)		CE 2. Working with Real Problems (13 replies)
CP 3. Contributions to students' teaching-learning (8 replies)		CE 3. Relationship theory and practice (25 replies)
CP 4. Resources (8 replies)		CE 4. Resources (5 replies)
CP 5. Negative Aspects for Pedagogical Practice (5 replies)		CE 5. Organization of activity / time and planning (21 replies)
CP 6. Negative Aspects for Students (5 replies)		CE 7. There were no negative aspects (16 replies)

Table 1: Emerging categories of data analysis for teachers and students.

It was possible to relate positive perceptions in the different groups that agree with aspects already mentioned in the literature about technological resources [3, 4] such as categories CP3 and CE3, and particular aspects of RL, represented in CP1, CP2, CE1 and CE2. A large number of students reported no impairment in the use of RL (CE7) and the need for specific organization and planning as well as the need for resources to use was highlighted by both groups. The use of remote experimentation in the studied groups proved to be a viable alternative for conducting didactic experiments according to students' and teachers' perceptions. It should be noted that during the experiments described, some adjustments were made in relation to the technology used, both image and data transmission have been optimized to provide the information with a shorter latency time.

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Fourteen-year-old Students' Misconceptions Regarding the Submicroscopic and Symbolic Levels of Specific Chemical Concepts

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Teaching and learning chemical concepts at their triple level provides opportunities for the development of misconceptions [1]. In chemistry teaching, the integration of the triple nature of chemical concepts and the use of diverse educational materials and teaching approaches are essential for the adequate development of mental models of chemical concepts, which also affect problem-solving abilities [2, 3].

This research aimed to identify potential misconceptions of chemical concepts at triple level of representations. The researched topics are: the states of matter, a pure substance, a mixture, an element, a compound, a physical change, and a chemical reaction at the submicroscopic level when solving problems incorporating submicrorepresentations (SMR).

A total of 188 14-year old students, attending six different elementary schools, participated in the research. A chemistry achievement test comprising five problems at the macroscopic, submicroscopic, and symbolic levels was used to obtain data about students' misconceptions of selected concepts.

The results showed that the majority of students had formed inadequate mental models (misconceptions) for the chemical concept of the liquid state of water (66.5%). The lowest level of misconceptions is related with the gaseous state of matter, because almost all students (98.5%) solved the problem correctly. Students often expressed a misconception of a compound, related to the non-differentiation between the SMR of molecules of an element and the molecules of a compound (38.8%). The most common misconception of physical change (21.2%) is related to the fact that students think that physical change is actually a chemical reaction. Therefore, most of the our research results are consistent with the fact that the submicroscopic level is more difficult for students to understand, which is related to the invisibility of the particles in matter.

It can be concluded that the results of the research are significant for chemistry teachers, because they can: select and apply adequate educational strategies to avoid the deepening or development of misconceptions and make the courses practically oriented by analysing students' misconceptions and develop teaching strategies to minimise these problems in the chemistry classroom.

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Teachers Understanding in Redox Reactions: Redox Models, Simultaneity and Reducing Agent

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It is known that, in the teaching of chemistry, the redox reactions (RR) are a difficult subject for both learning and teaching and research has documented students' misconceptions in this topic [1]. Some of difficulties may be due the existence of different models for the explanation of this content. The use of these models by teachers without explanation may favor the emergence of students' misconceptions [2]. However, studies on teachers' conceptions of RR are still scarce [3]. Thus, it would be important to study teachers' understanding of RR, the redox models used in teaching, and how they justify them.

In this way, the aim of this study was to investigate secondary chemistry teachers' understanding of RR, more specifically redox reactions models, simultaneity and reducing agent. Data were collected with 24 chemistry teachers through an adapted questionnaire [4-5], in which it was required to identify i) RR in nine equations, ii) simultaneity, and iii) reducing agent in two situations: iron in natural environment and iron in contact with copper in natural environment. Two researchers analyzed the data by codifying teachers' answers.

Results show that the oxidation number was the most used model (48%), followed by the electron model (24%). It was also observed that the electron model was more used than oxidation number just when the electron was explicit in the equation. Regarding to simultaneity, 75% of the teachers claim that the RR occur simultaneously. In relation to the third item, 88% of teachers identified the iron as the reducing agent, while in the situation 2, the answers were disperses: 38% iron, 33% copper, 21% no answer, and 8% others.

From the results, it was observed that teachers present some difficulties in relation to the content of RR, mainly to use different models and recognize the reducing agent. It is suggested more continuous professional development programs about RR. They could discuss the activity series of metals in the RR in order to improve in-service teachers´ identification of reducing agent in different situations.

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And You, Do You Protect Yourself from the Sun? An Interscience STEM Project to Develop Critical Thinking about Risks of Sun and Effectiveness of UV Solar Filters

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STEM education involves students in scientific research processes for learning new concepts within a practical process of design and problem solving, similar of those of the real world [1]. Learning based on projects (PBL) is increasingly used nowadays [2]. Some of them focus in the construction of the theoretical models and other in using them, and this project seeks a balance between both approaches and teachers can adapt it to their aims.

The STEM project designed [3] is an open proposal addressed to students aged 15-17 and that integrates curricular contents of Biology, Geology, Physics and Chemistry and asks team working. It starts from a common situation such as the risks and benefits of sun exposure and promotes critical thinking to make scientifically argued decisions. Students are asked to look for information from labels of suncreams and discuss several ways to classify solar filters. A role play activity is included. The final product, which will be used to show students' learning, is an educational fair for students in lower grades, or the elaboration of flyers or posters to communicate results. The main chemistry content is the interaction of UV radiation with matter, types of radiation, chemical changes produced by UV radiation, composition and action of solar filters, and the methods used to make sun creams in the lab.

The approach of experimental activities is inquiry-based science education and its objective is to investigate the effectiveness of sun protectors as sun creams and sunglasses. Based on the analysis and interpretation of the results, students should realize how important it is to protect themselves from the sun, and to make the correct decisions regarding the use of sun protectors. Some activities use UV beads that arouse student's curiosity, some others use technologies as a visible spectrophotometer and UV sensors to make connexions with digital technologies and the professional world. UVA and UVB radiation intensity values which is detected by sensors are compared with sunlight and various UV (UVA and UVB) light sources that cross transparent surfaces impregnated with creams of different SPFs, different commercial brands, and creams prepared in the school laboratory.

The experimental activities and the whole project have been implemented respectively in two secondary schools. Feedback reveal that experiments goes well and that learning objectives are reached. The teachers consider the activities of the project very useful and emphasize the involvement of the students. The proposal has also been implemented in workshops for teachers and for students in STEM conferences. Feedback from students and teachers was positive and always useful to improve the design of the workshop.

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Phylogeny of Teaching the Concept Chemical Reaction

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The specialists in science teaching have been focused on reconstruction of teaching science [1] content for last 20 year period because of analyzing and re-evaluation of Slovak primary and secondary school curriculum, and central Europe as well. This reconstruction consists of complete ambition of individual´s cognitive development understanding and science concepts evolution understanding by community of researchers and teachers.

The simplified explanation of scientific content [2] is not automatically associated with concept grasping in its depth and core, but in many cases it causes misunderstandings and mis-application in practice. Therefore, it is necessary to approach the issue like teaching of the new content to pupils and students responsibly. It is necessary to examine not only their current understanding of the content, but also to know the historical background and the basis of key concepts of the various areas of natural science subjects.

We have been paid an attention to the phenomenon of chemical reactions in our excurcus. In our contribution we would like to present several views on the understandings of chemical reaction concept. The content analysis of different chemistry textbooks was used as a research method. It was focused on teaching this concept considering the age of pupils, type of schools they attend, etc. The historical aspect of teaching concept chemical reaction at Slovak primary and secondary schools in approximately 100 years period will be presented. We are thinking about its implementation in context of other chemical key and initial concepts, findings and associated content [3].

One of the most important science teacher´s ambition is to respect and follow the teaching principles of scientific but adequate approach, however, on the other hand not to do simplifications that could cause misunderstandings of science concepts. It is the reason for being interested in history of using chemical concepts in classroom and science teaching.

Key words: concept phylogeny, reconstruction in teaching science, chemical reaction, content analysis of textbook

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Raw Communication and Engagement (RACE) – a Joint European Project for Enhancing Scientific Communciation and Wider Society Engagement

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Science, Technology, Engineering, Mathematics and Medicine (STEMM) disciplines are increasingly shaping our lives and the world we live in. Addressing challenges across these areas requires engaged and informed citizens as well as a pool of STEMM professionals. There is an increasing demand from public bodies and research funding agencies for public engagement, believing it to provide a pathway towards research with impact. Yet many STEMM graduates and professionals lack the very skills required to communicate and engage with the public.

To address some of these issues, the project RACE (RAw Communication and Engagement) was jointly initiated by universities and industrial partners across Europe. Through the design and implementation of adaptable training modules incorporating content knowledge, scientific communication and public engagement skills, this international project aimed to equip students and researchers alike to situate their work within the wider global society and communicate their work with broader societal audiences. A key feature is the direct incorporation of actual public engagement activities into the training modules, for the mutual benefit of the module participants and wider society.

The implementation and evaluation of some of the modules at the Masters and PhD levels, including an intensive international summer school in scientific communication and public engagement, are discussed in this paper. Analysis of questionnaire and interview data have demonstrated positive impacts on participants' attitudes and preparedness to communicate science effectively through public engagement events. Emergent themes from initial analysis of the semi-structured interviews indicate that students were unaware of the level and degree of effort that is warranted to conduct effective Education and Public Engagement (EPE) events. Previous to the course, they attributed a communicator's success to talent as opposed to effort or combination of both. Participants intimated that the course provided a set of steps and key things to contemplate prior to engaging with any audience. As such, the learning from the week was not primarily skills based, rather, the development of a professional approach/attitude toward science communication; the provenance of which resides in its transferability to a multitude of contexts.

Benefit to the wider community has also been shown in evaluations of the outreach events conducted during this project.

Kitchen Chemistry Adds New Dimensions to Chemistry Education

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This study focuses on the Kitchen Chemistry (KC) course, an optional course in advanced studies for chemistry teacher students in the Department of Chemistry at the University of Jyväskylä. Among the goals in chemistry education is to familiarize students with laboratory activities that are suitable for school teaching and to encourage them to develop their skills in new and challenging situations. Our aim in this study was to determine how the KC course could meet these requirements in chemistry education.

Integrative instruction is an important part of a school's culture, and it supports comprehensive basic education [1]. The KC course integrates knowledge of two subjects: home economics and chemistry. KC allows participants to learn science and engage in scientific practices within the context of cooking [2]. Interdisciplinary learning in higher education aims to develop boundary-crossing skills [3]. KC can be defined as a life-relevant learning environment which engages learners in science through the pursuit of personally relevant and meaningful goals. Those can be in formal as well as informal learning contexts.

The purpose of this research was to determine the following: (a) What new viewpoints does KC bring to chemistry education? (b) According to the chemistry education students and the KC course teachers, were the goals of the course achieved?

This study is significant because it will help develop the KC course for the future. This year, the course was attended by 15 students and taught by two university teachers. The data were collected through questionnaires and interviews, and then analyzed both quantitatively and qualitatively.

The KC course was popular because its theme was seen as particularly interesting, with the connection to everyday life and cooking being highlighted. Teacher students felt that KC provides good yet challenging opportunities for learners to learn science through cooking. The KC course promoted a deeper knowledge of science and offered novel possibilities to teach chemistry in a new learning environment. In teaching, the teacher students found it difficult to simplify the learning goals for the younger pupils. The KC course teachers saw students' heterogeneous subject knowledge as a challenge, but this heterogeneity also spurred the students to collaborate. According to the teachers, the students appeared highly motivated, and the course succeeded in providing novel practices for chemistry education.

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Digitisation in Chemistry Lessons an Experimental Digital Learning Environment with Universal Accessibility

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Today, digital media are an integral part of the daily routine. Therefore, tablets, smartphones and the internet are also increasingly important at school. Learning with and about digital media is absolutely essential and explicitly demanded in the German strategy paper "Education in the Digital World" [1]. At the same time, the digitisation offers great potential for teaching highly heterogeneous learning groups individually and comprehensively [2, pp.1-5]. However, the use of digital media at German schools is still in its infancy. In order to create a basis for the successful implementation of digital media in teaching, it is necessary to generate profound knowledge about the effectiveness of digital learning environments regarding heterogeneous learning groups [3].

Against this background, in this project we develop and evaluate a digital learning environment for lower secondary classrooms. Regarding the design of the teaching unit, we follow the concept of Universal Design for Learning (UDL) [4], which represents a model for joint learning of learners with and without special needs. The aim of the study is to determine the effects that the use of tablets in different teaching phases has on the pupils' learning outcome. In order to analyse the effectiveness of the tablets in the classroom, we determine the content knowledge before and after the teaching unit as well as the students' attitude towards the teaching unit and towards working with the tablets. With help of a screen-capture-software, it is possible to retrace the students' action steps while working with the tablets. Additionally, the lessons are filmed using a 360° camera to record the work behaviour of the learners with and without tablets. Furthermore, the cognitive abilities and the self-concept of the students are assessed. The poster presents the research questions as well as the design of the study, selected elements of the digital learning environment and first results of the preliminary study.

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Double role of an academic teacher, in pre-service chemistry teachers training at Jagiellonian University

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Pre-service teacher (PST) training in Europe is organized in many, extremely diverse ways. Approaches of designing chemistry classes is a common element in all countries, where the pre-service training is organized, but school practice is realised very differently regarding length and position [1]. Among various competences which university students who like /plan to became school teachers have to develop, ones of the most common are preparation, conducting and evaluation of the class activities (chemistry lesson). Organisation of PSTs first school activities differs not only from country to country, from the state to the state (Germany) but also between universities. A few factors which influence such diversity can be considered e.g. a complexity of training and an educator. Some universities apply microteaching. It means that PST plans and conducts only a part of a school lesson such as e.g. demonstration or engagement. Some others require to conduct the whole 5E structure [2]. At some universities academic teachers are experts in research in subject education and school teachers are experts in practical dimensions of chemistry education. In some others e.g. Poland there is a common agreement that everybody who teach PSTs should have personal experiences in teaching at school level also [3].

At the Faculty of Chemistry JU, PSTs participated in the module called " Chemical education" which consists of two courses: one organised at the faculty (30 hours) and one in a school (15 hours). During that school-based course a group of 8 chemistry students under supervision of an academic teacher observed and discuss 10 lessons conducted by a school teacher and peers, as well as conduct their first 45' chemistry class with 25-30 pupils.

This case study describes a unique situation when in the autumn semester 2018/19 a school teacher visited by the group of JU students is also employed as a lecturer at the some HEI (at the Department of Chemical Education). The second university teacher – a supervisor of the group of PSTs was also present at the school. The classes covered following topics: chemical laws (with gases law), the mole and Avogadro'snumber, amphoteric oxides and hydroxides, hydrides and coordination compounds.

The main aim of the study was to find out how university students deal with their tasks and how a school teacher managed the situation. For this purpose students scenario of lessons, school teacher, notes, peer observation sheets, academic teacher, notes were analysed. On the one hand, a high level of stress was associated with such a double role of the teacher: PSTs look at her both as a school teacher (expert in practice) but also as an academic teacher (expert in theory). On the other hand, such the double role of the teacher made it possible to better fit her school lessons to the needs of the university students. The poster will discuss the advantages and disadvantages of such a situation.

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DiSenSu – Diversity Sensitive Support for Girls with Migration Background for STEM Careers

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The main goal of the project DiSenSu („One step back, two steps forward!" – Diversity Sensitive Support for girls with migration background for STEM careers) is to support young girls with migration background to find their way to and in STEM career. From different studies we know that connection of female and migration in vocational view has a "double disadvantage" [1].

In our project, we would like to reach young girls in their preferred visited places, e.g. Youth Clubs, Cultural Clubs, Shopping Malls, etc. showing them possibilities and the richness of STEM careers. Thus, our concept is focusing on the idea of Science in Public, however paying the attention on cultural and linguistic diversity of our target group. Special about the present project is the involvement and the participation of parents as well at such events. We are using different tools which focus on specific vocational oriented skills in STEM career. Additionally, we are cooperating with different female role models who are having different migrations background comparable to our target group.

As a framework for our project we see the movement „One step back, two steps forward!". In the meaning of "One step back" we elaborate the status quo. We would like to know more details about young girls' possibilities for information about the STEM career and their interest for such career paths. We analyze their self-concept about STEM career and their beliefs about choosing STEM career. Parallel, we are adapting our vocational oriented tools to be more language and culture sensitive. Starting from here in the meaning of "two step forward!" the support (events) for STEM vocational orientation in daughter-parent(s)-dyad will be offered. Image-based visualization and hands-on actions for evaluation of own skills and comparing to behavior typical of STEM profession will be focus of the events.

The evaluation of the offered events will be done by a Mixed-Methods-Design [2]. The concentration of the single case studies will be done following Case-Study-Design by Yin [3].

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Bridging Scholars and Practitioners: Towards a Network Based on Chemistry Teachers' Needs

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There is a gap between scholars working at the universities and teachers working at schools [1]. It is up to higher institutions to open their doors to innovative teachers, but not to impose a research agenda upon them. Instead, scholars should look into teachers' needs in order to get a closer understanding of the field and, thus, define common agendas, at the example of what has already been done to identify teachers' training needs [2, 3]. With these goals in mind, we challenged Portuguese science teachers that have attended at least one of the three conferences on science education and communication held at our faculty in the last three years to join us on a meeting to discuss their thoughts about current innovations on science education and communication. More than 100 teachers participated in the three-hours meeting. They had the chance to get to know researchers and discuss ongoing projects with them. After a short presentation, by the research group leaders, about the goals of the meeting and the kind of projects going on, participants were randomly assigned to groups with 5-7 elements and asked to reflect on their own priorities and concerns about science education and communication. At the end of the meeting, one spokesman of each group delivered a synthesis of the discussion held in the group. In this communication, we focused on the expectations, needs and interests of 67 physics and chemistry teachers as reported on individual worksheets. A content analysis was carried out in order to identify the major themes. The most frequent themes reported by teachers were: integration of digital technologies in the classroom and in the laboratory (e.g., computer simulations, educational tools, and smartphones); maker spaces in the schools (often to connect with families); evaluation (with a special focus on laboratory activities); pedagogical strategies (inquiry, projects and problem-based learning); spaces or opportunities to share of experiences among teachers; enhancement of laboratory practices; science communication; citizen science and connection among schools, firms and universities. If many of these themes are aligned with our own research agenda (digital technologies, maker spaces, inquiry, science communication and citizen science), others are beyond our current interests (e.g., evaluation of laboratory activities). Likewise, some themes in which we are interested on did not grab teachers' attention (e.g., activities with parents on the computers, science and religion, storytelling in primary schools). These results, even if preliminary and exploratory, ask for further tuning of interests, expectations and needs between scholars and practitioners. The network of teachers and scholars, which relevance is acknowledged both by us and teachers, might become a space for this tuning to happen, if only we allow it to grow as organically as possible.

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Real chemical experiments or the use of IT in non-formal teaching?

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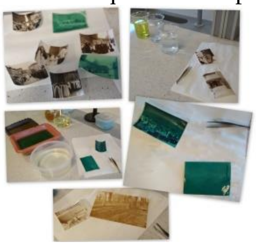
Children's Universities (ChU) involve extracurricular activities for children. It is an idea to combine learning with fun [1, 2]. Because ChU classes should be interesting for students, it was decided to check what technique of toning fotos the students prefer. Students had a choice of two techniques to toning photography: traditional with the use of chemical compounds and modern with the use of TI. Research hypothesis: children will prefer traditional technology because it will be a new experience for them. (Students never used traditional technique to tonic photograph).


A


B

Fig. 1. Selected children's works regarding chemical toning of photos (A) and computer toning of photos (B).

50 students of the Children's University of Wadowice took part in the research. The students' task was to determine how much they liked the particular toning techniques. The results shown in the chart below (Fig. 2.).

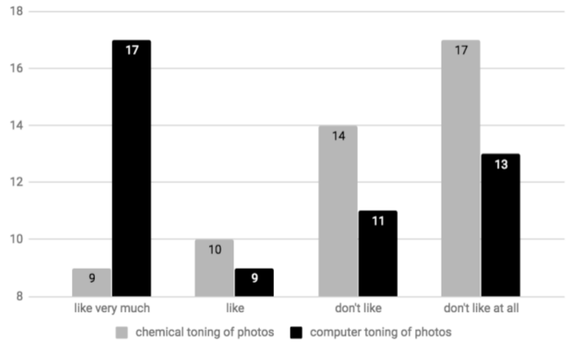


Fig. 2. Preferred techniques for toning photos by students.

The obtained results did not confirm the hypothesis. It turned out that students prefer the use of TI. It can therefore be concluded that contemporary children feel better and are more willing to learn in a virtual environment. The question then arises: should ChU be teaching the way his students want? Should, however, show children activities in the real world?

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Developing Non-Classical Educational Methodologies to Introduce the Chemical Elements to Secondary Students: "Find Your Particular Elements (FYPE)"

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The periodic table of the elements is essential to study Chemistry and thus introduced as one of the first issues in every introductory chemistry course. However, its study is not well appreciated by the students because it means facing 118 chemical elements, the vast majority of them unknown to pupils. Moreover, memorizing the chemical symbols associated to their names, which often seem arbitrary or counter-intuitive, is found boring and usually has a demotivating effect. In parallel to this boring memorizing, students are forced to write chemical formulas, hardly understanding what these mean truly. All of this brings up feelings of anxiety to many students and gives rise to disinterest. Creative educational methodologies capable of engaging students in interactive, enjoyable learning help to lessen students` anxieties and motivate them. In this context, we have designed a fun activity that we have named FYPE (Find Your Particular Elements). It is aimed at eighth-grade students (13-14 years) that corresponds to the second course of Compulsory Secondary Education in Spain, and which means the first contact of our students with Chemistry as an independent subject.

In FYPE, students have to find their "personal chemical formula" based on their names (Figure 1), rummaging through the symbols of the elements in the periodic table. With this activity our students realized that "J" is the only letter missing in the periodic table or that single "A" is not a chemical symbol although the names of six elements start with this vowel (Note: "A" is a very common final letter for Spanish female names).

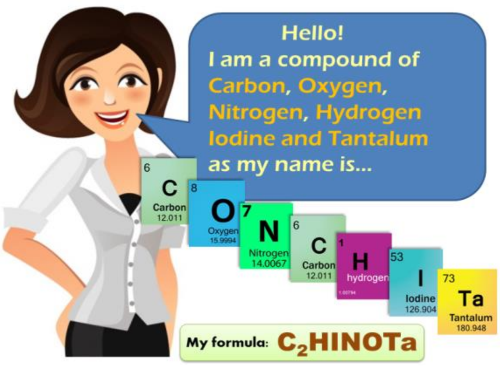

Figure 1

This creative activity also awakes the curiosity of the students, who require more information on the elements (reasons for their names, how and when were discovered…). This is why, as a second part of the activity, students have to select one of the elements of "their formula", find out information about it and do a presentation in class. It is particularly welcome that they explain how the chosen element is present and/or has an influence on our ordinary lives.

During the 2016/2017 academic year, an art exhibition with the corresponding pictures, graphs, artistic images etc. prepared by the students was carried out at the main hall of the High school. Parents and relatives were invited to visit it, making this activity go beyond the classroom.

Opening the Mind of Primary School Students to Science: "It`s Magic!!!… It`s Chemistry!!!"

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As one of the outreach activities developed in the Faculty of Science at the University of A Coruña (Spain), we have designed a striking chemistry class based on demonstrations specially aimed at fifth-grade scholars (10-11 years). The main goal of this activity, which we have named "MAGICHEMISTY", is to awake the curiosity of the children and to spark an enduring interest in Science in general (Chemistry in particular). This activity has been undertaken for the last ten years with great success.

MAGICHEMISTRY: The activity is carried out in a teaching laboratory of the Chemistry Department, which, in most of cases, also implies the first touch of the young visitors with the University. Maximum number of students per group: 25. Length: 2.5 hours.

The activity is conducted by an academic and presented as a dynamic master class of Chemistry. Scholars take part as active viewers. The demonstrations have been selected in the light of their spectacular nature and are carried out in a particular order and way so trying to capture and hold the attention of the young audience all the time. They comprise: 1) "Making Gold"; 2) "The Miracle of Turning Water into Wine… or Cognac!"; 3) "Magic Ice"; 4) "The Balloon Comes to Life"; 5) "The Intelligent Clip"; 6) "Levitating" and 7) "Water is in Flames". Some of them are based on classical chemistry demonstrations, which have been properly revisited in order to make the children see them as magic tricks. The scholars are encouraged to participate in their performance (Figure 1).

Figure 1. Fifth-grade students of the primary school "Hijas de Jesús – A Coruña" (10-11 years) during the activity. (Academic year: 2015/2016)

With this in vivo activity, primary students feel Chemistry like something close and fun. They demand to know more. Wh-questions (what? why? how?) break out spontaneously. Students receive explanations at the same time that they are encouraged to think thoroughly about what`s going to happen and the "tricks" they have seen. Pupils get an illustrated Periodic Table as a gift at the end of the session. [Next step: "What matter`s hiding"].

Using Scenarios to Enhance Students' Awareness of Science-Related Careers

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The problem of lack of student interest or motivation in secondary science education is seen to lie in pedagogical considerations [1] and the lack of interest in science careers to unawareness [2]. This paper reports on an EU funded project (MultiCO) designed to attract more students towards studying science, by focusing on making school science more relevant for students, as well as raising their awareness of science-related careers. The project examines the impact of introducing career-focused scenarios within the science curriculum for 13-15 year olds with an inquiry element. The intended outcome is to motivate young people to extend science studies and orient them towards science-related careers. The scenarios are created with multi-stakeholders (scientists, industry partners, teachers, parents, students) and are linked to curriculum topics.

The project is being undertaken in five countries using design-based research. This paper focuses on one chemistry-based scenario (called Chemical Engineering) developed in three schools in the UK. The objective is to report on the design of the scenario, how teachers incorporated it within their teaching and how students responded to it. The project has five 'cycles' of intervention with the same cohort of students over two years. This scenario was initially designed by the UCL team with stakeholders in cycle 2 in one school, then further developed in cycles 3 and 4 in two other schools. The career context is chemical engineers who work in sports companies. The student task is to design sports injury packs (for warming or cooling) and carry out inquiry using chemicals that will produce exothermic or endothermic reactions on mixing. Data sources include planning meeting notes, lesson observations, student evaluation questionnaires on knowledge and skills acquisition, interest, career relevance.

Results show that students in cycle 2 were enthusiastic with the inquiry activity presented in the scenario, they liked the scenario and the format, and they gained new knowledge. Students liked learning about the career but did not relate personally to engineering. In cycle 3, the teacher focused more on the skills and work of the chemical engineer. A similar pattern of results from the students emerged, with high percentages of interest and knowledge acquisition (77%, 90%) but low with respect to career relevance (17%). This pattern was repeated in cycle 4. The design of appropriate scenarios that can link to the curriculum, include a career focus, have an interesting context and good inquiry activity is challenging. More work needs to be undertaken to portray career skills and practices that students can identify with and aspire to, as well as link instructional practices to those skills.

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Successful and Unsuccessful Students' Information Processing at Solving Problems in Context Related with Dynamic 3D Submicrorepresentations of Specific States of Water and Phase Change between them

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Eye-tracking represents a viable technique used in science problem-solving [1]. The process of individual's problem solving can be identified with eye-tracking because information processing is related to eye movements [2] (e.g. fixations indicate which information will be processed by the individual's cognitive system [3]).

Research problem was to identify how successful and unsuccessful 12, 16 or 23-year old students differentiate between themselves in information processing at solving problems in context (related with different states of water and phase change between them) including dynamic 3D SMRs. Objective of the research was to determine if successful students in all age groups had lower mean values of absolute and/or relative total fixation durations (TFDs) and fixation counts (FCs) on the appropriate dynamic 3D SMRs than unsuccessful students. 79 students, attending seventh grade of primary school, first year of secondary school, undergraduate or master level participated in the research. The problem set consisted of three problems in context including macroscopic and submicroscopic level of representation.

Results of the research showed that successful and unsuccessful: (1) 16-year old students differentiated between themselves in values of relative TFDs on the SMR characteristic for solid state of water, (2) 12-year old students differentiated in values of relative FCs and TFDs on the SMR for freezing of water, representing nonmovement of particles in solid state of water. Spearman correlation coefficients indicated strong or perfect correlation between absolute and relative TFDs and FCs on the SMR characteristic for solid state of water (unsuccessful 16 and 23-year old students), liquid state of water (16-year old successful students) and freezing of water (unsuccessful 12 and 16-year old successful students).

The significance of the research is related to the investigating of information processing during solving problems in context (including dynamic 3D SMRs) at different age groups of successful and unsuccessful students.

We can conclude that information processing is not necessarily related to successfulness at solving problems in context at different age groups of students, but further research is needed.

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Using Eye-Tracker to Explore Students' Achievements in Solving a Context-Based Air Problem

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While the matter cools, the particles are reduced in size and at warming or cooling of matter, the particles of which the matter is composed, are also heated, or cooled were students' misunderstanding statements presented in the research [1, 2]. However, submicroscopic representations - animations can significantly help to correct misunderstandings and improve the science knowledge. The researchers highlighted that students have to be skilled of observing two or more variables at the same time in particulate matter animations when solving context-based problems [3].

The purpose of the research is to explore and explain students' achievements in solving context-based air problem comprising macroscopic and submicroscopic level of science concepts. The influence of other independent variables such as motivation, formal-reasoning abilities, visualization abilities, general intelligence are also important factors that should be considered when explaining students' ability to solve problems. 79 students of 3 age groups (12, 16 and 23) participated in the study. Questionnaires, tests and a semi-structured interview including computer-displayed context-based problem were used for the data collection. The eye-tracking was used to determine the exact location of the point of gaze of a participant's eye. The research results showed that students achieve average scores in solving air compression context-based problem and it is indicated as difficult for them. The difficulties in explanations including macroscopic and submicroscopic levels of science concepts representations are indicated in all 3 groups of students. Results show that students' achievements in solving context-based air problem do not depend on motivation and visualization, whereas the correlation between total fixation duration on the correct animated submicroscopic representation and formal-reasoning abilities is statistically significant. The findings confirm commonly identified misconceptions in the groups all school levels and bring to the front the importance of previous experience as well as ability to transfer the gained knowledge to new examples [1-3].

To conclude, the research results provide an insight into the mindset of students and serve as a starting point for teachers' lesson planning as well as for exploration of effective strategies for science teaching and learning.

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Chem-Tracking – Pointing out Chemical Processes in Students Daily Surroundings with the Help of Digital Media

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Many pupils consider science and especially chemistry to be important and useful, but rate their own chemistry lessons rather negatively compared to science as such [1]. However, the presentation of a positive image of chemistry in school is important in several ways, for example for a chemistry-related career choice [1]. In the Chem-Tracking project, we aim to demonstrate the importance of what has been learned in chemistry lessons by showing a stronger everyday life relevance of chemical topics. In addition, we try to counteract the negative image of chemistry and chemical processes [2].

The Chem-Tracking project [3] is based on the pimlico chemistry trail by Peter Borrows [4] but was transformed into a geocaching adventure and interactive virtual nature trail. A first trail was implemented in cooperation with the regional forestry office along a section of the hiking trail "Rothaarsteig" in Germany. In order to connect the real and the digital world, QR codes are used to arrive the project website, which contains information and instructions for experiments for each station. With the help of an "experimental backpack" it is possible to carry out selected experiments on site.

On the basis of previous trials, further applications of Chem-Tracking will now be developed and researched [5]. As Chem-Tracking offers a low-cost easily implementable alternative to typical experimental settings, it is possible to set up individual theme stations near school grounds giving pupils the opportunity to participate in a flexible, individual and differentiated learning in authentic places with relevant topics.

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Teaching chemistry and science using game-based learning approach

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Teaching chemistry is a very demanding process especially when dealing with abstract concepts or concepts which cannot be immediately connected to the real life. Learning about the periodic table and the chemical bonding are examples of such concepts. Therefore, teachers are challenged to find new ways to accomplish these learning objectives and, in the same time, to hold students' interest and motivation for particular topic.

Game-based learning approach can be useful in the realization of this type of lessons [1-3]. It seems that this method provides engagement of students [4,5] thus leading to the development of positive attitudes toward chemistry (and science in general). Game-based approach was introduced during a workshop aimed for science teachers. In this workshop several chemistry games were presented to the teachers. All materials needed were easily available or made by the authors. These educational games are intended to be used among primary school students in science and chemistry courses, although some can be used even in high-schools. The games in question were: Surprise Box, Domino, Ion Poker [6] and The Longest Word.

A survey was used to perceive the willingness and views of science and chemistry teachers to apply this approach in their classrooms. A 4-point Likert-scale questionnaire was developed to get insight into teachers' opinions regarding the effectiveness of the presented games in improving the teaching process. Additional comments of teachers were valuable in expanding our research to address further difficulties students might have as well as revealing possible misconceptions.

The feedback from teachers was positive. Their satisfaction of game-based approach as a tool to make lessons more enjoyable was evident. These games are especially useful in realization of review lessons in which teachers can deliver the material in new interesting way and make students learn and have fun at the same time. Our expectation is that educational games will find its place in the classroom and motivate students to like and learn chemistry.

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How Can We Teach the Experimental Design Skills?

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Encouraged by the positive results of our earlier empirical research project [1] we initiated a longitudinal study to investigate the effectiveness of the approach for younger students and over a period of time. The method used in our earlier work was straightforward: established 'step-by-step' instructions were modified to practical activities requiring one or more steps to be designed by the students. Preparation required little time and effort, yet results suggested that many 14-15 years old students benefited from the approach. The longitudinal study that followed took the form of a four year research project that began in September 2016. Over 900 students have been involved. All were 12-13-year-old in the beginning of the study. Each year they will spend six lessons carrying out practical activities using worksheets we provide. The students were allocated to one of three groups. Group 1 (the control) simply followed the step-by-step instructions. There were two experimental groups. Group 2 followed the same instructions, but also had to complete experimental design tasks on paper. Group 3 followed the same instructions, but one or more steps were incomplete and students were required to design these steps. The impact of the intervention on the students' experimental design skills, disciplinary content knowledge and attitude toward chemistry is measured by structured tests.

After the first school year of the project it was clear that the approach used previously with 14-15 year-old students in short term does not seem to work for 12-13 year-olds in long term. Discussions with experts of psychology and assessment lead to the thought that a more focused intervention with detailed explanation/practice of the main principles of designing experiments in the experimental groups and closely related testing is more promising than simply asking the students to design one or more steps of some experiments. Therefore we decided to consider the first school year of the project as a 'pilot' and use a different method in the remaining three years of the project. However, we only made changes in the research model that we thought absolutely necessary to handle the students' cognitive load properly. In the school year 2017/2018 the student sheets of the experimental groups already contained the main principles and ideas of designing experiments related to the concrete tasks. For instance, 'ceteris paribus' ('other things/variables held constant') is one of the most important principles to consider while designing experiments. If we take that as an example, the work in the three groups from the beginning of the second school year (autumn 2017) was different in the aspect of the application of that principle as follows. Group 1 (control): Kept doing only step-by-step experiments. Did not learn about the ceteris paribus principle. Group 2: Did the same step-by-step experiments than Group 1, but after carrying out the experiments they analysed (together with their teacher) how the ceteris paribus principle had been applied for those experiments. Group 3: The students were explained the ceteris paribus principle by their teacher and after that they designed experiments while they had to apply the ceteris paribus principle. The post-test in the end of the second school year intended to measure whether the students could design experiments when this principle had to be applied. The lecture provides the details of the results of the tests and draw a conclusion.

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How to keep students' interest: The challenge of a systematic chemistry course for 8th graders

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Our long-term goal is to design a better chemistry curriculum that will improve not only the students' outcomes but also their engagement in learning. We build on our quite interactive "Introduction to Chemistry" course [1, 2] where the 6-7th-graders (11-13 year-olds) learn by hands-on experiments that chemical elements stay the same in chemical reactions while the substances change. The students plan and carry out experiments to solve a riddle of strange rust, mystery of copper appearance on iron tools, etc. This way, they learn why and how people used to produce metals in the past and what they needed for it (coal, ores, etc.). After such an introduction, by the 8th grade (13-14 year-olds) more than a half of our students choose honor chemistry vs. a standard course. A focus of this research is how to incorporate an experiment planning activity that appeared so attractive to our students into the systematic chemistry course that follows the introductory one. What such an activity could look like at the new level? We assumed that the answers may be drawn from the central analytical problem of chemistry. Historically, a simple question "what is this substance?" gave rise to the basis of the general and inorganic chemistry. So, in the first pilot study, the students (organized in small groups or individually) tried to identify the common chemicals used in the school lab. After yielding promising results, our teaching strategy was revised, refined, and tested again during the next 4 years (85 students in total). Such an activity lets students realize that a study of the products can give essential clues to uncover the nature of the unknown reagent. Along this work, students face and explore the main patterns of various chemical reactions such as double replacement, redox, etc. When someone comes up with a reasonable guess, s/he can check it by testing a sample of the actual substance against the expected composition. This way, the students incorporate the analytical chemistry logic into their own point of view on the properties of substances. In particular, they see each unique substance as a representative of a group characterized by some common features. As an indication of the successful teaching, every year some of our students (34 in total) become finalists of various levels of Chemistry Olympiad, from regional up to the national level, and then choose the subject as a major in college.

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Conveyer Activities in Chemistry for Public Events

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Polytechnic museum (Moscow, Russia) organizes outreach events for general public. There we provide an opportunity to conduct various hands-on activities. The main question was how to organize activities for about 1000 participants a day. Discrete slots proved to be inadequate, because the participants have to waste their time waiting for the beginning of each slot. To avoid waiting the activity should be continuous. For this conveyer principle was adopted.

The conveyer comprises of several sequenced stations (from 4 to 12) where a participant performs one operation basing on the instruction. Then the participant moves to the next station. The operation all the stations (including reading of instruction) should take approximately the same time (no more than three minutes – depending on the expected flow of the participants). If operation at one station takes much more time than on others, this station should be duplicated. One supervisor usually watches 2-4 places. Because the supervisors watch limited number of operations, they can be low-qualified and instructed just on spot. All the process is managed by a qualified master, who (a) instructs supervisors, (b) regulates the flow of the participants, (c) distributes all the necessary consumables and (d) solves all the arising problems. All the supervisors are managed by an elaborator

The example is an activity “Corrosion and protective coverage”. The conveyer comprised eight stations.

1.Start. Put on laboratory coat and goggles (1-2 min).

2.Watching corrosion. Put a zinc-plated piece of iron into solution of sodium chloride and attach it to (+) of 5V power supply (2-3 min).

3.Chemically joining coverage. Paint a piece of iron and take it on a tray with them (1-2 min).

4.Physically drying coverage. Dissolve colophony in alcohol and cover a piece of iron with the solution (2-3 min).

5.Hardening coverage. Put melted glue on a surface of iron by a glue gun (1-2 min).

6.Testing mechanical strength of the coverage. Scratch the coverage by nail (2-3 min).

7.Testing corrosion of covered iron as at station 2 (5-6 min; the station is duplicated).

8.Finish. Put off the coat and goggles; throw away all the rubbish.

The other activities were dying fabric by making dye directly on fiber; painting by light; burning iron in oxygen; launching gas rockets. They let pass about 500 unprepared participants a day with no queues and breaks.

The Sense of a Substance

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The author has observed many times that some students make more mistakes while conducting chemical experiments than others. For example, some students heat test-tubes in the way that they crack, the others – that they do not crack. Some students take optimal amount of substances, the others – too much or too little. Some of 6 y.o. (and even older) children can safely burn a candle with a match, whereas the other rather burn their fingers instead of the candle. These observations could be expanded on all the people: some of them manipulates with substances and materials in optimal way, the others – with many mistakes.

Our hypothesis is that some of the people posses “the sense of a substance”. We would define it as an ability to manipulate with substances and materials in an optimal way without explicit instructions. On the contrary to skills, that are applicable in familiar situations, the sense of a substance becomes apparent in unfamiliar situation. For example, in our experiments some of the children obtain stable electric arc using given power supply, coal rods and general explanations, while the others hardly got the arc ever. Thus a task to make something with an unknown substance (or to perform unknown task with a known substance) could be a good test for detecting the sense of a substance.

Formation of the sense of a substance could be regarded as the main goal of general chemistry education. Modern industry requires a very small number of people who develop and produce new substances and materials (that requires professional chemical education). However it requires many people who work with very different substances and materials – plumbers, car mechanics, physicians etc. Of course, one could elaborate precise instructions for such people, but there are many subtleties that could be hardly explained or even noticed (as for the experiment with electric arc and hence with electric welding).

What is the nature of the sense of a substance? It could be a result of low-order neuron connections that are formed basing on practical experience. It is of the same kind as to distinguish a pine from a spruce (many people, especially from forestall rural area can’t explain the difference but do distinguish) or abilities to hit a moving target by a ball (nobody calculates moment, velocity and trajectory of the ball explicitly).

How to develop the sense of a substance? As for any development of neural connections – by practice. The key question is which practices are appropriate for a certain age. Certainly the age of 14-16 (when chemistry is began to be taught in different countries) is too late because the majority of connections are still formed at this age. In Polytechnical Museum in Moscow we develop hands-on activities with substances for children from 5 y.o. – the age when fine motor skills are formed. We are going to present our observations and share disputable questions on the topic. In general it seems quite promising. For example, 8-10 y.o children that manipulate with glass for the first time (bending and pulling glass tubes etc) made much less mistakes that 13-14 y.o. Children of the same age made less mistakes in heating substances than even chemistry teachers. Experienced children successfully solved tasks on treatment of plastics, making solid substances etc.

Professionalisation of Future Teachers for Digitisation in Chemistry Education

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With the publication of the strategic concept "Education in the Digital World" in Germany in 2016, learning with and about digital media and digital tools becomes mandatory at all German schools [1]. While education policy makers have recognised the great potential of innovative information and communication technologies regarding teaching and learning, especially in times of inclusion, German schools are facing the challenge of implementing the law and adapting to the increasingly digitalised society [2]. Hence, the qualification of teachers sets the essential basis to ensure this transformation process [3]. Consequently, this project aims to develop and evaluate a university seminar that prepares prospective chemistry teachers for implementing digital tools in teaching and learning effectively as well as appropriately. The seminar will also address the Universal Design for Learning (UDL) with which it is possible to design classrooms that are accessible for all students, even for those with special needs, particularly because technology is seen to be indispensable for the implementation of the UDL [4].

The study is an intervention study that tests the interventions' effects by using a pre-post-follow-up-design. Based on the adapted evaluation steps by Kirkpatrick (1979), this seminar is evaluated on the four levels attractiveness, cognitive changes, practical implementation, and effect on the students [5]. To explore the influence of the seminar on the level of cognitive changes, we use an online test to measure the future teachers' changes in their attitudes (6-point Likert-scale, 23 items, α = .886) and self-efficacy (6-point Likert-scale, 20 items, α = .768) concerning the implementation of digital tools in chemistry lessons. In this regard, we will also collect data on the future students' experiences with digital tools prior to the seminar (online test). The methods for assessing the prospective teachers' skills in implementing digital tools in their lesson plans and evaluating the practical implementation at school are still in the works.

Since the pilot study will be accomplished in June-July 2018, its first results can be presented and discussed at the conference.

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Spis treści

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