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BOOK OF ABSTRACTS

FACULTY OF CHEMISTRY
JAGIELLONIAN UNIVERSITY IN KRAKÓW

Editorial board:

Iwona Maciejowska
Mária Babinčáková
Aneta Woźniakiewicz

Typeset by:

Aneta Woźniakiewicz
Mária Babinčáková

Graphic design:

Mária Babinčáková

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INTRODUCTION

PREFACE

It is with great pleasure that we welcome you to the 11th European Variety in University Chemistry Education Conference—EuroVariety 2025—held at the Faculty of Chemistry, Jagiellonian University in Kraków. This year’s edition is especially meaningful, as we celebrate the 20th anniversary of the very first EuroVariety conference, which also took place right here in Kraków, back in 2005.

EuroVariety was originally conceived as a European counterpart to the UK-based Variety in Chemistry Education (ViCE) conferences. Members of the organising committee of both the first and current editions of EuroVariety had the privilege of attending ViCE in its early years—and those encounters left a lasting impression. The experience of participating in a conference so devoted to sharing good practice in university-level chemistry education was eye-opening and energising, especially for young academics and doctoral students from our university. The spirit of ViCE continues to inspire and shape our work.

Over the last two decades, EuroVariety has become a beloved and respected gathering for chemistry educators and researchers across Europe and beyond. From Prague, Tartu and Manchester to Limerick, Belgrade, Prato and Ljubljana, each meeting has brought fresh perspectives, lively discussions, and above all—a sense of belonging to a community that shares a passion for teaching and learning chemistry at tertiary (university) level. Many of us remember the early days, while others are joining us for the first time. To all of you—old friends and new—we say: welcome!

This year, we are proud to host more than 100 participants from over 20 countries, representing a wide variety of experiences, institutions, and educational cultures. The programme features 6 engaging keynote lectures, 56 oral presentations in 3 parallel tracks, and an inspiring interactive poster session. You’ll also find workshops, symposia, and plenty of opportunities for informal conversation—the very heart of EuroVariety.

As you leaf through this book of abstracts, you’ll quickly notice the diversity and depth of the contributions. From the use of virtual reality and AI in chemistry education to the development of sustainable laboratory practices; from game-based learning and inclusive design to the challenges of assessment, pre-service teacher training, and student engagement—these are not only examples of good practice, but also thoughtful responses to the complex challenges facing higher education in the second decade of the 21st century.

Challenges such as demographic change, digital transformation, growing demands for sustainability and inclusion, and a global need for better scientific communication, all call for fresh thinking and collaborative solutions. As stated in our conference invitation: “only together can we meet these challenges—and only by sharing, listening, and learning from each other.”

We hope this book of abstracts will guide you in selecting presentations that spark your interest, resonate with your practice, or stretch your perspective. Let it be your companion in discovering ideas that will travel with you long after the conference ends.

On behalf of the Local Organising Committee, I warmly thank all contributors, presenters, reviewers, attendees and coworkers. Thank you for joining us in Kraków to exchange, explore, and celebrate two decades of educational innovation in chemistry learning and teaching at European universities.

Let the conversations begin!

Iwona Maciejowska

Chairperson of the Organizing Committee

INTERNATIONAL SCIENTIFIC COMMITTEE

Ron Blonder, Israel
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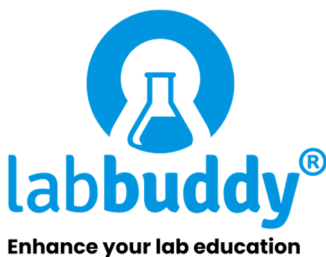
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KEY NOTE

HOW TO MAKE A STUDENT FALL IN LOVE WITH CHEMISTRY USING HISTORY, LITERATURE, AND RELATED DISCIPLINES

Andrzej Danel^{1*}, Julia Galas², Dagmara Ruta-Kowalczyk², Kacper Markiel²

¹*Department of Physics, Faculty of Materials Engineering and Physics,
Krakow University of Technology, Poland*

²*Students of Nanotechnologies and Nanomaterials Study Programme, KUT, Poland*

*andrzej.danel@admin.pk.edu.pl

When I teach chemistry to students at the Faculty of Materials Science and Physics, I often meet students who had very little contact with chemistry at lower levels of education or even none at all. However, when choosing such a course of study, you have to be aware that this contact will occur at some point. Then there is a need for very quick education in the basics of chemistry to prepare the ground for relatively efficient movement in the area of modern materials or nanotechnology. Because it is obvious that before a future physicist or specialist in materials engineering starts investigating a potential material that can revolutionize our civilization, someone has to prepare this material. Therefore, such elementary knowledge of chemistry is necessary for specialists to be able to communicate relatively efficiently. How to do this? First of all, you should not bombard the student with a huge amount of dry facts to catch up. You have to educate in such a way that after the lecture is over, there is a feeling of dissatisfaction and impatience for the next one... and the height of joy for the lecturer is when students stay after the lecture and discuss. I managed to achieve this by combining chemistry with various aspects of history, literature, painting, music... generally disciplines that are thoroughly humanistic. All supported by experiment, because teaching chemistry without experiment is a form of sabotage on the student's mind.

What connects Homer's Odyssey, dried peaches or a car battery...? Did Bolesław Prus in his famous novel "The Doll" predict the emergence of modern alloys and ceramic materials used, among others, in military technology. "What has been will be, and what has happened will happen; therefore, there is nothing new under the sun" this quote comes from the Bible... the same can be said about nanotechnologies... they have already been used, ex. Mayan blue, or glass in medieval stained glass windows... but the "material engineers" of that time were not aware of it.

Did Jewish craftsmen in ancient times use photochemical reactions to dye prayer shawls? You can create hundreds of such examples...they remain in memory and sometimes arouse great surprise and that's the point. Where to look for such combinations/examples...I think that in the era of instant access to all kinds of internet resources such searches should not be difficult. The classic is the Journal of Chemical Education but there are also books where you can find lots of interesting ideas and contacts with teachers of the previously mentioned disciplines. Science should bring a smile to your face.

NOTES

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DIGITAL PLATFORMS TO SUPPORT A SUSTAINABLE LEARNING COMMUNITY

Fun Man Fung*

School of Chemistry, University College Dublin, Ireland

**funman.fung@ucd.ie*

In today's interconnected world, technology-enabled learning is widely used in higher education. However, the core challenge of digital learning resides in its social aspect. Current digital instruction methods often decrease student-faculty interaction due to the lack of visual cues and slower response times. Furthermore, reduced peer interaction hinders collaborative learning and negatively impacts student well-being, as seen during the recent pandemic of the coronavirus. The literature suggests these issues disproportionately affect students from lower socio-economic backgrounds, thus widening educational gaps. Therefore, we develop a framework "Supplementary Discourse (SD)" by Fung & Kim, leveraging readily available digital platforms to build learning communities in a simple and affordable way. We posit that this framework is helpful for educators who seek a low-cost technological method to support students' learning in a sustainable fashion.

GAMIFICATION FOR IMPROVING STUDENT ENGAGEMENT AND CONSOLIDATION OF LEARNING

Alison M. Hill^{1*} and Nicholas J. Harmer^{1,2}

¹*Department of Biosciences, University of Exeter, UK*

²*Living Systems Institute, University of Exeter, UK*

*A.M.Hill@exeter.ac.uk

We had noticed in our Analytical Techniques in Biochemistry module that students were compartmentalizing their learning and not making connections between the various techniques. We had also noticed that student engagement tended to decrease throughout the module. Our solution was to create a Murder Mystery session synoptic gamification session to integrate and consolidate their learning with an activity that encouraged student collaboration and problem-solving skills (Hill and Harmer, 2023).

Gamification benefits from a game fiction, splitting the game into smaller 'quests' and for students to work together in teams (Saler and Homner, 2020; Huang *et al.*, 2020). We based our game on the well known games 'Among Us' and Mafia' which have in turn inspired the popular TV programme 'Traitors'.

Our aim was to create an activity that would require students to integrate their knowledge of four biochemical techniques that had been taught in the module: mass spectrometry, high performance liquid chromatography (HPLC), sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), and Western blot. Each game comprises two-three cycles and each cycle starts with a murder followed by a complete data set. We have embedded errors into each data set to distract students from correctly identifying the Imposter. We did this deliberately to help them prepare for their capstone projects where data is not always straightforward to analyse. Student feedback on this formative synoptic session has been overwhelmingly positive with feedback on this first session (2021/2022) being used to improve the session for subsequent years. We have found students liked working in teams, the interactive nature of the session, the element of data ambiguity and liked the mild time pressure.

In this presentation we will discuss the benefits of gamification and factors to consider when designing games for educative purposes.

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EXPLORING THE POTENTIAL OF VIRTUAL REALITY TO HELP STUDENTS LEARN CHEMICAL CONCEPTS

Mauro Mocerino^{1*}, Henry Matovu², Dewi Ayu Kencana Ungu³, Mihye Won⁴, David Treagust⁵, Ricardo Bruno Hernandez-Alvarado⁵, Roy Tasker⁶, Chin-Chung Tsai⁷

¹*Science and Engineering, Curtin University, Australia*

²*Science, University of Sydney, Australia*

³*Education, Nanyang Technological University, Singapore*

⁴*Education, Monash University, Australia*

⁵*Education, Curtin University, Australia*

⁶*Science, Western Sydney University, Australia*

⁷*Education, National Taiwan Normal University, Taiwan*

*m.mocerino@curtin.edu.au

Immersive virtual reality (iVR) offers a powerful educational tool, enabling students and researchers to explore virtual environments that are either inaccessible or difficult to access in the real world. In chemistry education, iVR provides an opportunity to visualize and interact with molecular structures at a level of detail that would be impossible in a traditional classroom. Beyond chemistry, iVR has been applied across a range of disciplines such as astronomy, geology, biology, and medicine. However, the full educational potential of immersive VR remains underexplored (Matovu et al, 2023). We have developed three immersive VR activities where students actively assemble and explore molecular structures to understand molecular shape, polarity, and intermolecular forces. In these iVR activities, students collaborate and navigate the shared virtual environment to address big questions such as "Why do snowflakes have hexagonal symmetry?" and "Why does D-phenylalanine taste sweet?" and "Why are enzymes such good catalysts?" In this presentation, we will describe the VR learning activities we have developed and share preliminary evaluations of their effectiveness (Matovu et al., 2022; Matovu et al., 2024).

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This image shows a full page of dot grid paper. The dots are arranged in a precise, repeating pattern across the entire surface, forming a grid that is useful for writing, drawing, or organizing information. The dots are small and dark, set against a plain white background.

TEACHING ANALYTICAL METHOD DEVELOPMENT FROM AN INDUSTRIAL PERSPECTIVE

Cari Sanger – van de Griend^{1,2*}, Ewoud van Tricht¹

¹*Kantisto BV, The Netherlands*

²*Faculty of Pharmacy, Uppsala Universitet, Sweden*

*cari.sanger@kantisto.nl

At university, I learnt the basics of analytical chemistry and the analytical technologies. While working in the pharmaceutical industry, I learnt how to use them.

I work in the field of pharmaceutical analytical chemistry. The first thing I learnt in my first industrial job at Astra Pain Control in Sweden was that the patient should always be the focus. This fundamental and ethical attitude to research and drug development has far-reaching consequences, and influences how analytical methods are being developed. I want to share how this fundamental and ethical foundation has influenced me in my development and in my work, and how I convey it in my teaching at all levels.

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This image shows a full page of dot grid paper. The dots are arranged in a precise, repeating pattern across the entire surface, forming a grid that is useful for writing, drawing, or organizing information. The dots are small and black, set against a plain white background.

ADDRESSING VISUAL LITERACY SKILLS THROUGH A NEUROPEDAGOGICAL APPROACH - IMPACT ON ORGANIC CHEMISTRY STUDENTS' ACHIEVEMENTS

Tamar Traube¹, Debora Marchak^{2*}, Inna Shvarts Serebro^{3*}

¹Department of Chemistry, Bar Ilan University, Israel

²Department of Science Teaching, Weizmann Institute of Science, Israel

³Department of Education, Bar Ilan University, Israel

*Tamar.Traube@biu.ac.il

Organic chemistry is considered to be a complicated subject, identified as difficult by many learners (Pribyl & Bodner, 1987). To succeed, students must master the complex conventions of the organic chemistry language and use multiple types of visual representations to signify molecular structures and processes that molecules undergo during chemical reactions. Despite educators' attempts to apply varied teaching strategies, organic chemistry heavily relies on visuo-spatial thinking and visualization (Salame & Kabir, 2022), and many students struggle to make the conceptual and visual transitions involved in multi-level thinking. In this study, we investigated one implication of educational neuroscience for the teaching and learning of organic chemistry: addressing students' visual thinking skills, necessary for integrating new and complex visual input, through verbally-mediated reasoning. The intervention consisted of training organic chemistry students in visual literacy. With this aim, we developed 10 content-related, visual literacy exercises based on visual thinking strategies and neuropsychological understandings (Marchak & Shvarts-Serebro, 2021). These were introduced along the semester in otherwise traditional lectures; while keeping up with the rapid teaching rate required by the university curricula. Through these exercises, students explicitly learned how to observe, read, interpret, and generate graphical displays used in organic chemistry. Regardless of the large size of the class, we found a significant correlation between performing the visual literacy tasks in class and students' achievements. Moreover, students' self-reported attitudes towards the impact of the intervention on their organic chemistry-related visuo-spatial capabilities were positive. Our results suggest that implementing neuropsychology-based visual literacy strategies in organic chemistry teaching and learning has the potential to improve, with minimal educators' effort, students' understanding of this complex subject.

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ICT AND LAB DEMONSTRATIONS AND WORKSHOPS

WORKSHOP: HOW TO PUBLISH IN CHEMISTRY TEACHER INTERNATIONAL

Mustafa Sözbilir¹, Iztok Devetak^{2*}, Iwona Maciejowska³

¹*Atatürk University, Kazım Karabekir Faculty of Education, Department of Mathematics and Science Education, Chemistry Education, Erzurum-Türkiye*

²*University of Ljubljana, Faculty of Education, Department of Biology, Chemistry and Home Economics, Ljubljana, Slovenia*

³*Jagiellonian University, Department of Chemistry Education, Krakow, Poland*

*iztok.devetak@pef.uni-lj.si

Chemistry Teacher International: Best Practices in Chemistry Education (CTI) is a peer-reviewed, open-access journal published by the Committee on Chemistry Education of IUPAC and supported by the Division of Chemical Education of EuChemS. The journal aims to provide a platform for chemistry educators at all levels, with a particular focus on researchers in chemistry education. The journal's objectives are:

- To bridge the gap between research and education, and
- To establish an international journal not limited to a specific field or nation.

CTI is indexed in leading international databases, including the Web of Science – Emerging Sources Citation Index Expanded (ESCI, JIF: 2.2) and SCOPUS (CiteScore: 3.1). With these impact factors, CTI is classified among Q2 journals.

This workshop seeks to bring together Editorial Board Members and potential authors to facilitate face-to-face interaction. The workshop will cover the following topics:

- A meeting with the Editorial Board Members,
- An introduction to the aims and scope of CTI, types of manuscripts accepted, and future policies,
- Encouraging chemistry educators to publish in CTI to promote knowledge sharing on effective teaching methods in university-level chemistry,
- Sharing essential information about the journal (indexing and citations, statistics for content and coverage, etc.),
- Presenting the submission and review processes, as well as the open-access policy and APC payment, including the APC waiver policy from DeGruyter,
- Introducing the CTI special issue on the Eurovariety Conference, and
- A question-and-answer session with discussion.

INNOVATING LABORATORY EDUCATION WITH BLENDED LEARNING

Charita Furumaya*, Annereinou Dijkstra

LabBuddy, The Netherlands

*charita.furumaya@labbuddy.net

In the past 10 years, leading European universities have transformed their laboratory teaching practices using innovative pedagogical insights and the digital tool LabBuddy (Erzinger *et al.*, 2024; Jongsma *et al.*, 2024; Moelans *et al.*, 2024). This online learning platform supports students and instructors in preparing for, conducting, and reporting on lab sessions. The replacement of traditional lab manuals with a blended learning approach has enabled a more efficient and impactful structure for practical courses, even with large student groups.

This workshop provides an opportunity to gain knowledge and inspiration for designing practical courses in a blended or digital format. Participants will explore effective methods for creating instructional materials that align with key educational theories such as Cognitive Load Theory (Sweller, 1994), the 4C/ID model (Van Merriënboer *et al.*, 2024), and the ARCS model for student motivation (Keller, 1987).

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SMARTY PANTS! LET'S SHOOT DICE TO LEARN NOMENCLATURE AND FORMULA WRITING!

Julio Garay^{1*}, Jairo Orjuela Segura²

¹*Department of Chemistry, Earth Sciences and Environmental Sciences, City University of New York / Bronx Community College, USA*

²*Business Administration, University Colegio Mayor de Cundinamarca Colombia*

*julio.garay@bcc.cuny.edu

STEM subjects are the cornerstone of a technology-driven society, yet a significant number of students harbor negative perceptions about these fields. This growing apprehension has already sparked concerns about a future shortage of qualified engineers capable of tackling the increasingly complex challenges presented by both current and emerging technologies. Among these subjects, chemistry stands out as particularly challenging for many students, often leading to an emotional disconnect with a science that is essential for understanding the very nature of matter and its transformations. Chemistry is central to any engineering program because everything in our world, including ourselves, is composed of matter. To address the environmental crises, we face and develop sustainable solutions for the future, understanding the principles of chemistry is not merely an academic pursuit—it is a vital necessity.

The fundamental question arises: How can we hope to solve global challenges if we lack an understanding of the natural world? Since everything we interact with is made from combinations of the elements of the periodic table, it is crucial to instill an early appreciation for chemistry in students. To achieve this, we propose introducing chemistry through a game-based learning approach early in students' academic careers, allowing them to form a positive emotional connection with the building blocks of chemistry. By creating an interactive environment, where students can visualize and manipulate elements and their interactions, we remove some of the intimidation that comes with chemistry and instead foster an engaging and intuitive understanding of the subject.

At the elementary school level, our magnetic periodic table can serve as an engaging puzzle, helping students match element symbols with their names, while connecting the elements to the world around them. This interactive approach fosters critical thinking through cause-and-effect dialogue, encouraging students to explore and understand the connections between science and the world they live in. The hands-on nature of this puzzle allows students to experience firsthand how the properties of elements determine their interactions, which ultimately form the basis for chemical reactions. As students' progress to higher grades, the complexity of the subject can be gradually increased, introducing them to the concept of chemical combinations and the formation of new compounds—beginning with simple binary compounds, both ionic and covalent, and advancing to polyatomic ions. In doing so, students will not

only learn the rules for writing chemical formulas but also gain proficiency in naming chemical compounds, further reinforcing their understanding of the subject.

The final step is to bridge chemistry with other basic sciences, helping students see how the integration of these disciplines can provide a holistic understanding of the world. This interdisciplinary approach will equip students with the knowledge necessary to make informed decisions and drive the creation of a sustainable future—one in which science and technology are harnessed to preserve our planet and its resources for generations to come. By demonstrating how chemistry connects with other fields, such as biology and physics, students can better appreciate the value of chemistry in everyday life, as well as its potential to solve pressing global issues like climate change and resource management. With this well-rounded understanding, students will be prepared not just for academic success but for the larger role they will play in shaping a sustainable future.

By introducing chemistry in this dynamic, hands-on, and interdisciplinary manner, we create an environment where students can thrive. As they connect scientific principles with the real world, they gain the tools to become innovators and problem-solvers, equipped to meet the challenges of a rapidly changing and increasingly complex global landscape.

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TEACHING STATISTICAL THINKING WITHOUT CODING

Volker Kraft^{1*}, Paolo Chiappa²

¹*Global Academic Program, JMP Statistical Discovery, Germany*

²*Global Academic Program, JMP Statistical Discovery, France*

*volker.kraft@jmp.com

Statistical thinking and data-driven problem-solving is essential for any Chemist who wants to transform data into insight. This workshop will get instructors started with a free package to teach analytical skills in the easiest and most engaging way.

Using JMP, students get direct access to their data and analyses through a no-code and graph-first interface. Without any programming challenges or other technical hurdles, they can clearly focus on the data, asking the right questions and better understanding the answers. Moreover, the JMP tools and analytical workflows reflect the methods and skills applied by leading companies in the Chemical industry today (Chemical Industry, 2025).

Teachers – in addition to all students and academic researchers – get free access to JMP software through an academic license called JMP Student Edition (2025). In addition to comprehensive statistical methods and interactive data visualization, the software also supports design of experiments (DOE), predictive modeling and machine learning, quality methods and six sigma, as well as the analysis of multivariate data and functions like spectra or time series. A smooth integration into new and existing courses is supported by free teaching material (2025) like quick guides, cases studies or online courses.

Following a brief overview of supported methods and courses, participants can directly experience the power of JMP in the classroom, by watching and discussing teaching best practices during a live demonstration of the software and resources.

After attending this workshop, participants will...

- understand if and how JMP meets the needs of their course or curriculum
- get access to the free JMP Student Edition
- know how to leverage free resources to teach these methods in Chemistry

The demo content from this workshop plus recommended case studies and other teaching material will be shared with the participants. Pre-knowledge in statistics or JMP is not required.

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"COFFE TIME": A VIRTUAL CHEMICAL ESCAPE ROOM

Ayelet Shvalb^{1*}, Debora Marchak², Shelley Rap², Ron Blonder²

¹*Mechanical Engineering, AFEKA-The Academic College of Engineering in Tel Aviv, Israel*

²*Department of Science Teaching, Weizmann Institute of Science, Israel*

*ayelets@afeka.ac.il

Physical or virtual escape games are a contemporary educational method that can be adapted for any age group and academic discipline, enhancing learning through competitive group activities (Veldkamp et al., 2020). Game-based learning integrates games to promote knowledge acquisition and skills development, contributing to cognitive growth and enhancing key 21st-century competencies like teamwork, critical thinking, problem-solving, and creativity, which are essential for integration into the workforce (Bonwell, 1991; AAC&U). It also helps bridge the gap between formal and informal education, enabling experiential learning (Yayon et al., 2023).

The virtual escape game "Coffee Time" was developed at Afeka College of Engineering for mechanical and biomedical engineering students taking an introductory chemistry course. Its development was driven by four main goals: 1) creating a positive and engaging learning experience, 2) encouraging the application of 21st-century skills in an interactive context, 3) providing an alternative assessment to traditional quizzes, and 4) supporting first-year students' social adaptation through group-based activities. The development process integrated chemistry principles, puzzle design, and fostering peer interaction through immediate feedback. Feedback from 251 participants highlighted enhanced teamwork, creative thinking, and the application of course content. These findings suggest that the escape-room model can effectively reinforce scientific and engineering subjects, supporting the integration of game-based learning in higher education.

In this workshop, participants will experience the escape game while learning about its unique design principles, which consider the development of 21st-century skills in higher education.

Teaser: <https://www.youtube.com/watch?v=iBmJO3M6Ch0>

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PREPARING A MODERN VIRTUAL LABORATORY CLASS OF CHEMICAL KINETICS TEACHING BY USING MATLAB LIVE SCRIPT

Jakub Szyman*, Miłosz Augustyński

Oprogramowanie Naukowo-Techniczne

*jakub.szyman@ont.com.pl

Present reality is strongly integrated with digital technology. It brings to the society massive streams of information at every second. Handheld devices, by which these pieces of information are transferred, are able to make even more powerful computational operations than specialized computers in the past. Nowadays, the main challenge is to share knowledge in the most attractive form and what follows to build awareness off the topic. On the other hand, wide access to the potentially used computational power may be a chance to use the simulation environment in didactic activities of students in their everyday lives. MathWorks has been providing professional data analysis and simulation tools which are dedicated especially to professional scientists and engineers, whose are not necessarily specialists in programming. Working in MATLAB allows us to use interactive Apps. When specific problems require writing code, the MATLAB Live Script environment lets you to achieve your goals with a low-code approach and easily implement interactive features into it.

In this hands-on session, participants will prepare the academic teaching materials using low-code methods in MATLAB Live Script. During the workshop, it will be shown how to add interactive control tools into it that allow to import and analyze data, simulate and then change the program behavior with several clicks. Apart from the setting of the virtual experiment engine, there will also be shown how to keep the experimental part close to the theory by using the text edition tools, equation editor and video content. As a follow-up, it would be shown how to integrate script into the cloud. It allows instant communication with students as well as setting evaluation tasks in MATLAB Grader. The simple chemical kinetics analysis is an example in this workshop. However, the same steps may be reproduced in different cases of data analysis: in topics related to microscope image processing, statistics, machine and deep learning and many more.

SYMPOSIA

GOOD PRACTICE IN CONTINUOUS PROFESSIONAL DEVELOPMENT IN TEACHING AND LEARNING IN HIGHER EDUCATION CHEMISTRY

Chair: Nataša Brouwer^{1*}

Speakers: Vânia Calisto², Iwona Maciejowska³, Mauro Mocerino⁴, Jurica Bauer⁵

¹*Faculty of Science, University of Amsterdam, The Netherlands*

²*Department of Chemistry, University of Aveiro, Portugal*

³*Faculty of Chemistry, Jagiellonian University, Krakow, Poland*

⁴*Faculty of Science and Engineering, Curtin University, Perth, Australia*

⁵*Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands*

*natasa.brouwer@uva.nl

Disciplinary focused continuous professional development (CPD) in teaching and learning is essential for addressing the specific pedagogical needs of learners in chemistry. It also enables continuous improvement of teaching approaches in response to rapid scientific and technological development and helps to effectively prepare students for global challenges (Brouwer, 2022).

In this symposium, the panel will discuss in depth the challenges and opportunities in the professional development of university chemistry teaching staff. Four speakers from three different European countries and Australia will share good practices on how CPD for lecturers is organized at their university and opportunities they envision for CPD.

Questions for the panel will include: the benefits and drawbacks of bottom up CPD approaches, how communities across the borders of universities and countries influence CPD (Brouwer, 2024), the impact of secondary school chemistry on teaching and CPD, what specific requirements chemistry topics, such as laboratory teaching, place on staff (Brouwer, 2022), and how we can professionalize collaborative teaching teams where members have different roles.

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RETHINKING CONTINUING PROFESSIONAL DEVELOPMENT TO SUPPORT DIVERSE EDUCATORS

Jurica Bauer*

Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

**j.bauer@maastrichtuniversity.nl*

At Maastricht University (UM), Continuing Professional Development (CPD) has been introduced to support the lifelong learning of teaching staff beyond the University Teaching Qualification (UTQ) (*Continuous Professional Development at Maastricht University, 2025*). It emphasizes personal reflection, workplace-based learning, and flexible, goal-oriented development rather than rigid, course-based formats. CPD aims to enhance teaching quality, strengthen teacher identity, and foster communities of practice by integrating development into everyday academic work and annual appraisal interviews. Implementation at the Faculty of Health, Medicine and Life Sciences (FHML) is coordinated by a dedicated workgroup, supported by HR and departmental representatives. Staff receive compensated CPD hours to pursue relevant formal and informal learning activities. CPD is positioned not only as a means for skill development but also to elevate the visibility and value of teaching within the academic community. A variety of training formats, coaching, and self-directed learning options are offered, with ongoing evaluation to ensure impact and sustainability.

While the CPD programme offers a diverse range of workshops and modules—often rich in educational vision and inspiring in scope—participants sometimes find that the content lacks the concreteness needed to address specific teaching challenges. For example, translating the university's assessment philosophy to lab-based modules can remain a gap. Moreover, most CPD offerings are not discipline-specific, making it difficult for STEM educators—and chemists in particular—to find support that directly aligns with the pedagogical demands of their subject area. In addition, because the majority of modules is developed and delivered by UM staff, they are strongly grounded in the university's educational philosophy. This can make it challenging for educators seeking to explore approaches that fall outside this framework. Despite these limitations, CPD modules help expand academic networks and strengthen the teaching community. They bring together colleagues from different faculties, fostering interdisciplinary exchange and broadening perspectives on teaching and learning. This presentation will reflect on these experiences and explore how CPD at FHML and UM might further evolve to better support both disciplinary diversity and openness to alternative educational approaches, while maintaining its focus on quality, collaboration, and community.

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BOTTOM-UP APPROACHES TO CONTINUOUS PROFESSIONAL DEVELOPMENT – A CASE STUDY ON MOTIVATING NON-CHEMISTS TO CHEMISTRY SPECIFIC COURSES

Vânia Calisto*

Department of Chemistry, University of Aveiro, Portugal

**vania.calisto@ua.pt*

The continuous professional development (CPD) of university STEM teaching staff is crucial to help lecturers to cope with the growing challenges of teaching STEM to very heterogeneous groups of learners, with distinct knowledge backgrounds and motivations. The University of Aveiro (UA) has been developing a Pedagogical Training and Updating Program that qualifies lecturers to migrate from passive to increasingly student-centered teaching and learning processes. This program offers from short training actions to the creation of communities to share and implement best practices, such as the Peer Observation Program and the Communities of Practice. A bottom-up approach was implemented, supported by regular reflection, evaluation and program restructuring according to identified needs. While these actions are offered by the University Pedagogical Innovation Office, very specific needs emerge not only at departmental level but also in the context of different courses. Thus, the role of a CPD-Ambassador could be fundamental in the organization of activities to help fellow lecturers developing skills to address specific contexts, breaking barriers more effectively than broader training programmes.

In the above-mentioned context, user cases, describing how lecturers can collaborate in CPD actions with result-oriented approaches, can be an important tool. In the Chemistry Department of UA, it was identified that many students struggle to find the purpose of studying non-specific subjects in their BSc, evidencing severe lack of interest and motivation. Specifically, this is the case of analytical chemistry related courses included in the curricular plans of non-chemistry BSc degrees, where teachers fail to convince students of the transversal importance of the course for their professional careers. A user case, aimed at raising awareness among other lecturers to this issue, encouraging the introduction of small but meaningful modifications in the courses specifically tailored for non-chemist students, is currently being implemented. While initiating a local shift in how analytical chemistry is taught to non-chemists is challenging, some positive results have already been achieved, with certain courses receiving positive recognition from students for the applied approaches.

References:

Motivating non-chemists to analytical chemistry courses (2022, October 3) <https://starfish-education.eu/usercase/1356/>

CONNECTING ACROSS BORDERS: INTERNATIONAL AND LOCAL PERSPECTIVES ON CONTINUOUS PROFESSIONAL DEVELOPMENT IN UNIVERSITY CHEMISTRY EDUCATION

Iwona Maciejowska*

Faculty of Chemistry, Jagiellonian University, Poland

**iwona.maciejowska@uj.edu.pl*

In recent years, Continuous Professional Development (CPD) has gained increasing recognition as a key element in enhancing teaching quality and academic engagement in higher education. This presentation draws on multiple European initiatives—most notably the STEM-CPD@EUni Erasmus+ project (<https://ectn.eu/work-groups/stem-cpd/>), which included international summer schools for CPD ambassadors, a series of MOOCs, and practical user cases of CPD implementation across STEM disciplines. I will also share insights from peer groups and projects coordinated by the European University Association (EUA, eg. <https://www.eua.eu/publications/reports/staff-development-in-learning-and-teaching-at-european-universities-2.html>), focusing on institutional strategies and the cultural shift needed to foster a sustainable CPD ecosystem.

The talk also reflects on the role of international associations, such as ICED (International Consortium for Educational Development, <https://icedonline.net/>), in shaping global conversations on educational development. Additionally, I will present the evolving landscape of Teaching & Learning Centers in Poland, which play a critical but still emerging role in supporting academic staff through professional development opportunities.

Across these initiatives, we have gathered rich experience on the importance of bottom-up, cross-border collaboration. Such international and interdisciplinary exchanges have proven to be highly valuable and inspiring. However, they also reveal a persistent challenge: ensuring active and sustained engagement within professional communities.

Drawing on both project experience and theoretical foundations, as well as my own practice as an educational developer and researcher, I will offer a reflective view on what helps CPD thrive in the context of university chemistry education—and what makes it so complex. The session aims to contribute to a broader understanding of how CPD can be meaningfully embedded in academic culture, with relevance to both local and international settings.

ENHANCING LEARNING IN THE LABORATORY: IDENTIFYING AND PROMOTING BEST PRACTICE IN UNIVERSITY SCIENCE LABORATORY CLASSES

Mauro Mocerino*, Alexandra Yeung, Joanne Castelli
Faculty of Science and Engineering, Curtin University, Australia
*m.mocerino@curtin.edu.au

Laboratory classes are a vital part of most science and engineering programs, offering opportunities to achieve both practical and theoretical learning outcomes. However, their full educational potential is often not realized. In the report *Tertiary Science Education in the 21st Century*, Rice et al. (2009) highlighted the crucial role laboratory instructors play in higher education, emphasizing their significant influence on students' development as science professionals. Similarly, O'Neal et al., (2007) in their research on the impact of teaching assistants and student retention in science and engineering, underscored the importance of delivering high-quality instruction in lab settings.

To address concerns about the quality of laboratory teaching, Curtin University introduced the Laboratory Demonstrators Professional Development Program (LDPDP), designed to improve the teaching capabilities of lab demonstrators. In parallel, the European Chemistry Thematic Network (ECTN) working group on Lecturing Qualifications and Innovative Teaching Methods created a MOOC titled *Teaching in University Science Laboratories: Developing Best Practice*, available on the Coursera platform. These initiatives specifically target relatively inexperienced university educators. (Brouwer et al., 2022).

This paper will present some of these strategies for enhancing the visibility and impact of high-quality laboratory instruction.

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BEYOND THE LAB BENCH: THE DIGITAL SHIFT IN CHEMISTRY EDUCATION

Chair: Bartosz Trzewik^{1*}

Speakers: Heinz Krebs², Denise Rooney³, Fun Man Fung⁴, Michał Woźniakiewicz¹

¹*Faculty of Chemistry, Jagiellonian University, Krakow, Poland*

²*ChemIT e.U. & TU Wien, Austria*

³*Maynooth University, Ireland*

⁴*University College Dublin, Ireland*

*marek.frankowicz@uj.edu.pl

While digital methods have been increasingly used in chemistry education in recent decades, the COVID 19 pandemic has caused a rapid acceleration in this area. New solutions were often introduced ad hoc, as a kind of reconnaissance in battle. Now is the time to reflect and organize the digital landscape in chemistry education. This was the goal of, among others, the recently completed ERASMUS+ project "Digital Support in Chemistry Teaching" (DISTINCT).

During this symposium, four speakers will present different aspects of the digital shift in chemistry education, showing both a general perspective and specific solutions for application in teaching practices. Our ambition is to show the possibilities of a synergic approach to digital transformation and to emphasize the importance of cooperation between educators in this field; such cooperation will be promoted by the DISTINCT Community of Practice recently established under the umbrella of ECTN.

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DISTINCT Project <https://ectn.eu/work-groups/distinct/>

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SPATIAL REALITY IN STEM UPSKILLING

Fun Man Fung*

School of Chemistry, University College Dublin, Ireland

**funman.fung@ucd.ie*

Pre-laboratory preparation in chemistry education often depends on students' ability to interpret textual descriptions from lab manuals and mentally construct representations of unfamiliar spatial phenomena. Conventional pedagogical approaches—such as passive video demonstrations or static manual-based instruction—frequently fall short in effectively conveying the complex laboratory processes.

Spatial reality-engineered chemistry lab present an opportunity to bridge this gap by fostering immersive, interactive learning experiences. We applied spatial reality in environmental chemistry and forensic science training. Our findings suggest that spatial reality improves pre-laboratory preparedness.

DIGITAL INK IN EXAMINATIONS (AND ONBOARDING)

Heinz A. Krebs^{1,3*}, Benjamin Schallar², Robert Liska³, Andreas Limbeck³

¹ChemIT e.U., Austria

²Campus Information Technology, TU Wien, Austria

³Faculty of Chemistry, TU Wien, Austria

*heinz@ixam.cloud, heinz.krebs@tuwien.ac.at

Assessment systems have been growing out of the ground like mushrooms in the time during (and after) the COVID19-Pandemic. Many of them just support common question types like multiple choice answers, numeric expressions or essay answers.

Chemists however are used to answer many questions by drawing structures, diagrams or sketches. There exists some plugins [1] to extend common assessment systems and get around these limits, but they cannot cover all eventualities. Other solutions like drawing on paper and scanning afterwards to get them into the examination report result in a media break and might also lead to low quality images.

To overcome this limitation we have developed a(nother) assessment system [2] with extension to a simplified whiteboard application [3]. The examination room at TU Wien now hosts 50+ computer stations (VDI-based) equipped with a digitizer, and candidates now answer their exams either by typing into the assessment system or by drawing them onto the tablet (like they would draw on a sheet of A5 paper). The full examination report is ready for grading at the second the candidates submits the exam, and the whole process is fully digital now (even the cheat sheets by the students get digital).

Although the system is reported to be very easy to handle we put effort into onboarding the students to the system. As part of a chemical calculation lecture they have to do a weekly calculation example to stepwise get in contact with the different modules (secure browser, whiteboard app, video interface) of the system and get prepared for the first exam at the end of the first semester.

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- [3] tldraw, (2025, February 20), <https://tldraw.dev/>

IRISH THIRD-LEVEL INTER-INSTITUTIONAL STUDY ON DEVELOPING A BLENDED APPROACH TO LABORATORY TEACHING & LEARNING: INTEGRATING TRANSVERSAL SKILLS

Denise Rooney^{1*}, Frances Heaney¹, Carmel Breslin¹, Bernard Drumm², Ronan Bree²,
Brian Murphy³, Aoife Morrin⁴, Blánaid White⁴, Eric Moore⁵, Christopher Burke⁵

¹*Department of Chemistry, Maynooth University, Ireland*

²*Department of Life & Health Sciences, Dundalk IT, Ireland*

³*Department of Pharmaceutical Science and Biotechnology, TUS: Midlands Midwest*

⁴*School of Chemical Sciences, DCU, Ireland*

⁵*School of Chemistry, UCC, Ireland*

*denise.rooney@mu.ie

The centrality of laboratory work within chemistry programmes, already challenged in some quarters, has come in for greater re-evaluation in the post-Covid period (Betz, 2019; Simmons & Mistry, 2023), highlighting the need for a clearer awareness of the pedagogical basis for lab teaching (Seery, 2020). With these concerns in mind, we, a consortium of five Irish Higher Education Institutions, have been working on a widescale study, funded by the Higher Education Authority (HEA), to understand the most effective pedagogical approaches to teaching practical chemistry.

The advantages of virtual simulations and video content in terms of accessibility and repeatability are obvious, and they have the potential to offer a sustainable approach to lab teaching. Moreover, students can access equipment or experiments that would otherwise be unaffordable.

Our initiative involves students from introductory to master's level. We are studying the pedagogical value of virtual laboratories as resources for pre-laboratory preparation work and for post-laboratory skill reinforcement experiences. We are also exploring the potential of this educational approach to support teamwork and development of transversal skills, including industry engagement. Our findings indicate that virtual labs are useful preparatory resources for students. Students were positive about their experience of collaborative teamwork and reported that their understanding of concepts was reinforced by using virtual laboratories.

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DIGITAL SUPPORT IN CHEMISTRY TEACHING – THE RESULTS OF “DISTINCT” PROJECT

Michał Woźniakiewicz*, Marek Frankowicz, Bartosz Trzewik

Faculty of Chemistry, Jagiellonian University, Poland

*michal.wozniakiewicz@uj.edu.pl

The DISTINCT project was a response to the questions of the chemical community regarding digital transformation. How to sustainably carry out the digital transformation of chemical studies? How to live and survive in a digital world (with digital natives, immigrants and "technophobes")? How to build resilience to possible future crises using digital solutions?

As part of the Project, we have created a free and accessible platform in the Zotero environment containing a rich collection of materials related to the use of digital tools in chemical education. We have also developed training modules supporting the organization of remote classes. As the COVID-19 pandemic has shown, such digital support is particularly important when preparing and conducting practical classes, both for instructors and participants. Suddenly and unexpectedly, the previous methods of conducting laboratory classes had to be adapted to remote work on an unprecedented scale. Elements of such work, to a greater or lesser extent previously used in various higher education institutions in STEM fields, had to be significantly developed, expanded and deepened. Teaching chemistry, by its nature a largely laboratory-based course, had to undergo these changes to an exceptional extent. It would be a great mistake to reject the experience of the pandemic and the wealth of remote materials developed and developed at that time, as well as the methods of their application during laboratory exercises. Films, quizzes and a whole range of other remote materials collected on our platform can be used to enrich and improve traditional methods of conducting classes in stationary work conditions. At the same time, it is a safeguard in case, for various reasons, it is necessary to temporarily return to remote learning. In addition, our academic experience can be useful for other sectors (secondary schools, vocational training systems in the chemical sector); in this respect, we cooperate with the Sector Skills Council of the Chemistry Sector.

References:

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ORAL PRESENTATIONS

EMPOWERING STUDENTS TO ASSESS GREENHOUSE GAS EMISSIONS IN STEM LABORATORIES: A HANDS-ON APPROACH TO ENVIRONMENTAL AWARENESS

Katarzyna Dziubińska-Kühn¹, Renaud Jolivet¹, Gavin Phillips¹,
Annemarie van Zeijl-Rozema², Jurica Bauer^{3*}

¹*Faculty of Science and Engineering, Maastricht University, The Netherlands*

²*School of Business and Economics, Maastricht University, The Netherlands*

³*Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands*

*j.bauer@maastrichtuniversity.nl

Universities play a crucial role in addressing global environmental challenges, yet one overlooked contributor to greenhouse gas (GHG) emissions comes from their own laboratories. While sustainability efforts in STEM education often focus on lifestyle choices or large-scale industrial impacts, emissions from routine chemistry experiments remain largely unexamined. To bridge this gap, an extracurricular research project engaged undergraduate students in assessing laboratory-generated GHG emissions and their role in climate change.

A multidisciplinary group of students conducted real-time measurements of GHG emissions during chemistry-oriented practical courses. Using commercially available probes equipped with sensors for CO₂, CO, NH₃, and total volatile organic compounds (TVOCs), as well as a particle counter, they gathered qualitative and quantitative data. By linking their findings to specific laboratory activities, students identified frequently neglected sources of gaseous waste and gained a deeper understanding of their own chemical footprint. Their work culminated in a published paper, on which they are co-authors (de Raad et al., 2024).

This hands-on approach not only provided students with direct experience in analytical chemistry but also encouraged critical thinking about sustainable laboratory practices. Students reported developing a stronger personal connection to environmental responsibility. Extracurricular research projects like this offer invaluable opportunities for students to apply their knowledge beyond the classroom, fostering scientific curiosity, independence, and practical problem-solving skills. This initiative highlights the benefits of research-based learning in STEM education, particularly in sustainability, and we are now exploring ways to integrate it into the curriculum. In addition, we are expanding our focus to assess air quality in various university study spaces and to explore how students perceive its impact on their health and academic performance.

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TEACHING CHEMISTRY FOR REGENERATIVE MEDICINE: A MULTIDISCIPLINARY APPROACH

Jurica Bauer*

Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

**j.bauer@maastrichtuniversity.nl*

Regenerative Medicine (RM) is an emerging field at the intersection of science, technology, medicine, and entrepreneurship, focused on replacing, mimicking, or recreating human cells to restore damaged or diseased tissues and organs. To meet the growing demand for multidisciplinary expertise in this field, Maastricht University has launched the pioneering undergraduate program Regenerative Medicine and Technology (*Bachelor Regenerative Medicine and Technology*, 2025).

This program is designed to equip the next generation of researchers and engineers with the skills to navigate various RM domains and contribute to the development, evaluation, and commercialization of innovative (bio)medical therapies, products, and devices. By focusing on disease treatment at its root rather than on symptom management, it aims to improve patient outcomes while fostering a more sustainable healthcare system and economy.

Chemistry plays a fundamental role in this multidisciplinary curriculum, providing students with essential understanding of biochemical processes critical for tissue growth. It is also integral to designing, synthesizing, and characterizing biomaterials able to direct cell behavior and promote regeneration. The program seamlessly integrates chemistry with biology, engineering, medicine, and entrepreneurship, employing problem- and research-based learning to encourage students to think and innovate beyond traditional disciplinary boundaries. This multidisciplinary approach requires careful balancing to ensure students gain both a broad perspective and sufficient depth in individual disciplines like chemistry.

As a young and evolving program, we are dedicated to continuously refining our curriculum and teaching methods. We actively seek insights from the international higher education community and welcome collaborations on multi- and transdisciplinary projects, striving to advance education and contribute to a more sustainable future.

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INTEGRATION OF GENERATIVE AI IN CHEMISTRY TEACHING: COMPETENCIES AND CONCERNS

Ron Blonder*

Department of Science Teaching, Weizmann Institute of Science, Israel

*Ron.Blonder@weizmann.ac.il

The integration of Artificial Intelligence (AI) into education is transforming teaching and learning in schools and higher education. AI technologies, such as intelligent tutoring systems, automated assessments, and adaptive learning platforms, enhance learning experiences and personalize education, leading to improved student outcomes (Lee et al., 2024). However, AI also presents challenges like data privacy and the digital divide, which educators and policymakers must address. The evolution of AI necessitates a reevaluation of the teacher's role in education (Zhai, 2025). Zhai (2025) highlights that AI integration significantly changes teachers' roles, requiring adaptation to new classroom dynamics and ongoing professional development. In this talk, I will examine the competencies required for integrating AI in chemistry teaching, based on the UNESCO AI competency framework for teachers (UNESCO, 2024). This framework includes five aspects that we integrated into an academic course for teachers that will be described (Alexandron et al., submitted). However, the integration of AI in teaching also raises teachers' concerns. The concern-based adaptation model (Hall, 1979; Aroch & Blonder, submitted). was applied to learn about teachers' concerns regarding AI. We have identified different concern profiles that distinguish AI adaptation by teachers from the adaptation of general technology. This difference can be related to the human-centered mindset and ethical concerns (Blonder & Feldman-Maggor, 2024), one of the UNESCO aspects that raises additional concerns beyond those described in the traditional concern-based adaptation model. The unique teacher concerns regarding AI adaptation will be presented, and I will discuss approaches to addressing them via teacher preparation and PD programs.

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ENHANCING WORKPLACE SKILLS THROUGH A TEAM-BASED WATER ANALYSIS PROJECT

Carmel Breslin^{1*}, Denise Rooney¹, Frances Heaney¹, Bernard Drumm², Ronan Bree², Brian Murphy³, Aoife Morrin⁴, Blánaid White⁴, Eric Moore⁵, Christopher Burke⁵

¹*Department of Chemistry, Maynooth University, Ireland*

²*Department of Life & Health Sciences, Dunalk IT, Ireland*

³*Department of Pharmaceutical Science and Biotechnology, TUS: Midlands Midwest*

⁴*School of Chemical Sciences, DCU, Ireland*

⁵*School of Chemistry, UCC, Ireland*

*Carmel.Breslin@mu.ie

It is now well recognised that the teaching of Chemistry at University level, which remains dominated by examinations, requires more emphasis on the skills needed in the workplace (Wilson et al., 2023). In this study, we set out to address this by designing a team-based module, where the students could not only develop their analytical skills in Chemistry but also improve their team-working and collaborative skills (Hapiot et al., 2025). The project was centred on water analysis in the local community and the activities were designed to give the students confidence, effective communication, and various team-based and collaborative skills.

Student teams were assembled by the coordinator of the module, with the average team consisting of four to five students. The project consisted of five weeks. The first week was devoted to an interactive virtual lab component aiming to encourage the students to actively prepare for the different analytical tests and team roles. Each team was assigned the task of developing an analytical procedure for the analysis of water contaminants, and the teams worked on different analytical methods. Once the analytical procedures were formulated, the teams developed standard operating procedures (SOPs) for their analyses. The SOPs were then exchanged between the teams, for evaluation and to facilitate peer-to-peer feedback between the teams. Real water samples were collected and the SOPs were used to measure the nature and level of contaminants in the water samples. Finally, each team presented their findings focusing on the team roles, data analysis and sharing, SOP evaluation and revisions.

The students were very positive about their experience of teamwork, the feedback that they received, their introduction to SOPs and the virtual resources provided.

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COMPARING THE EFFECTIVENESS OF LIVE AND VIDEO-BASED CHEMICAL DEMONSTRATIONS IN CHEMISTRY EDUCATION

Tereza Bryxová*, Martin Rusek

Faculty of Education, Charles University, Czech Republic

**tereza.bryxova@pedf.cuni.cz*

The aim of this study was to compare the effectiveness of chemistry demonstrations conducted in a real environment and on video (cf. Oliveira & Bonito, 2023). The research involved third-year undergraduate students who, as part of the course School Chemical Experiment, observed experiments both in real and video form. Afterwards, they completed worksheets focused on affective and cognitive components (Baddock & Bucat, 2008), the interpretation and description of chemical processes, and observed reactions. Based on the analysis of the completed worksheets after both types of demonstrations, six students were selected for further observation of video demonstrations using a stationary eye-tracker. This tool enabled detailed mapping of students' visual attention and together with the demonstrations' description in the worksheets provided deeper insight into their cognitive processes when observing chemical phenomena (Childs et al., 2015). The study results indicate differences in the perception and processing of information between live and video demonstrations and identify factors influencing their didactic effectiveness. The findings may contribute to optimizing chemistry education and the more effective use of visual demonstration methods (Cheng, 2018).

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RELATIONSHIP BETWEEN WORKING MEMORY AND CHEMISTRY LEARNING AMONG UNIVERSITY STUDENTS: TEACHING IMPLICATIONS

Francesca De Vita^{1*}, Anna Maria Re², Barbara Sini²,
Elena Maria Ghibaudi³, Renato Lombardo⁴, e Antonella Maria Maggio⁴

¹*Dipartimento Fisica e Chimica E. Segrè, University of Palermo, Italy*

²*Dipartimento di Psicologia, University of Torino, Italy*

³*Dipartimento di Chimica, University of Torino, Italy*

⁴*Dipartimento STEBICEF, University of Palermo, Italy*

*francesca.devita@unipa.it

Chemistry requires students to engage with abstract concepts at the microscopic level, that cannot be directly observed. Understanding these concepts relies on mental representations that, while essential, tend to oversimplify reality (Johnstone, 2010). Effective teaching strategies depend on knowledge of cognitive processes, yet research remains limited. Working memory (WM) plays a key role (Rhodes et al., 2016), acting as a mental board where verbal (words, symbols) and visuospatial (graphs, images) information are processed during a task (Uttal & Cohen, 2012). Further research is needed to clarify the role of verbal and visuospatial WM in chemistry learning, particularly at the microscopic level, and to understand its impact on students with Specific Learning Disabilities (SLDs).

To address these gaps, we developed a chemistry learning task for undergraduate Italian students, assessing their chemistry learning (CL) abilities and WM skills. We examined the relationship between CL and WM in TD students (Study 1) and those with SLDs (Study 2). We also tested whether dynamic visualization of molecular structures could enhance understanding (Study 3). Results show that CL is significantly related to visuospatial WM, with an even stronger association in students with SLDs. Preliminary findings suggest that dynamic visualization tools are particularly beneficial for students with lower visuospatial WM skills.

These results emphasize the crucial role of WM, particularly its visuospatial component, and highlight the need for targeted teaching strategies to support students with weaker visuospatial WM skills.

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This image shows a full page of dot grid paper. The dots are arranged in a precise, repeating grid pattern across the entire surface. There are no margins, text, or other markings present. The dots are small, black, and evenly spaced both horizontally and vertically.

DESIGNING AND EVALUATING A SEMINAR ON GREEN AND SUSTAINABLE CHEMISTRY

Paula Deuermeier*, David-S. Di Fuccia
Chemistry Education, University of Kassel, Germany
*paula.deuermeier@uni-kassel.de

Sustainability has become a highly discussed topic (Mensah, 2019) which states a current challenge for industry, economics, politics etc. as well as for educators (UN GA, 2015). On the one hand, the UNESCO (2020) asks to embed Education for Sustainable Development in all levels and sectors and on the other hand, human resource forecasts predict an increasing demand of sustainability-related job characteristics (Linkedin, 2024). Especially the chemical sector has large potential and responsibility. Furthermore, chemical research offers a variety of approaches and concepts that foster sustainability (UNEP, 2020). In contrast to this, we perceive a lack of topics of Green and Sustainable Chemistry (GSC) in chemistry bachelor's degrees and chemistry teacher trainings in Germany.

To gain first insights in students' views on sustainability, resp. GSC, in chemical higher education we conducted a survey at the University of Kassel. The results of the questionnaire indicate a lack of knowledge about sustainability in general and in relation to chemistry. According to the students' answers, most of the queried topics of GSC have not been discussed in their studies yet, although they are rated as quite relevant by the students.

As next step, we designed a new seminar focusing on GSC to pick up the survey results. The seminar was evaluated in a first run in chemistry teacher training using a qualitative analysis of written feedback and comments by the participants. All in all, the results are promising and indicate some adaptations for the next run of the GSC seminar. The detailed structure, evaluations and further adaptations of the seminar as well as an outlook on embedding it in a chemistry bachelors' degree will be explained and discussed in the presentation.

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CHEMISTRY DEGREE PROGRAMMES WITH A FOCUS ON SUSTAINABILITY: THE EMBEDDING OF INTERDISCIPLINARITY AND AN OUTLOOK ON INTERNATIONALISATION

Paula Deuermeier*, David-S. Di Fuccia
Chemistry Education, University of Kassel, Germany

* paula.deuermeier@uni-kassel.de

While the scientific community of chemistry has made large progress towards more sustainable solutions, so-called Green and Sustainable Chemistry (UNEP, 2020), this has not been properly reflected in chemical higher education (HE) in Germany. Therefore, we have developed chemistry degrees with a focus on sustainability in line with the UNESCO requirements (2020). Due to the multidimensionality of sustainability, which goes along with the suggestion of interdisciplinary teaching (Aktas, 2015), we have embedded interdisciplinary aspects in our new sustainability-focused chemistry bachelor's degrees. Basic courses on sustainability from a social science perspective are embedded to ensure that students are aware of the multifacetedness of the topic. Courses from neighbouring disciplines such as engineering are offered, e.g. to help understand sustainability aspects concerning the life-cycle of (chemical) products or to give more insight into the application or transfer of chemical innovations/processes. Alternatively, courses offered by the mathematics department can provide students with insights into modelling techniques that are important in the context of sustainability. As sustainability is also a multinational challenge and internationalisation of HE can be multifariously linked to education for sustainable development (Healey, 2022; Leal Filho, 2022), we propose to go further and combine sustainability, interdisciplinarity and internationalisation in our future master's programmes in chemistry. Therefore, we present the theoretical framework of our already developed programmes and give an outlook on our next steps in international degree development.

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FRAMEWORK FOR DESIGN AND CONSTRUCTION OF AN ACIDS AND BASES TEACHING SEQUENCE IN AN EXTENDED ENGINEERING PROGRAMME

Nadine Dharsey*

Academic Development and Support, University of Johannesburg, South Africa

*nadined@uj.ac.za

For the past 20 years, science education research has focused on the design, construction, analysis and validation of teaching and learning sequences (TLS). However, there are few research studies that used more than one framework for the design of a TLS. Since there is no 'one size fits all' to develop TLS, a number of frameworks, models and approaches were used to develop a framework for the context of this study. In this study which is part of a broader study, a framework was developed for the design and construction of an acids and bases teaching sequence (TS) for students in an extended curriculum programme (ECP). The *Ingénierie Didactique* framework (Artigue, 1988), the learning demand approach (Leach & Scott, 2002), the model of educational reconstruction (Duit et al., 2005), the novel framework (Ghirardi, 2014) and the TSPCK model (Mavhunga, 2012) were used to develop the framework known as the 'Integrated Framework'. Each of these models, approaches and frameworks provided useful information and characteristics for developing the 'Integrated Framework'. However, all except for the TSPCK model, focused mainly on the content, science resources, context and learning of the students rather than on the teachers' expertise in teaching the students (role of the teacher).

A qualitative, case study research method and design-based research design was used in the study. The development of the Integrated Framework was phase four of the five phases of the design-based research. This resulted in a framework which is made up of 13 steps that were used to design the TS. These will be highlighted later.

Although this Integrated framework was developed for the design and construction of an acids and bases TS for students in an extended engineering programme, it can be used to design and construct TS in other chemistry topics at higher levels.

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25 YEARS OF POST-GRADUATE EDUCATION IN GREEN CHEMISTRY

Thomas I.J. Dugmore*, James H. Clark, Glenn A. Hurst, Duncan J. Macquarrie and Avtar S. Matharu
*Green Chemistry Centre of Excellence, Department of Chemistry,
University of York, York, UK, YO105DD*
*tom.dugmore@york.ac.uk

In 1998, Anastas and Warner published the 12 Principles of Green Chemistry, designed to be a guiding point to reducing the environmental impact of chemical processes. Soon after, the RSC journal Green Chemistry was launched, led by Professor James Clark and Dr Duncan Macquarrie, to showcase research being done in the field. Recognising the need to pass the knowledge and principles on to the next generation, Clark also launched the first of its kind postgraduate MSc in Green Chemistry and Sustainable Industrial Technology in 2001 to cover not just the theory of green chemistry, but the application and communication of it in the wider community with classes and assessments ranging from traditional exams and laboratories to business planning and outreach.

25 years on and the course continues to be an internationally leading postgraduate course attracting students from some 20 countries across the world. During this time Green Chemistry has evolved from being seen as somewhat of a niche area of chemistry to one that underpins many disciplines in the chemical sciences. Many of the principles once considered specialist are now core requirements for undergraduate teaching.

The MSc course has similarly evolved to be at the forefront of Green Chemistry developments as older more established material is successfully embedded in undergraduate programs. The course has also been refined to reflect the many demands from an increasingly diverse cohort of home and international students as well as unforeseen global changes, including the global financial crash of 2008, and the Covid-19 pandemic of 2020

This talk will explore some of the obstacles and success stories the postgraduate course has had in feeding green chemistry into the global educational sphere as well as exploring some of the challenges that green chemistry education is likely to encounter. We can also explore how the postgraduate course can support new initiatives in the field such as the growing interest in renewable chemistry.

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ADVANCING SUSTAINABILITY TRANSFORMATIONS VIA GREEN CHEMISTRY EDUCATION

Vesna Ferk Savec* and Katarina Mlinarec
Faculty of Education, University of Ljubljana, Slovenia
*vesna.ferk@pef.uni-lj.si

Education for Sustainable Development (UN, 2017) is anchored in the *2030 Agenda* (UN, 2015), which emphasizes the central role of education in achieving the 17 Sustainable Development Goals (SDGs). Redman and Wiek (2021) assumed that promoting transformations towards sustainability requires change agents and developed the *Framework of competencies for advancing sustainability transformations*, which includes eight core competencies (systems thinking, futures thinking, values thinking, strategic thinking, implementation, interpersonal competence, intrapersonal competence and integration competence). As there is so far no systematic literature review addressing the role of green chemistry in promoting sustainability transformations within educational context, this study aims to analyze the relevant literature to identify the most frequently highlighted educational levels and key competences. Using the PRISMA methodology, a systematic review of literature from 2015 to 2024 was conducted in three electronic databases: Web of Science, Scopus and ERIC. After applying predefined inclusion and exclusion criteria, a set of the most relevant articles was selected for in-depth analysis. The results show that systems thinking, implementation and strategic thinking were the most emphasized competences, while values thinking and intrapersonal competence received the least attention. Furthermore, the competences to promote sustainability transformations were predominantly associated with tertiary education, especially in non-pedagogical study programmes, while they were hardly represented in pedagogical study programmes. The results emphasize the need for their more systematic inclusion in teacher education and in-service teacher training to effectively promote sustainable transformations in the context of green chemistry.

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COMPETENCE BASED CHEMISTRY EDUCATION AND EUROPEAN COMPETENCE FRAMEWORKS

Marek Frankowicz^{1*}, Aleksandra Lis², Bartosz Trzewik¹

¹*Faculty of Chemistry, Jagiellonian University, Poland*

²*Faculty of Production and Power Engineering, University of Agriculture in Krakow, Poland*

*marek.frankowicz@uj.edu.pl

According to David Pink, 21st century will become a conceptual age; human factors will become more and more important in the world dominated by technology. It is also reflected in present-day competence frameworks developed at the European and global level. In recent years several frameworks important for education and training provisions have been developed, such as DigComp, EntreComp, GreenComp, LifeComp and competence framework for researchers. Sectoral qualifications frameworks, such as Polish SQF for Chemical Industry have been also designed.

However, in general, individual competence frameworks are not correlated with each other, and there is no direct reference of these frameworks to the European Qualifications Framework and the National Qualifications Framework, which in turn determine curriculum development at different levels of education.

We propose to develop a methodology that will allow the integration of transversal competences into regular curricula; we have taken the first step in this direction within the DISTINCT project for digital competences. We are currently working on a synergistic approach taking into account three dimensions of the competence space: digitalization, entrepreneurship and sustainability.

Our work is aligned with the activities of the European Chemistry Thematic Network and at the national level will be linked to the activities of the Sector Skills Council for the Chemistry Sector.

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RPL AS A PICKLOCK FOR OPENING DOORS IN THE HOUSE OF CHEMICAL EDUCATION

Marek Frankowicz^{1*}, Aleksandra Lis², Bartosz Trzewik¹

¹*Faculty of Chemistry, Jagiellonian University, Poland*

²*Faculty of Production and Power Engineering, University of Agriculture in Krakow, Poland*

*marek.frankowicz@uj.edu.pl

Two decades ago, the Forum for Alternating Chemical Education (FACE) project introduced the idea of a "House of Chemical Education" with floors corresponding to different levels of education and multiple doors between rooms. It was concluded that we need to use and refine instruments that help make the different approaches to entry, exit and passage through the House of Chemical Education transparent and therefore comparable in the process of lifelong learning.

Since then, significant progress has been made: cooperation between universities and industry has been strengthened (industrial doctorates), interdisciplinary specialisations have developed, schools and universities have worked more closely together, and qualification frameworks and the introduction of micro-qualifications offer new tools that open doors that were previously closed.

However, these tools are not fully used, and the idea of recognition of prior learning is struggling to make its way into the academic world. In the Tirana Communiqué announced after the last ministerial EHEA conference, the issue of RPL was considered one of the key issues for the development of European higher education. Last year, the European RPL Network was established. The main purpose of the ERPL Network is to enhance the use of RPL in Higher Education by supporting its members in establishing, maintaining, and fostering sustainable national RPL networks. The chemical environment should add a new dimension to RPL - the sectoral dimension. ECTN is particularly suited to this, having offered quality labels for formal education for many years.

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LEARNING STYLES THEORY: COULD STUDENTS' LEARNING PREFERENCES MAKE STEM SUBJECTS EASIER TO LEARN?

Julio Garay^{1*}, Jairo Orjuela Segura^{2*}

¹City University of New York- BCC, New York, NY, USA

²Colegio Mayor de Cundinamarca, Bogota, Colombia

^{1*}julio.garay@bcc.cuny.edu

^{2*}jgoscilearn@gmail.com

Abstract: Understanding how the learning really occurs, seems to be the logical pathway to tweak the teaching approach in order to maximize effectiveness in the learning process. Nevertheless, the complications of this logical approach start once one put more than one student together in the same classroom, as the ways that each person learns can be truly unique. This is particularly notorious issue with STEM subjects, as the wrong approach to teaching these areas can have a lasting negative impact in students' perception of these topics often times scaring them away, causing them to miss out opportunities to explore the great potential that STEM has as career pathways in a society that becomes more and more technological driven.

When it comes to learning styles, it is difficult to predict what the preferred style will be for a given group of learners, because of factors such as individual's interest, previous exposure to the concepts presented, psychological estate, emotional estate, the expertise of the teacher to capture their pupils' attention, the meaning of the information. All these factors together could potentially affect the outcome.

Objectives: The purpose of this study is to explore whether the learning styles model can effectively make a meaningful difference in the students' learning outcome by helping them to identify their natural abilities to assimilate new information or situations, utilizing two of the most popular learning styles models, namely, Kolb's learning style model and the VARK model. The intention is also to determine whether the input of these two models will facilitate their work and engagement with STEM related subjects/careers.

Driven by the need to find a more comprehensive method of teaching we proposed the use of a virtual-real world hybrid method that we called Virtual Experiential Learning Environments (VELEs), where the students can become actively involved in the learning process, in this environment, physical or mental limitations cannot interfere with their performance. VELEs allows students to act and participate through their avatar solving meaningful real-world problems, leveling the ground to provide an emotionally safe and meaningful learning experience to every participant.

Keywords

Education, STEM Subjects, Learning Styles, Virtual Experiential Learning

MIND THE GAP! BRIDGING PRE-KNOWLEDGE GAPS USING DIGITAL CONCEPT MAPS

Stefania Grecea^{1*}, Natasa Brouwer²

¹*Van 't Hoff Institute for Molecular Sciences, Faculty of Science,
University of Amsterdam, The Netherlands*

²*Teaching and Learning Centre, University of Amsterdam, The Netherlands*

*s.grecea@uva.nl

Students entering the track Science for Energy and Sustainability of the MSc Chemistry programme at our university have diverse pre-knowledge background and skills. This has an influence on how they acquire, interpret and organize new knowledge. A mismatch between the student's knowledge and lecturer's expectation hampers the learning process of students. Some students struggle to follow the course and some even drop out. Diverse knowledge background and skills also change the landscape for the lecturer who must teach while adapting to class fluctuations, all within a specific context. To tackle these challenges, we introduced digital concept maps in the course *Materials Design for Circular Economy*, which can be used in teaching to bridge pre-knowledge gaps and enhance student learning.

In this talk, we will show how digital concept maps enable lecturers to assess students' understanding of chemistry concepts, how they can be used by students as a learning strategy and by lecturers as an instructional tool. Furthermore, we will introduce the *micro-MOOC Bridging Pre-knowledge Gaps*, a powerful tool to increase the awareness of the lecturers concerning the diversity in students' backgrounds and facilitate learning in such conditions without lowering the level of the course in which they teach.

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CHALLENGES IN DATA INTERPRETATION: INSIGHTS FROM PRE-SERVICE CHEMISTRY TEACHERS

Lucie Hamerská*, Dominika Koperová, Tereza Bryxová, Martin Rusek

Faculty of Education, Charles University, Czech Republic

*lucie.hamerska@pedf.cuni.cz

This study examined pre-service chemistry teachers' ability to engage with data from tables and graphs commonly used in chemistry teaching materials. As shown in literature, students' have difficulties in working with such data (e.g. Klein et al., 2019). To further investigate this, a multi-tier test was developed to assess not only students' performance, but also explanations of their progress as well as confidence enabling deeper analysis of their alternative conceptions and their metacognition.

This study investigated 55 first-year pre-service chemistry teachers from four Czech universities. To gain deeper insights, eye-tracking (ET), think-aloud protocols (TA), and interviews were conducted with six successful and six unsuccessful students. Descriptions from think-aloud protocols and interviews enabled a better identification of alternative conceptions in data interpretation and their underlying causes.

The results showed students performed well in direct data extraction. However, their skills remained superficial in tasks requiring higher cognitive demands (Sharma, 2006). Moreover, task type was found to significantly affect the students' confidence judgement (Klein et al., 2019). Open-coding analysis of verbal responses revealed common errors, such as misinterpretation and insufficient explanation. In addition, the ET and TA revealed students' attention while reading assignments, omissions of key information (Atkins & McNeal, 2018) or solving strategies (see Tsai et al., 2012).

The findings highlight the presence of students' alternative conceptions in data interpretation, which may stem from the current teaching approaches. It is essential to integrate data interpretation more thoroughly into undergraduate instruction to address these alternative conceptions effectively.

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ENHANCING FIRST-YEAR UNIVERSITY CHEMISTRY LAB EDUCATION THROUGH UNIVERSAL DESIGN FOR LEARNING (UDL) PRINCIPLES

Frances Heaney^{1*}, Denise Rooney¹, Carmel Breslin¹, Bernard Drumm², Ronan Bree², Brian Murphy³, Aoife Morrin⁴, Blánaid White⁴, Eric Moore⁵, Christopher Burke⁵

¹*Department of Chemistry, Maynooth University, Ireland*

²*Department of Life & Health Sciences, Dunalk IT, Ireland*

³*Department of Pharmaceutical Science and Biotechnology, TUS: Midlands Midwest*

⁴*School of Chemical Sciences, DCU, Ireland*

⁵*School of Chemistry, UCC, Ireland*

*frances.heaney@mu.ie

The shift from secondary school to university poses challenges for all students and there are additional challenges for STEM students where practical lab work is a central component of their curricula. The laboratory is a complex learning environment (Bretz, 2019) to which first year students arrive, often in large numbers, from a diverse range of backgrounds. The lab environment, with its diverse learning goals, can be daunting (Flaherty, 2022). Students often feel frustrated, confused, and nervous, impeding their learning progress (Galloway et al., 2016). To address these challenges we have re-developed our first-year laboratory classes and teaching materials with the integration of UDL principles (CAST, 2024). It is known that in applying these principles STEM educators can design inclusive learning materials and establish pathways which minimize student stress (Kirsch et al., 2024; Miller & Lang, 2016).

This presentation will discuss the pre-university STEM educational experience of our incoming students, and their aspirations for learning practical chemistry at university. It will describe how, informed by the principles of UDL, we have revised our pedagogic approach to first year laboratory education. Finally, we will share findings from the end-of year student survey on their experience of practical chemistry.

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NOTES

INTEGRATING GREEN AND SUSTAINABLE CHEMISTRY CONCEPTS IN PRESERVICE CHEMISTRY TEACHER EDUCATION BASED ON THE ANALYSIS OF TEACHING MATERIALS FOR PRE-UNIVERSITY EDUCATION

Taja Klemen*, Nika Saksida, Katarina Mlinarec and Vesna Ferk Savec

Faculty of Education, University of Ljubljana, Slovenia

*taja.klemen@pef.uni-lj.si

Integrating green and sustainable chemistry principles into preservice chemistry teacher education is essential for preparing future teachers to promote sustainability in chemistry lessons (Burmeister et al., 2012; Ferk Savec & Mlinarec, 2021). However, the implementation of green and sustainable chemistry education varies across institutions, with different approaches, materials, and focus. Specific initiatives have influenced patterns in different communities, including the greening of universities and companies, as well as advances in chemistry teacher education, highlighting the need for more consistent and systematic integration of these concepts (Dittrich et al., 2024; Zuin et al., 2021). The aim of the study was to analyze how sustainable and green chemistry concepts are addressed in the teaching materials for the pre-university education level and to elaborate how these findings can be integrated in preservice chemistry teacher education. The research focused on a qualitative content analysis of chemistry textbooks approved by the Slovenian Ministry of Education, Science and Sport and used at different levels of pre-university chemistry education. The results indicate that concepts sustainable and green chemistry are not explicitly addressed in the chemistry textbooks, however, related concepts such as hazardous substances, pollution, fuels and recycled materials are explicitly addressed in most of the analyzed chemistry textbooks. Textbooks provide support for teaching and learning chemistry contents, but teacher autonomy is critical in deciding which teaching approaches to use when implementing green and sustainable chemistry concepts in the chemistry lessons, so it is important to provide during their study at the university possibilities for preservice teachers to develop adequate understanding on one hand of green and sustainable chemistry and on the other hand the related knowledge of chemistry didactics.

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RECYCLING OF REPORTS IN DEVELOPMENT OF CRITICAL THINKING AND EVALUATION SKILLS

Alicja Kluczyk*, Mariola Kuczer, Monika Biernat

Faculty of Chemistry, University of Wrocław, Poland

*alicja.kluczyk@uwr.edu.pl

The importance of critical thinking in laboratory work is evident when considering the future employment of Master-level students of chemistry departments. The search for synthetic procedures and analytical data, actual performance of experiments and verification of results find conclusion in laboratory report. There are numerous books on lab report preparation (Kanare 1985), however, the impact of report quality on the overall effect is frequently lost on students used to instructions, routine procedures and report schemes (Grancharova, 2024).

To increase the awareness of students of the responsibilities and consequences of reporting, during the course “Reliability in chemical analysis II”, offered for the Chemistry and Forensic Toxicology students at the Faculty of Chemistry, University of Wrocław, we used a Moodle-based workshop structured around grading reports, comparing grades and comments, and evaluating or modifying rubric. We used anonymized reports from different Master-level course, providing pairs of students with a set of two reports, selected according to the original grades (top grade and low grade report). The results of student grading and comments were discussed during a seminar, including comparison of grades and comments on instructions and experiences.

This activity provided students with opportunity to change roles into instructors, experience the effects of evaluating work of varied quality, develop insight into consequences of establishing instructions and criteria, and reflect on their own work and attitude to reporting. We noticed vivid interest in this workshop and increased attention to the quality of work in the following classes.

In our opinion, such approach not only improves the performance of students, but provides them with examples of real-life tasks in laboratory environment. There are conditions for the reports to achieve maximal efficiency, however, the idea of providing reports for re-evaluation is worth considering.

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MEASURING THE EFFECTIVENESS OF (ST)EXPERIMENTS: INSIGHTS FROM PILOT TESTING

Dominika Koperová*, Tadeáš Matěcha, Martin Rusek

Faculty of Education, Charles University, Czech Republic

*dominika.koperova@pedf.cuni.cz

The role of experiments in science education remains widely debated, with research highlighting a persistent disconnect between theory and practice (Abrahams & Millar, 2008; Hofstein & Lunetta, 2004). This study is part of the STExperiMents project (Preparation and Evaluation of Experiments for Effective Undergraduate Teacher Training in STEAM Disciplines) and presents preliminary findings from piloting a set of STEAM experiments – one real focused on a study of candle burning, one virtual focused on pH measurements. An updated version of the Intrinsic Motivation Inventory (IMI) tool (Ryan & Deci, 2000) was implemented to measure the effects of the experiments across various domains—value and usefulness, interest and enjoyment, perceived competence, effort and importance. It builds upon previous work by adapting the IMI tool for STEAM-based experiments by incorporating additional dimensions, such as metacognition, cooperation, hypothesis formulation and reflection.

Pilot testing was conducted in March 2025 on a group of pre-service chemistry teachers. Findings suggest that the modified IMI tool demonstrates strong reliability ($\alpha = 0.899$; IMI = 0.889, AD = 0.774) and can effectively assess STEAM experiments and their intended outcomes. Students rated all monitored IMI domains positively on a 7-point Likert scale (>5.5) and additional abilities positively on a 4-point scale (>3.0).

The findings emphasize the importance of perceived competence and interest, while the perceived value of the experiment was rated lower, suggesting that students may not immediately recognize its broader applicability or relevance. Additionally, the study highlights a gap in students' metacognitive awareness, pointing to potential areas for improvement in teacher training.

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PERSPECTIVES OF CHEMISTRY TEACHERS ON TEACHING SUSTAINABLE DEVELOPMENT

Katarína Kotuláková*, Viktória Sláviková, Mária Orolínová

Faculty of Education, Trnava University in Trnava, Slovak Republic

*katarina.kotulakova@truni.sk

Chemistry education plays a crucial role in preparing students to engage with sustainability and environmental challenges. However, chemistry teachers worldwide face barriers such as limited time, resources, and curriculum constraints that impact their ability to incorporate hands-on practical experiences and sustainability topics into their teaching. This research explores how chemistry teachers integrate sustainability into their instruction, what factors influence their choice of practical activities, and their perceptions of teaching sustainable development goals (SDGs). Through an international survey conducted in over 60 countries and a Q-methodology study with Slovak and Czech teachers, we identified key trends in teachers' perspectives on sustainability in chemistry education. Our findings suggest that chemistry teachers vary in their emphasis on sustainability, with some prioritizing prosocial attitudes, others focusing on quality education as a driver for sustainable actions, and some encouraging student-led environmental initiatives. Additionally, teachers report challenges such as resource limitations, lack of training, and competing curriculum demands. By analyzing these perspectives, this research provides insights into how chemistry education can be better supported in fostering sustainable development and preparing students to tackle global challenges.

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NOTES

EXCELLENCE IN ANALYTICAL CHEMISTRY: A JOINT MASTER'S PROGRAMME

Ivo Leito^{1*}, Riin Rebane¹, Anu Teearu¹, Irja Helm¹, Johan Bobacka², Jérôme Randon³,
Jonas Bergquist⁴

¹*Institute of Chemistry, University of Tartu, Estonia*

²*Faculty of Science and Engineering, Åbo Akademi University, Finland*

³*Université Claude Bernard Lyon 1, France*

⁴*Department of Chemistry, Uppsala University, Sweden*

*ivo.leito@ut.ee

EACH - Excellence in Analytical Chemistry (www.analyticalchemistry.eu) is an **international two-year Erasmus Mundus master's programme** in analytical chemistry, taught in collaboration with **four partner universities** – University of Tartu (UT, coordinator), Estonia; Uppsala University (UU), Sweden; University Claude Bernard Lyon 1 (UCBL), France; and Åbo Akademi University (AAU), Finland – and a number of **associated partners** – industries (Bruker, Axel'One, Arkema, IFP, etc), laboratories and academic institutions.

Students spend the first study year at UT learning the fundamental concepts and skills of analytical chemistry, metrology in chemistry, and the quality and socio-economic aspects of analytical chemistry. The second year is specialization oriented and is spent either at UCBL, UU or AAU. The master's thesis is done at one of the second-year universities or at associated partners.

Teaching in the programme involves a significant amount of **learning by doing**, as opposed to the typical lecture-based teaching. The **active involvement of industry** via teaching courses, providing internship placements and supervising master's theses ensures that EACH responds to the needs of industry and laboratories, including applications in the interdisciplinary areas (sustainable energy, trade, climate, security, “omics”, industrial processes, etc).

The presentation will focus on the following:

1. Highlights of some of the more interesting and innovative **teaching approaches** used in the programme.
2. **Employability** of the EACH graduates – what measures the programme has taken to achieve it and what are the results.
3. Developing EACH into a **pan-European Analytical Chemistry Hub** – involving universities from different European University Alliances with the aim of developing a shared European competence framework, aligning curricula and creating resources with a European dimension.

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DESIGNING FOR ALL: INTEGRATING DIFFERENT PERSPECTIVES IN LAB COURSE DEVELOPMENT

Stefanie Lenzer^{1,2*}, Leander H. Mecklenburg², Maximilian Traub²

¹*Department of Chemistry Education, Leibniz Institute for Science
and Mathematics Education, Germany*

²*Institute of Inorganic Chemistry, Kiel University, Germany*

*lenzer@leibniz-ipn.de

University chemistry lab courses are complex learning environments that can be challenging for both educators and students (Seery et al., 2019). Challenges can arise from domain-specific learning objectives themselves as well as from the interplay between these objectives and diverse backgrounds students bring to the lab, such as differences in prior experience, hands-on skills, career aspirations and interests (e. g., Augustian et al., 2022; Lenzer et al., *under review*). To develop lab courses that enable all students to achieve the domain-specific learning objectives, approaches that integrate different perspectives from both educators and students are promising (e.g., Vaughan et al., 2024). Despite its great potential, this approach of incorporating different perspectives in the development process has rarely been presented so far.

Therefore, we share empirical findings on perceived learning objectives and challenges for a first-year inorganic chemistry lab course, derived from semi-structured focus group interviews with educators (N=11) and students (N=11). A qualitative content analysis (Kuckartz & Rädiker, 2019) revealed a discrepancy between the educators' and learners' perspectives related to both learning objectives and challenges. For instance, from students' perspective, the perceived lack of relevance to their specific study profile represents a challenge — educators have a different perception. Based on these findings, we propose approaches to meet diverse backgrounds and discuss broader implications for future development of university chemistry lab courses.

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IMMERSIVE VIRTUAL REALITY AS A TOOL FOR TEACHING MOLECULAR MODELS: A DUAL APPROACH

Francesca De Vita¹, Renato Lombardo^{2*}, Antonella Maggio²

¹*Dipartimento Fisica e Chimica E. Segrè, University of Palermo, Italy*

²*Dipartimento STEBICEF, University of Palermo, Italy*

*renato.lombardo@unipa.it

The teaching of chemistry is deeply rooted in the interplay between the three domains described by Johnstone's triangle (Johnstone, 1991): the macroscopic, the symbolic, and the submicroscopic. Since direct experience of the molecular scale is impossible, conceptual understanding heavily relies on symbolic representations and models. Visualizations and visual models are essential for learning in science (Harrison & Treagust, 2000), and chemistry education is almost unthinkable without them. However, understanding these visual representations is challenging for many learners (Johnstone, 2000), particularly at the university entry level.

In this study, we present a dual-faceted educational project aimed at leveraging immersive virtual reality (VR) for chemistry teaching. The first goal was to employ a game-based VR platform to allow high school students to explore molecular and supramolecular structures (e.g., liquid crystals) in a three-dimensional immersive environment. Through various visualization models (ball-and-stick, space-filling, etc.), students not only improved their understanding of molecular structures but also gained an appreciation for the fact that all representations are models, not reality itself. The second goal was to train university students as peer tutors, guiding high school students through the virtual activities.

Our findings suggest that high school students showed increased engagement and improved comprehension of molecular representations, while university students developed enhanced communication and teamwork skills through their tutoring role. This approach suggests that immersive VR can be a valuable tool for bridging gaps in molecular visualization, fostering active learning, and supporting students in the early stages of chemistry education. Further investigations will explore the long-term retention of conceptual understanding and the scalability of this approach to broader educational contexts.

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ONLINE LEARNING WITH CHEMISTRY IN KITCHEN

Asmo Roponen¹, Jouni Välisaari¹, Jan Lundell^{2*}

¹*Department of Chemistry, University of Jyväskylä, Finland*

²*Department of Chemistry, University of Helsinki, Finland*

*jan.lundell@helsinki.fi

Online learning is meant to provide unique form of learning with its own strengths and challenges. Some strengths of online learning are enhanced by flexibility in time and place, by accessibility to a wider audience and by immediate feedback.

Inquiry-based-learning is an overarching theme in science education. It focuses on giving students their own experiences with a chance of active learning and reflective thinking, instead of presenting observed phenomena by mere facts and theories. Inquiry-based experiments are known to improve student engagement, which enhances learning, critical thinking and understanding of scientific methods. (Jegstad, 2023)

Cooking-related contexts typically interest a larger audience since all people have personal relationship with food. This context can increase interest and enthusiasm in studying chemistry and engage in learning new things about common contexts. At the University of Jyväskylä, kitchen chemistry online courses were created as a part of the open university's continuous learning program to educate about chemistry. The goal was to build learning modules that would make connections between chemistry and everyday phenomena. The main content of the course, besides describing the theory of the chemistry of food preparation, was food-themed assignments to enable learners to conduct scientific experiments in their own homes.

Overall, the online courses provide an easy-access introduction to kitchen chemistry, introduce phenomenon-based approach to connect chemistry with everyday context, and to provide the possibility for experimenting as a tool for learning chemistry in a non-formal educational setting. Based on this research, the devised educational approach employed here is a model to provide chemistry educators the possibility to apply experimenting in online teaching surrounding. This also shows how to combine behavioral, emotional and cognitive engagement (Fredricks et al., 2004) by relevant (Stuckey et al., 2013) and meaningful learning tasks.

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THE REACTIVE CHALLENGES: REFLECTING ON RESPONSIBILITY AND SUSTAINABILITY IN CHEMISTRY EDUCATION

Iwona Maciejowska*

Faculty of Chemistry, Jagiellonian University, Poland

**iwona.maciejowska@uj.edu.pl*

In higher education, chemistry curricula traditionally emphasize factual knowledge, problem-solving, and practical skills. However, the extent to which we actively promote responsibility and sustainability within chemistry education remains a crucial question. The global literature suggests that these aspects are less integrated into chemistry programs compared to social sciences and even other natural sciences, although numerous examples of good practice exist (e.g., Middlecamp, 2015; Apotheker & Maciejowska, 2024). This presentation aims to explore this issue by reflecting on challenges and potential strategies for fostering responsibility and sustainability among chemistry students.

Observations reveal two concerning trends: (a) not all students transfer the positive behavioral patterns developed during courses into their daily lives, and (b) not all students apply the knowledge gained in class to socioscientific issues. It seems that sometimes too little time and effort are dedicated to shaping ethical and responsible attitudes. Our students can proficiently discuss topics critical for addressing global challenges such as climate change, green chemistry, and sustainable resource management, yet this alone is not enough to meet our expectations.

In the second part, possible approaches to integrating responsibility and sustainability into chemistry education will be discussed. Drawing from personal teaching experiences at the Faculty of Chemistry and the Faculty of Biology at Jagiellonian University, I will present examples of how sustainability concepts can be incorporated. Specific activities, case studies, and interdisciplinary approaches will be highlighted as effective methods for enhancing students' awareness and responsibility in their professional development. However, achieving these goals requires dedicating class time to discussions, fostering openness, and developing maturity among students.

By fostering a reflective dialogue on these challenges, this presentation aims to inspire chemistry educators to rethink traditional curricula and actively incorporate sustainability and responsibility into their teaching strategies.

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CHEMISTRY ON SCREEN: HOW E-TEXTBOOKS ARE TRANSFORMING CHEMISTRY EDUCATION

Katarzyna Madeja*, Karolina Grodecka

Center of e-Learning and Innovative Education, AGH University of Krakow, Poland

*kmadeja@agh.edu.pl, karolina@agh.edu.pl

The aim of the presented work is to highlight the role of the Center of e-Learning and Innovative Education in supporting academic teachers and students in the field of chemistry through the creation and dissemination of free open educational resources. As a part of an innovative approach to teaching, we focus on providing accessible and high-quality digital materials, such as e-textbooks and online courses, specifically tailored to the needs of higher education institutions. In particular, our initiative focuses on the creation of open-access e-textbooks in chemistry, designed to complement traditional teaching methods and improve students' engagement and understanding.

The methods employed include collaboration with academic experts in various fields, including chemistry, to ensure the content is scientifically accurate and pedagogically effective. Additionally, we use modern e-learning technologies, such as interactive platforms and multimedia to enhance the learning experience. The development process follows the user-centered approach, with continuous feedback from both students and teachers to ensure the materials meet their educational needs.

The results of our efforts demonstrate a positive impact on both teaching and learning outcomes. The availability of free e-textbooks and online resources has significantly increased access to high-quality educational content, particularly in resource-limited settings. Teachers report greater flexibility in delivering course materials, while students benefit from the ability to access resources anytime and anywhere, facilitating more effective self-directed learning.

In conclusion, the development and distribution of open-access educational resources represent a transformative step in modern higher education. We recommend that universities and academic institutions continue to invest in such initiatives, as they not only enhance teaching and learning but also promote the democratization of knowledge. Further research and development are necessary to expand the scope of available materials and improve their accessibility across different academic disciplines.

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TEACHER STUDENTS AS REFLECTIVE PRACTITIONERS IN THE FRAMEWORK OF A TEACHING CERTIFICATE PROGRAM

Rachel Mamlok-Naaman* and Veronica Starkov

Weizmann Institute of Science

*Rachel.mamlok@weizmann.ac.il

A program of pre-service training was launched at the Weizmann Institute of Science 20 years ago. The program is aimed at graduate students, who intend to become science teachers (teacher students), and consists of: (1) six courses of one semester: Introduction to science education; learning environments; assessment; educational psychology; history of science; special issues in teaching and learning, (2) Two didactic courses focusing on the chosen discipline (e.g., biology, chemistry, physics), and (3) 180 hours of practical work. 20 graduate students (teacher students) participated in the course, which was coordinated by two faculty members. The research question of this study was:

What was the impact of the course on the graduate students' understanding of issues in chemistry education?

The methodology included analysis of students' reflections. According to Farrell and Macapinlac (2021), reflection is a systematic process of analyzing experiences, actions, and beliefs to learn and improve future practice. Reflective ideas in education were already discussed by Dewey (1933). There are different tools for reflective practice, used in both pre-service and in-service contexts, e.g., post-lesson discussions, video self-observation, journal writing, interviews, action research, and questionnaires (Farrell, 2016; Feldman, et al., 2024). In the current course, action research activities, interviews and questionnaires served as reflective tools. For example, when student teachers engaged in action research activities, they described problems they encountered in understanding or implementing course topics. They received advice from their colleagues about how to address these challenges and presented the amendments they made in subsequent meetings.

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INFOGRAPHICS INTEGRATION TO FOSTER COMMUNICATION SKILLS - AN INTEGRATIVE, NEUROPEDAGOGICAL APPROACH

Debora Marchak^{1*}, Ayelet Shvalb²

¹*Department of Science Teaching, Weizmann Institute of Science, Israel*

²*Mechanical Engineering, AFEKA Academic College of Engineering, Israel*

*marchak@weizmann.ac.il

For higher chemical education graduates to successfully integrate into the workforce, essential skills are required. Industries today prioritize soft and higher-order thinking skills (AAC&U, 2013), such as creative thinking, critical thinking, effective communication, and collaboration, in parallel to disciplinary knowledge. Thus, by imparting content knowledge alone, academic institutions fail to equip their students for the future. Regarding the development of communication skills, infographics as a tool in higher chemistry education is gaining traction (Grieger, 2021). Infographics are visual compositions that integrate visual and textual information using graphics, symbols, and illustrations to summarize and present complex content in accessible ways (Blackburn, 2019). In a pilot evaluation with 3rd-year engineers taking a “Polymers and Plastic Materials” Chemistry course, we found that preparing and presenting chemistry-related infographics seems to have both enriched students' knowledge of chemistry and strengthened their communication abilities such as analyzing, summarizing, and expressing content efficiently. In this in-depth study, we set to assess the impact of integrating infographics on students' written communication skills, both textual and visual. Here, we present the development, implementation, and assessment of a semester-spanning intervention implemented in the same course. The intervention was designed by the Neuropedagogy-based Multidisciplinary Learning Grid (NP-MLG) model of integrative instructional design (Marchak, 2021). Accordingly, intervention tasks were developed considering three dimensions: a) disciplinary, curricular chemistry content, b) communication skills-related neuropedagogical principles found to support learning, and c) content and procedural knowledge on infographics. In this lecture, we present preliminary findings from this ongoing research.

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WHEN MOLECULES MEET WORDS: ON LEARNING SCIENTIFIC LANGUAGE IN CHEMISTRY

Silvija Markic*

Department of Chemistry and Pharmacy, Ludwig Maximilian University of Munich, Germany

**s.markic@cup.lmu.de*

In recent years, there has been significant progress in developing methods for language-sensitive teaching. Educators now have access to various strategies and tools aimed at supporting students in acquiring the academic language necessary for understanding subject-specific content (e.g. Markic et al., 2013). Simultaneously, research has deepened our understanding of the types of knowledge teachers need in order to effectively foster students' acquisition of scientific language (Mönch & Markic, 2023). However, a fundamental question remains largely unexplored: What does it actually mean to learn scientific language?

This presentation aims to initiate a discussion on the deeper dimensions of scientific language learning by exploring what is involved from a neurolinguistic perspective. Moving beyond instructional strategies and teacher knowledge, we seek to examine how the human brain processes and internalizes subject-specific language, such as the complex terminology and conceptual structures found in chemistry. What cognitive and linguistic mechanisms are involved when students begin to understand and use specialized terms like “oxidation,” “mole,” or “equilibrium”? And how do these processes differ from general language acquisition? These initial considerations raise important questions for chemistry education: What linguistic-cognitive barriers do students face when learning the language of chemistry? How can teachers support this process—not only through scaffolding, but also by considering the neurocognitive mechanisms involved? Moreover, how can insights into subject-language development inform teaching materials, assessments, and teacher training?

By bringing together perspectives from neurolinguistics and educational research, this presentation aims to stimulate a deeper conceptualization of what it means to learn the language of science. It also calls for a more integrated research agenda that considers not only the pedagogical how, but also the cognitive what and why of language-sensitive chemistry teaching. Ultimately, these reflections seek to enrich our understanding of language learning in subject-matter contexts and to contribute to more effective and inclusive chemistry education.

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COMPREHENSIVE ANALYSIS OF AN INTRODUCTORY LABORATORY COURSE FOR PRE-SERVICE CHEMISTRY TEACHERS: COGNITIVE, PSYCHOMOTOR, AND AFFECTIVE DOMAINS

Tadeáš Matěcha^{*}, Jiří Pavlečka, Martin Rusek
Faculty of Education, Charles University, Czech Republic
^{*}tadeas.matecha@pedf.cuni.cz

Experimental activities have historically been an integral part of chemistry education. However, despite their central role in fostering students' conceptual understanding and practical skills, robust empirical evidence supporting their effectiveness remains limited. Research suggests that traditional laboratory instruction often overemphasizes cognitive learning outcomes while neglecting affective, psychomotor, epistemic, or social domains. Recognizing the interdependence of these domains is essential for designing laboratory activities that holistically support students' development as scientifically literate individuals.

This study investigates 23 first-year pre-service chemistry teachers with diverse prior experience, assessing how an introductory university laboratory course influences their cognitive, psychomotor, and affective domains. A mixed-methods approach was employed. Cognitive progress was assessed using a pre- and post-test inspired by Fringer et al. (2022), covering laboratory literacy, safety, problem-solving, theoretical knowledge of laboratory methods, experiment design, chemical calculations, and laboratory documentation. The psychomotor domain was evaluated through a practical skills test, where students designed a separation method for an assigned mixture (distillation, gravity filtration, or vacuum filtration) and demonstrated proficiency in handling laboratory glassware (Chen et al., 2013).

The affective domain was measured using a validated questionnaire based on Agustian's (2024) Hexad Model, assessing motivation, volitional strategies, epistemic engagement, task value, extrinsic and intrinsic goal orientation, emotional responses (e.g., anxiety, frustration, positive affect), and collaborative learning strategies.

This study aims to explore the interplay between cognitive, psychomotor, and affective domains in laboratory learning, providing insights to enhance laboratory instruction and improve chemistry teacher preparation. Results will be presented at the conference.

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MIND THE GAP: CONNECTING THEORY AND PRACTICE IN TEACHER EDUCATION IN THE FRAME OF A STUDENT LABORATORY

Jannis Memmen*, Silvija Markic

Department of Chemistry and Pharmacy, Ludwig Maximilian University of Munich, Germany

**jannis.memmen@lmu.de*

Bridging the gap between theory and practice is a key challenge in university teacher education. Pre-service teachers often express a desire for more practical experiences within their initial teacher education (White & Forgasz, 2016). Integrating student laboratories into the university curriculum may help to address this problem, as these can act as ‘hybrid spaces’ between university and in-field teacher education (Zeichner, 2010). To stronger utilize this potential, an accompanying seminar unit was developed for our student laboratory – the LMUchemlab – to support student teachers’ professional development and foster their Pedagogical Content Knowledge. Since the PCK is heavily influenced by observation and reflection (Carlson et al., 2019), this seminar unit incorporates guided observation and reflection practices following the method of structured learning journals. First, the student teachers capture their prior knowledge (*‘Know’*) and their individual learning foci (*‘Want’*). In each observation session, notes to the chosen topic (inquiry-based learning; cooperative learning and further) are made. Finally, they reflect on their learning outcomes (*‘Learnt’*) regarding each topic. A case-by-case analysis revealed that the student teachers demonstrated varying levels of prior knowledge and learning foci at the beginning of the module. Despite this heterogeneity, the students highlighted that the observations and reflections provided them with practical examples of the different topics. This enabled them to further construct their understanding of these topics, facilitating their pedagogical growth.

This talk presents the developed university seminar unit with its structured learning journal for guided observations. Further, it discusses the potential of such modules in fostering student teachers’ PCK by reflecting on practical experiences.

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NOTES

ELECTRON LAND – LEARNING ELECTRON CONFIGURATION THROUGH GAMING

James Mendez*

Faculty Division of Science, Indiana University – Columbus, U.S.A.

**mendezja@iu.edu*

Using games to keep students engaged in the classroom is a growing trend with many successful examples (Hellerstedt & Mozelius, 2019). Various concepts in chemistry already have exciting ways to engage students, from using molecular model kits to represent various molecules to demonstrating electrochemistry with a potato battery. However, some topics, like electron configurations, are more difficult to visualize and lack practical in-class demonstrations. To fill this gap, this game, Electron Land, was designed to teach students about electron configuration in an interactive and (hopefully) fun way.

A previously designed game, Chemistry and Chaos (Mendez, 2023) helped demonstrate that games can keep students engaged and be a valuable educational tool. Electron Land shares similarities to other simple board games. Students take turns rolling dice to advance on a path where each space represents a different atom. The electron configuration is shown on each space, and students must identify the correct atom or fall back to the previous noble gas, whose name is written in full. The first person to get to plutonium wins. The rules are short and straightforward, with gameplay normally taking about 15 – 20 minutes.

Initial results indicate that students, while initially very skeptical, enjoy the game more than a typical lecture. Trials to quantify any learning gains are ongoing, but preliminary responses show much more confidence in students' ability to correctly identify electron configurations. While designed for introductory college chemistry courses, small-scale trials were conducted with younger students (10 – 18 years old) as well. Even the youngest students showed some learning gains, suggesting the potential benefit of the design for this demographic.

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FOSTERING CREATIVITY IN PRE-SERVICE CHEMISTRY TEACHERS THROUGH TEACHING AIDS DEVELOPMENT

Vesna Milanović Maštrapović*, Dragica Trivic

University of Belgrade – Faculty of Chemistry, Serbia

*vesnamilanovic@chem.bg.ac.rs

Creativity is one of the essential 21st century skills. It plays a crucial role in pre-service chemistry teacher education, as it enhances their ability to design engaging, effective, and inclusive learning experiences. Chemistry can be challenging for students, but creative teachers make lessons more accessible and enjoyable. Through creative teaching, students are encouraged to ask questions, experiment, and explore, helping them develop critical thinking skills, solve problems, and apply knowledge to real-world situations. If such activities are absent from chemistry lessons, students may fail to recognize that creativity is a fundamental feature of the nature of science. This, in turn, can lead to underdeveloped scientific literacy and a reduced interest in the natural sciences.

At the University of Belgrade - Faculty of Chemistry, students enrolled in four Chemistry Didactics courses engage in various tasks designed to foster creativity. One such task involves the preparation of teaching aids, where students choose both the content and the target age group (13 to 18 years). The open-ended nature of this task encourages divergent thinking and the integration of previously acquired knowledge in chemistry and chemistry didactics. The aim is to develop teaching aids that enhance the learning of specific chemistry concepts.

Before beginning the task, students and the professor collaboratively define the evaluation criteria, with originality consistently emphasized by each new generation of students. The final stage involves presenting the teaching aids to peers, followed by evaluation based on the agreed-upon criteria.

Year after year, students produce a wide variety of teaching aids, with an increasing incorporation of information and communication technologies (ICT). The presentation will showcase teaching aids developed by 4th-year students from the Chemical Education study program, covering topics such as atomic structure, chemical bonding, the periodic table, salts, and classes of organic compounds. These teaching aids come in diverse formats, including chemistry games, New Year's cards, quizzes, molecular models, and more.

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EXPLORING PRE-SERVICE TEACHERS' PERCEPTIONS OF DIDACTIC USE OF AUGMENTED REALITY IN CHEMISTRY EDUCATION

Katarina Mlinarec*, Vesna Ferik Savec, Iztok Devetak

Faculty of Education, University of Ljubljana, Slovenia

*katarina.mlinarec@pef.uni-lj.si

Advances in the field of augmented reality (AR) have generated great interest and promoted its use to support the teaching and learning of chemistry. Many advantages of its use have been reported, particularly in relation to affective and cognitive learning domain, but also its limitations and challenges (Mazzuco et al., 2022; Ribič & Devetak, 2024). For a meaningful integration of digital technologies into the learning process, it is important to support teachers in the development of their knowledge, skills and attitudes (Mishra & Koehler, 2006; Caena & Redecker, 2019) and thus provide them with opportunities to reflect on the didactic use of general and subject-specific information and communication technologies already during their university education. The aim of this study was to explore pre-service teachers' perceptions of AR, including their self-efficacy in using AR and their beliefs about its potential as a teaching and learning tool. A case study was conducted at the University of Ljubljana, Faculty of Education, with a sample of students, prospective lower secondary school chemistry teachers in study years 2023/24 and 2024/25. During the course "Information Tools in Chemistry Instruction", students were presented with activities that encouraged them to reflect on the didactic use of AR in chemistry teaching and learning. An adapted questionnaire from Cooper et al. (2019) was used for the study. The results show that prospective teachers generally have a positive attitude towards the use of AR in the teaching and learning of chemistry, but at the same time recognise the challenges associated with its use in educational settings. It is therefore important to support them in incorporating AR into their future teaching practice in a meaningful and successful way.

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AI AND INCLUSION IN SCIENCE EDUCATION: A SEMINAR APPROACH FOR FUTURE CHEMISTRY TEACHERS

Laura Naumann*, Silvija Markic

Department of Chemistry and Pharmacy, Ludwig Maximilian University of Munich, Germany

*laura.naumann@cup.lmu.de

Science educators nowadays face two major challenges: the need for inclusive science education and adapting to digital advances. Inclusive science education is crucial for enabling everyone to reach their potential in STEM fields (Stinken-Rösner *et al.*, 2020) and thereby addressing the growing shortage of skilled labor (Anger *et al.*, 2023). Meanwhile, digital innovations, particularly the rise of artificial intelligence (AI), are transforming society and especially teaching and learning (Baldassarre *et al.*, 2023), requiring educators and learners to develop AI literacy. According to Ng *et al.* (2021), AI literacy encompasses knowledge and understanding, behavioral adaptation, and ethical considerations. To support future teachers in these challenges, a seminar on AI in lesson preparation for inclusive science education was developed. The seminar focusses on various topics: (i) AI literacy, (ii) inclusive science education, (iii) transversal skills and (iv) chemistry education within the European Green Deal and health education. The seminar was accompanied by a pre-post mixed-method study that assessed AI literacy, understanding of diversity and inclusion and their intersection. Results showed that participants' AI literacy improved throughout the seminar. They demonstrated increased interest, self-efficacy, and a clearer understanding of AI's applications and limitations in inclusive science education. The evaluation also provided insights for refining the seminar. This talk will present the seminar structure, research findings, and its implications for future teacher training.

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CHEMMUNICATE: A CHEMICAL STRUCTURE DRAWING GAME FOR BUILDING SCIENTIFIC COMMUNICATIONS SKILLS AND ENHANCING ENGAGEMENT OF FIRST YEAR STUDENTS

Cristina Navarro Reguero^{1*} and Matthew N. Hopkinson^{2*}

*School of Natural and Environmental Sciences (Chemistry),
Newcastle University, United Kingdom*

^{1*}Cristina.Navarro-Reguero@newcastle.ac.uk

^{2*}Matthew.hopkinson@newcastle.ac.uk

Students' overall experience and assessment outcomes are partly determined by their engagement with teaching activities provided by academic institutions. Studies have shown that feeling part of a cohesive learning community can influence student's individual engagement. Gamification, or the incorporation of game mechanics in learning situations, provides strategies to increase students' motivation and develop their adaptability and responsiveness skills while enjoying themselves. With the aim of encouraging higher engagement among new first year chemistry students post-COVID, we have introduced a new chemical drawing game; CHEMmunicate. Across one semester we held 8 sessions with ca 15 students where two teams compete to draw chemical structures using yes/no questions (total 200 participants over two separate cohorts). At the end of the session having played 3-4 rounds, students were asked to fill out an anonymous questionnaire evaluating whether they enjoyed the game and found it useful for building their scientific communication skills. The results showed that the overwhelming majority of students found the game fun and felt the session had benefits for their learning experience. In the presentation, instructions and tips for playing CHEMmunicate will be shared and its effectiveness in improving student engagement will be discussed.

Keywords:

student engagement, learning community, sense of belonging, pastoral support, gamification.

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ENHANCING CHEMISTRY TEACHERS' AGENCY VIA PROFESSIONAL LEARNING COMMUNITIES

Shelley Rap* and Ron Blonder

Department of Science Teaching, Weizmann Institute of Science, Israel

*shelley.rap@weizmann.ac.il

Agency in education refers to the ability of individuals to act independently and make their own choices; this significantly impacts their learning and development. For students, it involves self-reflective actions that shape and influence their engagement with their learning environment (OECD, 2019; Rap et al., 2022). Empowering students and teachers through agency leads to more flexible educational systems, ultimately promoting lifelong learning (Brickhill et al., 2024).

Teachers' agency may play a vital role in chemistry education, significantly influencing teaching practices and student achievement (Emans et al., 2025). Successful reforms in education depend on empowering teachers to make informed decisions, innovate their pedagogical and curricular approaches, and engage in continuous professional development (Cochran-Smith et al., 2022). We suggest that professional learning communities (PLCs) of chemistry teachers can serve as centers of vital collaborative learning, where teachers share knowledge, pose professional questions, and engage in joint research practices as well as enhance teachers' agency.

This study investigates the development of agency among leading teachers within a leading chemistry PLC. The leading teachers are influential figures in their local communities and engage with other chemistry teachers nationwide. At the beginning of the year, the teachers were asked to articulate their objectives as community leaders. After about three months of participation, they were prompted to reflect on their goals and consider how they might adapt their actions to evolving circumstances. Subsequently, the concept of "agency" was introduced, encouraging the teachers to deliberate on how it could be effectively communicated to their peers, who would then support their students in developing it. Detailed findings and their implications for chemistry teachers' professional development will be examined in the presentation.

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A CROSS-FACULTY PROFESSIONAL DEVELOPMENT INITIATIVE FOR UNIVERSAL DESIGN FOR LEARNING

Denise Rooney^{1*}, Margaret Flood², Marian Crowley-Henry³, Alison Farrell⁴, Moynagh Sullivan⁵, Lisa O'Regan⁴, Patrick Fitzgerald⁴

¹*Department of Chemistry, Maynooth University, Ireland*

²*Department of Education, Maynooth University, Ireland*

³*School of Business, Maynooth University, Ireland*

⁴*Centre for Teaching and Learning, Maynooth University, Ireland*

⁵*Department of English, Maynooth University, Ireland*

*Denise.Rooney@mu.ie

In the pursuit of inclusive education, it is imperative to assess the accessibility of teaching methods, increase staff awareness of diverse learner needs, and bridge gaps in expectations between students and faculty. Universal Design for Learning (UDL) is a framework of values, principles and guidelines that can be used as part of an institutional, departmental and/or individual educator approach to inclusive education. Originating from CAST, Inc., The Center for Applied Specialized Technology, UDL addresses multiple intersectional barriers to learning (CAST, 2024). However, implementing UDL in practice can be daunting for educators, particularly when working with large classes.

This presentation describes our experiences at Maynooth University with an UDL Teaching and Learning Fellowship initiative. Funded by the Government of Ireland HEA PATH 4 and working in collaboration with the Centre for Teaching and Learning, four UDL Teaching and Learning Fellows, with backgrounds in diverse disciplines (Chemistry, Business, Education and English), have developed a transdisciplinary Resource Hub (CC-licensed Open Education Resources (OER)), and run an all-university awareness campaign. The aims of the campaign were to surface and celebrate on-campus UDL practice, and connect with colleagues across campus, including senior leaders, to progress the sustainable building of a culture of inclusion. The presentation will outline the rationale for the cross-faculty collaborative fellowship approach. We will discuss how the fellowship has enhanced educators' skills in inclusive teaching practices, fostered collaboration across disciplines, and provided ongoing support for implementing UDL. Additionally, we will identify key success factors, discuss challenges, and provide recommendations for colleagues considering pursuing similar work in their settings.

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INTRODUCTION TO ELECTROCHEMISTRY TO UNDERGRADUATE STUDENTS: AN INQUIRY BASED APPROACH

Antonella Rossi* and Bernhard Elsener

Department of Chemical and Geological Sciences, University of Cagliari, Italy

**rossi@unica.it*

The present unit was designed for a seminar of 15 hours, which included face-to-face lectures, 10 hours of practical laboratory activities, and final tests dedicated to students in the second year of the bachelor's degree in Chemistry. One of the main topics of the course entitled "Instrumental Analytical Chemistry" is electroanalytical chemistry. The students should learn the potentiometric measurements, using the reference electrodes and indicator electrodes, how to work when they receive a new task, and how to report the results and interpret them in a critical way, aiming to produce accurate and precise results. The second-year BSc students' knowledge about electrochemistry is mainly limited to an introduction to oxidation-reduction reactions and Faraday's law. In addition, the topic is considered difficult, and they need to be motivated to learn about potentiometry linking to practical applications. During the first lecture, the students were asked investigative questions, e.g.: What role do metals and electrolytic solutions play in an electrochemical cell? Then, four sets of experiments were proposed involving electrochemical reactions, with the first aim of becoming acquainted with the practical measurements of the difference of potential (DDP) using various couples of metals. Some of the experiments will be described during the presentation. The importance of a closed measurement circuit, e.g., the salt bridge, was then introduced, and the experiment using the approach described by (Silverman L.P. and Bunn B.B., 1992) was successfully applied.

Students had the opportunity to ask questions and discuss the results together. In addition, the preparation of silver/silver nitrate half-cells in which the concentrations of silver ions differ in steps of powers of ten was proposed. The DDP between the various combinations of these half-cells was measured, and the interpretation of the results allowed us to obtain the Nernst equation. The use of assessment to support the attainment of the learning goals indicated that the students achieved knowledge and competence. The survey results that indicate the students' satisfaction (ca. 80%) will be presented and discussed.

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CHALLENGES IN CHEMISTRY CALCULATIONS AMONG PRE-SERVICE CHEMISTRY TEACHERS: A LONGITUDINAL STUDY

Martin Rusek*, Dominika Koperová, Lucie Vydrová

Faculty of Education, Charles University, Czech Republic

*martin.rusek@pedf.cuni.cz

Chemistry calculations remain a fundamental yet challenging aspect of the chemistry curriculum (Clark et al., 2022). This presentation is part of a longitudinal research project that began with an assessment of freshman pre-service chemistry teachers' calculation skills in contrast to their mathematical abilities (Rusek et al., 2021). It was later expanded into a nationwide study on chemistry calculation proficiency among first-year pre-service chemistry teachers and chemistry students (Rusek et al., 2022).

Findings identified pH calculations and calculations based on chemical equations as the most problematic areas. This led to the development of a specialized test assessing key competencies, including understanding stoichiometric coefficients, balancing chemical equations, and solving calculations based on formula-based and word problems (Fach et al., 2007). In October 2024, the test was administered to students from six faculties across five universities, with a specific focus in this study on Charles University, Faculty of Education students.

The results suggest that previous findings may have been influenced by students' misconceptions regarding stoichiometric coefficients and difficulties in constructing chemical equations from verbal descriptions, indicating gaps in chemistry nomenclature knowledge. Additionally, preliminary results suggest a lower ability to extract relevant information from word problems, further hindering students' ability to perform calculations. This study thus highlights critical areas of struggle, emphasizing the role of general chemistry knowledge as a prerequisite for success in chemistry calculations. Addressing these gaps is essential for improving students' problem-solving skills and preparing them for future coursework and professional practice.

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DON'T PANIC!

A HITCHHIKER'S GUIDE TO EXTENDED REALITY WITH AI

Siegfried Schindler*

Institute for Inorganic Chemistry, Justus Liebig University, Gießen, Germany

*siegfried.schindler@anorg.chemie.uni-giessen.de

Artificial Intelligence (AI) can assist students and teachers in numerous ways. For instance, it can facilitate lecture recordings without requiring additional personnel [1], generate high-quality images and graphs without copyright concerns [2], and provide instant audio transcriptions [3].

In a chemistry lab, AI-powered safety glasses can collect data, such as a sample's weight, either by connecting to a balance via Bluetooth or by reading the display using an embedded camera. The data is then instantly accessible and analyzed within an electronic lab notebook. Additionally, AI can display synthetic protocols, references, safety information, and data sheets directly in the glasses. It will also control robots that perform various tasks in the lab.

One of the most fascinating applications is learning with avatars, both inside and outside the lab, through voice recognition. In the lab, avatars can provide real-time assistance with experiments and answer questions, much like a human teaching assistant. Outside the lab, they enable immersive language learning by facilitating conversations in appropriate environments. Moreover, AI can simulate conversations with historical figures (e.g., Albert Einstein), providing responses based on AI-generated knowledge rather than simply retrieving information from the internet [4].

Training, instructions, and learning through simulations—such as flight simulators for pilot training—will become increasingly accessible and affordable [5]. In chemistry, experiments can be conducted in virtual or augmented reality before being performed in the actual lab. While challenges remain, proof-of-concept studies already demonstrate the potential of these technologies [6–8].

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A MODULE ABOUT HEALTH AND MEDICINE FOR TEACHER EDUCATION

Edina Kiss, Luca Szalay*

Institute of Chemistry, Faculty of Science, Eötvös Loránd University, Hungary

*luca.szalay@ttk.elte.hu

Health education is a planned activity, stimulating learning through communication, to promote health behaviour (Kok & de Vries, 2015). Raising awareness to inform and motivate people about their own health and lifestyle factors that might put them at risk requires teaching young people to reduce risks associated with their social behaviour. It might include disseminating information on healthy diet, compliance with immunization recommendations, compliance with screening programs, and many others (World Health Organization, 1986). Core competencies can give coherence to the practice of teaching health (Madsen & Bell, 2012).

A TEACHER ACADEMY type project was launched in June 2023 titled „Trans-national STEM teacher education focusing on transversal competence and sustainability education” (acaSTEMy, 2023), co-funded by the ERASMUS+ programme of the European Union. The participants (seven universities, one research institute and one non-profit organisation) come from 8 countries. One of the goals of this project is to develop a module titled ‘Health and Medicine’ that could be used in pre-service and in-service STEM teacher education. Its purpose is to provide scientific and pedagogical background, as well as exemplar teaching materials to be used by the teachers in schools to promote health behaviour among their students.

A questionnaire was edited, piloted and filled in by 840 teachers and pre-service teacher students in 8 countries. Statistical analyses of the answers of its health and medicine section showed a high variability of the participants’ self-perception about scientific knowledge concerning the related topics and competencies to teach those. Teaching materials of the Health and Medicine module are developed based on the participants needs and translated to the 8 languages. The module will be piloted in Estonia, Hungary and Latvia by at least 25 participants in each of those three countries.

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TEACHING TEACHERS TO TEACH INQUIRY

István Füzesi¹, Luca Szalay^{2*}

¹Bolyai János Practicing School, Eötvös Loránd University, Hungary

²MTA-ELTE Research Group on Inquiry-Based Chemistry Education

Faculty of Science, Eötvös Loránd University, Hungary

*luca.szalay@ttk.elte.hu

The focus of student experiments should shift from reinforcing and demonstrating scientific content to practicing scientific thinking (Hofstein, 2015). The elements of scientific thinking that are closely related to scientific cognition are identification and control of variables, causality, hypothesis generation and testing and design of experiments (Csapó, 2022). In a guided-inquiry format students are required to design the experiment (Walker, 2007). Therefore, our research group have been developing student worksheets that apply guided inquiry since 2014 and piloting them with thousands of students aged 13-18. The present four-year research project (Szalay et al., 2023) started in September 2021 and the tried and tested student sheets are published on the research group's website.

To disseminate the guided inquiry method pre-service chemistry teacher students of the Eötvös Loránd University have been involved in the present longitudinal research. Some of them developed student sheets as part of their theses work and all of them piloted student sheets developed by the research group. Their opinion concerning the student sheets have been collected by questionnaires in three different years. Analysis of their answers shows that satisfaction with the practical applicability of the worksheets has gradually increased, with ease of use, visual appeal and use of everyday materials being positive factors. At the same time, the independent design of experiments by students was found to be challenging, which requires teacher's guidance and support. Year by year, the results show that the worksheets have become easier to integrate into teaching practice, more enjoyable and user-friendly than before, thus increasing student motivation and engagement.

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ARTIFICIAL INTELLIGENCE (AI) IN CHEMISTRY EDUCATION: A BIBLIOMETRIC AND CONTENT ANALYSIS OF PAPERS PUBLISHED

Dilek Teke*, Mustafa Sözbilir

*Kazım Karabekir Faculty of Education, Department of Mathematics and Science Education,
Chemistry Education, Atatürk University, Erzurum-Türkiye*

*dilekteke@atauni.edu.tr

Chemistry education is an important field that aims to provide students with practical skills as well as theoretical knowledge. In recent years, the use of AI technologies in education has started to reshape teaching and learning, so there is an increase in the number of papers dealing with use of AI applications in chemistry education research. This study aims analyze papers published on the integration of AI in chemistry education to identify the trends and developments. These trends will be useful in terms of determining the new studies on AI applications in chemistry courses and making chemistry teaching effective, efficient and interesting. We particularly, aimed to determine the research area, subject and research designs, data collection tools and analyses of the publications in Web of Science (WoS) related to AI in chemistry teaching.

We employed document analysis as a research design. The documents used in the study consist of research articles related to chemistry education AI in the journals indexed in the 'Web of science'. The data were obtained from the analysis of 91 research articles between 2015-2024. The articles were analyzed with VosViewer and ARRef-Man softwares. The data were analyzed by creating word groups obtained from the categories under the themes determined in the data obtained. The findings obtained from the analysis, trends were tried to be determined according to years, journal name, chemistry field, chemistry topics, teaching method used, universities where the first or responsible authors are located. In addition, the research approach, design, data collection tools, target group, sample size, data analysis types used in the method section of the research articles were also determined.

GAME-BASED LEARNING IN CHEMISTRY: ACTION RESEARCH BY PRE-SERVICE CHEMISTRY TEACHERS

Dragica D. Trivic*, Vesna D. Milanović Maštrapović

University of Belgrade – Faculty of Chemistry, Serbia

*dtrivic@chem.bg.ac.rs

In today's rapidly changing educational landscape, it is crucial for teachers to adopt effective approaches to address classroom challenges and make decisions informed by research from their teaching practice. Mastering action research methodology during initial teacher education and conducting research in school environments can empower future teachers to enhance their instructional methods through reflective practices based on collected data.

At the University of Belgrade – Faculty of Chemistry, these principles are embedded in the course Research in Chemistry Education, designed for fifth-year students in the integrated Chemical Education study program. This course guides students through: (i) learning about research methodologies and examples in chemistry education; (ii) identifying research questions based on classroom observations and literature reviews; (iii) preparing research project proposals; (iv) presenting projects and refining them through peer and teacher educators' feedback; (v) implementing projects in schools and collecting data; (vi) analyzing both quantitative and qualitative data; (vii) preparing final reports that include reflective insights based on their findings.

One effective strategy explored in this course is game-based learning. Pre-service chemistry teachers have designed various educational games to teach chemical concepts, such as valence, writing chemical formulas, and the structure, properties, and applications of hydrogen. These games were implemented with 13–14-year-old primary school students. Pre- and post-tests conducted with the students revealed significant improvements in their understanding of these concepts. Moreover, students reported positive attitudes toward game-based learning, citing increased engagement and motivation during the activities. The findings from these action research studies demonstrate that educational games can effectively stimulate active student participation, leading to enhanced knowledge retention and greater enthusiasm for learning. These outcomes highlight the potential of game-based learning as a valuable tool for future chemistry teachers.

Acknowledgements:

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This image shows a full page of dot grid paper. The dots are arranged in a precise, repeating grid pattern across the entire surface. There are no margins, text, or other markings present.

TECHNOLOGICAL CONTENT KNOWLEDGE OF PRE-SERVICE CHEMISTRY TEACHERS

Martina Tsenova*

Faculty of Chemistry & Pharmacy, University of Sofia, Bulgaria

**martinatsenova@gmail.com*

Modern teachers are expected to use ICT to support the teaching and learning processes. For the use of digital technologies to be successful, teachers must possess a combination of technological knowledge, content knowledge and pedagogical knowledge (Mishra & Koehler, 2006). In order to plan the development of technological pedagogical content knowledge in chemistry teachers, we must take into account the technological content knowledge that they have formed through digitally-assisted chemistry-specific activities.

The aim of this study is to establish through what software and what activities the technological content knowledge of future chemistry teachers is formed and developed during their training in basic chemistry courses at the university and whether this knowledge can be relied upon for the subsequent construction of technological pedagogical content knowledge in methodological courses.

Twenty Bulgarian pre-service chemistry teachers participated in the study. They were divided into groups according to their major. The students answered to questions about the digital tools and digital-enhanced activities in their classroom and extracurricular activities.

According to the survey data, students are engaged in the most digitally-assisted activities in the Theoretical Chemistry discipline, and the most frequently used software is ChemDraw.

Overall, the results show that pre-service chemistry teachers have not acquired lasting knowledge for working with digital tools in the course of studying mandatory chemistry subjects in the university.

A solution to this problem can be sought first in terms of the digital competences of university lecturers, as educators cannot pass on to their students digital skills that they themselves do not possess. Then, consideration should be given to establishing mandatory standards regarding the inclusion of digital technologies in the main university disciplines.

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A LAB-ORIENTED CHEMISTRY EDUCATION COURSE WITH DIVERSIFIED ASSESSMENTS FOR PRE-SERVICE TEACHERS

Karoline Faegri, Svein Tveit*

Department of Chemistry, University of Oslo, Norway

**sveint@uio.no*

From experience and literature, we know that teaching in the chemistry laboratory can be challenging for pre-service teachers and newly qualified teachers with preparations and logistics, together with the unpredictable nature of experimental work and responsibility for student's safety around hazardous chemicals (Yalcin-Celik et al., 2017). To address this challenge, we designed a chemistry education course for pre-service teachers with a large experimental component centered around weekly laboratory exercises intended for upper secondary chemistry. The activities cover a broad range of roles that practical work can have, such as illustrating key concepts, learning laboratory techniques, scientific inquiry, and developing observational skills. In the first part of the course, the practical work is led by the instructors. In the second part of the course, the students are given the responsibility to prepare, lead and assess one laboratory activity each, thereby preparing them for this part of their future work.

To emphasize the focus on professional skills as well as theoretical knowledge, student assessment is diversified. The final grade consists of three components: 20 % from points awarded for lab reports, peer reviews, and other written exercises; 30 % from the laboratory activity they lead; and 50 % from an oral exam at the end of the course.

Feedback from students show that most of them enjoy the practical and profession-oriented nature of the course. Many express that after taking the course, they now feel confident they will be able to do practical work with their own students as a teacher in the future. When it comes to assessment, several students point out that it is positive and motivating that the work they are doing through the course is affecting their final grade, but some also find it labor intensive with all the labs and submissions.

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FOSTERING SUSTAINABILITY COMPETENCES IN PRE-SERVICE CHEMISTRY TEACHERS THROUGH AN ENVIRONMENTAL CHEMISTRY COURSE

Luka Vinko^{1*}, Mojca Bavcon Kralj², Iztok Devetak¹

¹*Faculty of Education, University of Ljubljana, Slovenia*

²*Faculty of Health Sciences, University of Ljubljana, Slovenia*

*luka.vinko@pef.uni-lj.si

Education for sustainable development aligns with the UN's call to achieve sustainable development goals (SDGs) by 2030, focusing on water and pollution. Key goals include ensuring clean water access, reducing pollution, and protecting marine ecosystems. Achieving these SDGs requires reducing hazardous chemicals, improving wastewater treatment, and fostering scientific cooperation (Sustainable development goals, n. d.). Chemical education is essential in this process, helping students understand chemistry's impact on sustainability and the environment. By promoting responsible production and resource management, chemical education empowers future generations to contribute to a more sustainable world (Burmeister & Eilks, 2012; de Oliveira et al., 2020; Zuin et al., 2021).

The aim of this study was to enhance pre-service chemistry teachers' sustainability competencies through a module focused on hydrosphere pollution issues, including agricultural pollution, microplastics, ocean acidification, e-waste, and organic pollutants. This pre-post study combined qualitative and quantitative research approaches and involved 20 students, all pre-service chemistry teachers, from the University of Ljubljana, Faculty of Education. Conducted over one semester, the study included three laboratory activities and two Moodle activities, all based on the inquiry-based learning (IBL) method.

Results indicate that these activities significantly enhanced the sustainability competencies of the pre-service chemistry teachers.

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HELPING EDUCATORS TEACH GREENER CHEMISTRY: LLM-ASSISTED EVALUATION OF LABORATORY PROCEDURES USING THE CHLORTOX SCALE

Michał Woźniakiewicz^{1*}, Bartosz Trzewik², Paweł M. Nowak¹, Grzegorz J. Nalepa³,
Bartosz A. Grzybowski⁴

¹*Department of Analytical Chemistry, Faculty of Chemistry, Jagiellonian University, Poland*

²*Department of Organic Chemistry, Faculty of Chemistry, Jagiellonian University, Poland*

³*Jagiellonian Human-Centered AI Lab, Mark Kac Center for Complex Systems Research,
Institute of Applied Computer Science, Faculty of Physics, Astronomy and Applied Computer
Science, Jagiellonian University, Poland*

⁴*IBS Center for Algorithmic and Robotized Synthesis (CARS) and the Department of Chemistry,
Ulsan National Institute of Science and Technology, South Korea*

*michal.wozniakiewicz@uj.edu.pl

The integration of sustainability into chemistry curricula has become a growing priority in higher education. Yet, many academic laboratory protocols used in teaching remain poorly evaluated in terms of their chemical risk or environmental impact. This work presents a novel approach to addressing this issue by applying large language models (LLMs), such as ChatGPT, to assess the greenness of university-level laboratory procedures using the ChlorTox Scale (Nowak et al., 2023). This scale expresses chemical risk in units equivalent to the mass of chloroform, taking into account both the weighted hazards of substances used and their quantities.

The aim of the project is to support academic teachers in reviewing and comparing the chemical risk associated with the methods they teach. In the first stage, we focused on selected organic synthesis exercises. The LLM was prompted to extract relevant reagent data, retrieve or compute Weighted Hazards Numbers (WHN), and calculate the Total ChlorTox value per gram of the product. In a second case study, we extended the approach to the analytical chemistry lab, evaluating an experiment involving microscale thermophoresis for the pK_a determination.

Our findings show that with well-designed prompts and data validation, LLMs can effectively support risk-based evaluations of diverse chemical protocols in a friendly way. We discuss the main limitations encountered (e.g., hallucination of hazard values, misinterpretation of experimental steps), and propose strategies for reliable model use in educational contexts.

This AI-assisted method opens new opportunities for chemistry educators to integrate chemical safety and green chemistry assessment into their course design.

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THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN EDUCATION OF ANALYTICAL CHEMISTRY

Aneta Woźniakiewicz*, Małgorzata Król, Maria Madej, Justyna Paluch

Faculty of Chemistry, Jagiellonian University, Poland

**aneta.wozniakiewicz@uj.edu.pl*

Artificial intelligence (AI) is increasingly being integrated into various scientific disciplines, including education. This study explores the implementation of AI tools in laboratory courses for analytical chemistry students. Traditionally, students followed a predefined methodology that requires them to follow step-by-step instructions for sample preparation and analysis. Now, a new approach is being introduced that requires them to design and plan experimental procedures themselves using AI support.

This approach was aimed at 1) enabling students to develop independent thinking skills, 2) diversifying laboratory classes by implementing AI tools which are more and more trendy among young people. The introduced changes reveal the advantages and limitations of using AI in the educational process. AI systems, thanks to their ability to analyze large datasets from previous experiments of various research groups in the world, enable effective planning and optimization of methodologies (e.g. measurement conditions of the analytical method) used during classes. However, the reliability of AI-generated recommendations is highly dependent on the quality and completeness of training data. Data errors or their incompleteness can result in inaccurate predictions, potentially affecting the achievement of educational goals.

The results obtained indicate the great potential of AI in laboratory education, but also emphasize the need to critically analyze the information received, often with the help of a teacher. Verification of AI-generated results is a crucial element of the educational process, allowing for the effective integration of modern technologies with traditional teaching.

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ORAL PRESENTATIONS

PechaKucha

STUDENTS AS CHEMISTRY AMBASSADORS

Małgorzata Czaja*, Bożena Karawajczyk, Jolanta Kumirska

Didactics and Popular Science, Faculty of Chemistry, University of Gdańsk, Poland

*malgorzata.czaja@ug.edu.pl

The popularization of science plays a key role in building a society that is aware and open to scientific discoveries. Chemistry, as a field often perceived as difficult and abstract, requires particular attention in the area of science communication (Herron, J., 2000). Chemistry students, who are both enthusiasts and future specialists, play an important role at the Faculty of Chemistry at the University of Gdańsk in making this science accessible to a wide audience. Students have been involved in popularizing chemistry through various initiatives. One of them was the Baltic Science Festival. Participants – children, youth, and adults – took part in interactive activities that made science more accessible and engaging. Students actively participated in the implementation of the project "WITH CHEMISTRY FORWARD" as co-executors. The project aimed to support the children in day-care facilities in developing their skills through participation in educational activities. Students are also involved in regular chemistry laboratory workshops, targeted at students at different educational levels – from primary school to post-secondary education. These workshops are organized with the participation of students from the Teaching Module. Another successful initiative involving students in the popularization of chemistry was the cooperation with the Teacher Education Centre in Gdańsk. The result of this collaboration was the development of popular science publications that were presented at the Chemistry between Teachers and Scientists conference, "Chemistry Has Many Faces."

Involvement in the popularization of science brings many benefits to students: the development of communication skills – the ability to explain complex issues in an accessible way. Raising social awareness of science – combating myths and misinformation about chemistry. Expanding networks – building relationships with teachers and other science communicators. Better preparation for a professional career – gaining experience in presentations, event organization, and teamwork. Despite the many advantages of science popularization, students also face certain challenges: how to talk about chemistry in a simple and interesting way? The need to adapt the message to different target audiences. Myths and misinformation – combating misconceptions about chemistry, such as fears of chemical substances.

Student involvement in the popularization of chemistry and science communication is not only beneficial for society but also for the students themselves. Science popularization develops their skills, facilitates their future careers, and contributes to building a positive image of chemistry as a fascinating and useful field. It is worth supporting student initiatives and encouraging young scientists to share their passion with others.

ARTIFICIAL INTELLIGENCE IN THE TRAINING OF CHEMISTRY STUDENT TEACHERS

Veronika Švandová*, Leoš Šáblík, Kateřina Klebanová, Patrik Pospíšil

Faculty of Science, Masaryk University, Brno, Czech Republic

*106381@mail.muni.cz

Advancements in generative artificial intelligence are driving innovation in various sectors, including education (Bendel, 2023). As AI becomes integrated into education (Inamdar, 2024; Iyamuremye et al., 2024), it is essential for future teachers, not just those teaching chemistry, to learn how to work with this technology.

This study describes the implementation of AI in training chemistry student teachers at Masaryk University in the Czech Republic during spring 2024 and 2025. It explores student teachers' experiences with AI before and after taking the university course "Teaching Materials in Chemistry." The research identified their areas of interest, desired skill development, and opinions on AI's inclusion in the course and education overall. It also investigated how they used AI in their teaching practices. It covered AI tools like text generators (ChatGPT, Copilot, Gemini), graphics generators (Midjourney, DALL-E, Canva), lesson preparation applications (ScioBot), presentation applications (Gamma, Prezi AI), and digital assessment tools (Kahoot, Socrative, Quizizz).

The target group was the chemistry student teachers who joined the course "Teaching Materials in Chemistry" in spring 2024 (17 students) and 2025 (10 students). The research method was a questionnaire. Quantitative descriptive research was selected to gain initial insights into issues related to AI in the training of Chemistry student teachers. In the 2025 course, qualitative research tools were also used (a focus group).

Students primarily reported using ChatGPT free version among text generators and that was also the application they wanted to improve their skills (in both courses). A comprehensive study (Iyamuremye et al., 2024) found that chat applications like ChatGPT enhance students' problem-solving skills. Among graphic AI programs, students reported the most experience with Canva Free, and that was the application most students wanted to improve (in both courses). To ensure the success of future educators, it is crucial to prioritise these applications in the future educators training.

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POSTERS

STUDENTS CONSTRUCTING TITRATION CURVES IN PYTHON WITH HELP FROM GENERATIVE AI

Iselin Grav Aakre*

Faculty of Natural Science, NTNU Norwegian University of Science and Technology, Norway

**iselin.g.aakre@ntnu.no*

Generative artificial intelligence (AI) such as chatbots build on large language models (LLMs), are powerful tools with many uses. Although early versions of ChatGPT struggled with chemical calculations (Tyson, 2023), newer versions can perform acid-base calculations flawlessly (Schrier, 2024). AI use is widespread among students, with 83 % of Norwegian engineering students stating that they use generative AI sometimes or often, even though 67 % of students do not receive sufficient training in the use of such tools (NOKUT, 2025).

As a part of a mandatory fourth-semester course in analytical chemistry, 29 chemical engineering students at a Norwegian university completed a two-hour in-class exercise on constructing titration curves using Python in cooperation with a self-selected chatbot such as Copilot or ChatGPT. Short pre- and post-surveys was administered to the students. The exercise provided students with an AI-generated Python script for plotting titration curves for the titration of a weak acid with a strong base. The students were asked to describe what the code was doing, why it did not give the expected result and how it should be improved or remade in order to get a working script. Use of chatbots were recommended in solving all parts of the exercise.

The pre-survey confirms that students use AI a lot in their studies. A frequently raised concern about students' use of chatbots, is that students neglect to critically evaluate the answers they generate. In this exercise, students were given criteria for what the code should do and had to decide whether it succeeded or failed, and why it failed. In the post-survey, most students (75 %) confirmed that they used chemical knowledge while solving the exercise.

Students do use chatbots, and they need guidance from the university in how to critically and constructively make use of this versatile technology. Experiences with use of chatbots to solve relevant problems in a supervised setting, is one way of offering this guidance.

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NOTES

INTEGRATING AI-DRIVEN COMPUTATIONAL TOOLS IN CHEMISTRY EDUCATION FOR WORKFORCE READINESS

Hossein Jooya^{1*}, Miłosz Augustyński²

¹*MathWorks*

²*Oprogramowanie Naukowo - Techniczne*

*hjooya@mathworks.com

As the landscape of chemistry education evolves, there is an increasing need to equip students with the skills necessary for the modern job market. This presentation addresses this need by introducing an AI-driven computational workflow designed for chemistry education, implemented using MATLAB. By leveraging the power of generative AI techniques, this workflow provides students with hands-on experience in data extraction, molecular dynamics, and density functional theory calculations. The integration of MATLAB-Python interoperability facilitates a deeper understanding of predictive modeling through deep learning techniques, such as large language models and graph neural networks. These tools enable students to predict molecular and material properties, preparing them for real-world applications. The workflow concludes with system-level simulations that mirror industry scenarios, enhancing students' readiness for careers in molecular and materials design. By making all developed codes and examples accessible, this presentation fosters open science and collaborative learning, ultimately bridging the gap between academic training and industry demands. Through this approach, we aim to empower chemistry students to become adept professionals, ready to contribute to the evolving demands of the global workforce.

NOTES

THE CHEMISTRY OF IMMERSION: UNPACKING COGNITIVE LOAD IN VIRTUAL AND AUGMENTED REALITY LEARNING

Mária Babinčáková*, Paweł Bernard

Department of Chemistry Education, Jagiellonian University in Kraków, Poland

*maria.babincakova@uj.edu.pl

Evaluating the effectiveness of innovative chemistry teaching methods, such as augmented reality and virtual reality, is crucial for their successful integration into educational practice. This study focuses on assessing the cognitive load imposed by different representational formats – molecular models in augmented reality, virtual reality, on a computer screen, and physical models – during solving tasks involving changes in chemical representations. Moving beyond traditional subjective assessments, this study employs a different approach, including electroencephalography (EEG) and heart rate variability, alongside self-reported questionnaires and tests, to provide objective physiological measures of cognitive effort. Preliminary findings comparing student performance and cognitive effort across these conditions will be presented. This study aims to provide evidence-based recommendations for the optimal integration of VR and AR into chemistry curricula, and its results can significantly contribute to optimizing teaching and learning methodologies, informing lesson design, enhancing test development, and strategically integrating new technologies in education.

Acknowledgements

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NOTES

PROJECT "DISCOVER CHEMISTRY WITH US"

Joanna Hetmańczyk*, Paweł Bernard

Department of Chemistry Didactics, Faculty of Chemistry, Jagiellonian University, Poland

**joanna.hetmanczyk@uj.edu.pl*

Recent studies have shown that interest in Natural and Exact Sciences is decreasing significantly among students of European schools at various levels of education. According to the results of the ROSE project (The Relevance of Science Education Project) (Sjøberg, Schreiner, 2012), potential future students of exact sciences are not interested in science, and even have a negative attitude towards it. Chemistry as a subject is considered to be difficult, abstract, and has nothing to do with the reality around us. Students are unable to correlate the scientific knowledge they have acquired with the phenomena they observe. The reasons for this state are, among others, the teaching methods used. That is why at the beginning of the 21st century an expert group of the European Commission on science education was established. According to its recommendations (the so-called Rocard Report from 2007) (Rocard et al., 2007), chemical knowledge should be imparted by teachers by introducing activating methods and teaching methods based on making experiments during the lessons. The cited Report (Rocard et al., 2007) recommends the introduction of Inquiry Based Science Education (IBSE) methods, that provides students with the opportunity to explore a subject through hands-on activities, investigations, and asking questions.

In order to deal with these problems, the employees of the Department of Chemistry Didactics at the Jagiellonian University have taken steps to improve this situation. For several years, the Faculty of Chemistry JU has been conducting laboratory classes for secondary school students as part of a cooperation agreement between the Jagiellonian University and the school. High schools students have the opportunity to participate in chemistry lab in modernly equipped classrooms. In 2024 year, thanks to the funds awarded from the educational project "Discover chemistry with us" (Discover Chemistry with Us), this offer has been extended to include eighth-grade primary school students. Thanks to the conducted laboratory workshops, students can discover the secrets of the chemical world by formulating hypotheses, verifying them, and what is most important perform independently experiments.

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EDUCATIONAL APPLICATIONS OF CHROMATOGRAPHIC TECHNIQUES: ENHANCING LABORATORY SKILLS AND SCIENTIFIC INQUIRY

Katarzyna Makyla-Juzak*, Anna Chachaj-Brekiesz, Paweł Bernard
Faculty of Chemistry, Jagiellonian University, Gronostajowa 2, Kraków, Poland
*katarzyna.makyla@uj.edu.pl

Chromatographic techniques are standard analytical tools widely employed in laboratories for the separation and identification of mixture components. The simple, intuitive theoretical background and broad scope of applications (e.g., in food safety and environmental monitoring) makes chromatography an extremely valuable and enriching element of natural science education. Here, we present an organized approach to incorporating chromatography basics into chemistry education at various levels, from primary schools, through secondary education, to the early stages of academic studies.

Our objective is to draw attention to the pedagogical potential of simple chromatographic techniques, namely, paper chromatography (PC) and thin-layer chromatography (TLC). Their methodological simplicity, cost-effectiveness, and rapid visual results make them ideal for the use especially at the early stages of education. Three exemplary exercises are discussed: (1) the separation of synthetic dyes from pen ink using paper chromatography with two eluents of different polarity; (2) the extraction and separation of plant pigments (chlorophylls, carotenoids, and xanthophylls) from leaf tissue using thin-layer chromatography; and (3) the identification of colorless aromatic compounds naturally present in essential oils using TLC with ultraviolet light detection.

These exercises serve as an introduction to key chemical concepts such as polarity, adsorption, solubility, and the significance of eluent selection. Students are encouraged to analyze experimental data, calculate retention factors (R_f), and draw conclusions regarding the identities of compounds and the composition of mixtures. These activities not only develop essential laboratory skills and safety awareness, but also stimulate scientific curiosity and interdisciplinary thinking.

We also present practical aspects of using these exercises for educational purposes, along with strategies for adapting the content to different levels of student knowledge. By integrating chromatography into chemistry education, educators can provide students with tangible evidence that the chemistry methods employed in highly complex scientific research can also be practically applied to exploring everyday-life phenomena

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UNDERSTANDING THE REMOVAL OF TOXIC ELEMENTS FROM WASTEWATERS: THE ROLE OF SURFACE CHEMISTRY

Deborah Biggio*, Bernhard Elsener, Marzia Fantauzzi, Antonella Rossi

Department of Chemical and Geological Sciences, University of Cagliari, Italy

*deborah.biggio@unica.it

Following the introduction to the problem of recycling water, an inquiry-based approach was exploited. The work focuses on removing toxic elements from contaminated surface waters and /or wastewaters, aiming to teach master students of Chemistry who attended the course “Environmental Analytical Chemistry”. First, the technological approaches to produce “clean” and possibly reuse waters in a sustainable way in line with the principles of Agenda 2030 (<https://www.agenziacooperazione.gov.it/comunicazione/agenda-2030-per-lo-sviluppo-sostenibile/>) were presented. Then, the students were stimulated to propose a quick laboratory test for the identification of toxic elements such as lead, cadmium, and zinc before and after contact with calcium carbonate microfine powders in model solutions. The students were asked to exploit their knowledge about the solubility of the inorganic salts, and their critical thinking was stimulated to suggest experiments and possible reaction pathways for the removal of toxic elements. This work used the Inquiry-based science education approach and problem-solving methodology.

Particularly successful were the experiments carried out in the presence of lead. An example of a procedure developed during the course will be provided during the presentation. The students were very interested and participated in all the activities, including surface analysis by X-ray photoelectron spectroscopy (XPS) and scanning electron microscopy (SEM) (Fiorito et al., 2022; Fiorito et al., 2022). They were able to discuss the removal mechanism of lead. The combination of their results and the information from the surface analysis techniques allowed them to propose two removal mechanisms. Further experiments were then planned to decide which mechanism dominates.

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MAKING SCIENCE ACCESSIBLE – EDUCATING STUDENTS IN EFFECTIVE SCIENCE COMMUNICATION

Małgorzata Czaja, Bożena Karawajczyk*

Didactics and Popular Science, Faculty of Chemistry, University of Gdansk, Poland

*bozena.karawajczyk@ug.edu.pl

Dissemination of knowledge and popularization of research results is now an integral part of the activities of many universities in Poland. This type of activity of universities was included in the document Pact for Science among the ten demands, the fulfillment of which is aimed at improving the situation of science and improving the condition of universities in Poland (Muszewska et al.). The Department of Chemistry at the University of Gdansk has been taking part in popularizing science among the public for years. Not only academics, but also students are involved in popularization activities. Particularly noteworthy are students preparing to become chemistry teachers. In addition to skills that will allow them to do teaching work in schools, they are also acquiring skills in the dissemination of knowledge. They are prepared for this activity in several stages. In the first stage, they observe the work of experienced popularizers and at the same time assist them. Assisting them allows them to understand what popularizing science is and how it differs from teaching a lesson at school. After this experience, students prepare for independent popularization work on a topic indicated by the academic teacher. They begin their work by expanding their knowledge on the indicated topic. They then analyze school textbooks for content related to the topic. They do this in order to find out what scientific terms they can use when popularizing science in order to be understood by the audience. Most of the participants in popular science events attended by students of the teaching module are elementary and high school students. Once they have adequate knowledge and information on the topic being disseminated, the students think about the content of the message - how they can simplify the knowledge without distorting it, what concepts to use in doing so, how to show the relevance of this knowledge to people's lives. Depending on the formula of the planned popular science event, students of the university prepare a multimedia presentation or a set of experiments. Experiments are used in two ways: either as a demonstration or to be carried out by the students themselves. Before students begin their popularization activities, they initially conduct trials among a group of other students. In this way, they receive feedback on whether their plan of action, the way they convey knowledge, the presentations created, the experiments, etc., can be used to popularize knowledge among students. Often even at this stage the originators modify their ideas. Students preparing to become teachers participate in the act of popularizing science three times. The students' activities include, among others, short mini-lectures, demonstrations of experiments, conducting workshops during which students perform natural experiments on their own.

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SUSTAINABLE DEVELOPMENT IN PRACTICE: HOW EDUCATION CAN CHANGE HABITS AND ATTITUDES?

Małgorzata Czaja*, Bożena Karawajczyk, Jolanta Kumirska

Didactics and Popular Science, Faculty of Chemistry, University of Gdańsk, Poland

*malgorzata.czaja@ug.edu.pl

Education plays a key role in promoting sustainable development, as it is in schools, universities, and various educational programs that attitudes, beliefs, and behaviors are shaped—factors that influence our everyday lives (Domeracki et al., 2011; Rosik, 2017). Sustainable development in practice requires changes in habits, approaches to consumption, and environmental protection, and education can serve as a tool that enables this transformation (Tyburski, 2011).

Academic staff from the Faculty of Chemistry at the University of Gdańsk are actively involved in activities supporting sustainable development by sharing their knowledge and experience. Our aim is to raise awareness of human impact on the environment and to promote reliable, scientifically validated information in an accessible and comprehensible way. Through numerous educational initiatives, we inspire pupils and students to take a conscious approach to ecology, environmental protection, and public health. One of our initiatives is participation in the “Talented from Pomerania” project run by the University of Gdańsk, both in its first and second editions. Thanks to this project, young science enthusiasts can explore the secrets of chemistry at our Faculty, learning about its applications in environmental protection, health, and modern technologies. This initiative is part of an innovative and unique nationwide program launched and led by the Pomeranian Voivodeship Government since 2010. The Faculty of Chemistry enables primary and secondary school students to take part in a variety of academic support formats, which include: Academic meetings (“Encounters with Science”) – one-day scientific sessions held on selected Saturdays in the form of lectures, seminars, and laboratory classes; Academic olympiad clubs – year-long support for groups of gifted students preparing for chemistry competitions and the chemistry olympiad; Scientific workshops – week-long interdisciplinary classes for talented students from schools located outside the Tri-City area, held during a selected week in September; Mentor supervision – individual cooperation between a student and a scientific supervisor based on a personalized development program.

Approximately 470 students from across the Pomeranian Voivodeship participate annually in the part of the project conducted by the Faculty of Chemistry. Thirteen academic teachers are involved in delivering these activities. Our most extensive effort is organizing the so-called Encounters with Science, which reach the largest number of students. Each thematic meeting consists of a lecture, a discussion/exercise segment, and a laboratory session. During the discussion part, the knowledge and skills introduced in the lecture are practiced, while students are also prepared for the

subsequent laboratory work. In the lab, students work independently in groups, conducting chemical experiments related to the topics discussed in the lecture and seminar. For most students, this is their first opportunity to be in the facilities of the Faculty of Chemistry and to engage in activities resembling those of actual chemistry students. To assess the effectiveness of our educational activities, participants take knowledge tests both before and after the sessions. The analysis of the obtained results shows a statistically significant increase in average scores after the completion of the classes. These results confirm the effectiveness of the applied teaching methods and also indicate a noticeable increase in students' awareness of sustainable development – one of the key areas of the project.

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FROM SCHOOL KID TO CHEMIST. DEVELOPING SELF-EFFICACY AND CRITICAL THINKING IN UNDERGRADUATE CHEMISTS

Shaun-Jones, Eganda*, Frances T. Docherty

School of Chemistry, University of Glasgow, United Kingdom

*2804021e@student.gla.ac.uk

Over the past century our world as we know it has become more volatile, uncertain, complex and ambiguous. With a new world comes new challenges and therefore a new emphasis on essential skills needed by students to not just survive these changes, but also to thrive; the old saying of “a job for life” will no longer be relevant as we move into an increasingly technology based world. Critical thinking and self-efficacy will be just two of the main transferable skills that will be vital if students stand a chance to be competitive in the new job market and greater life once they leave the safety of school. The aim of this study is to evaluate and develop critical thinking and self-efficacy amongst undergraduate chemists. This will be achieved using a mixed-methods approach using questionnaires to firstly determine students understanding of the terms ‘self-efficacy & critical thinking’ as well as getting a baseline perspective of students self-efficacy and critical thinking levels across the 1st, 2nd, 3rd, and final year. The second stage is smaller focus groups to gather qualitative data to obtain a richer perspective. In addition this study aims to identify where students believe critical thinking and self-efficacy skills are currently being developed in their curriculum and their effectiveness; with the aims to improve current methods as well as develop new and innovative ones with the help of artificial intelligence.

LABBUDDY ENHANCES LABORATORY EDUCATION BY IMPROVING STUDENT PREPARATION, ENGAGEMENT, AND LEARNING OUTCOMES

Charita Furumaya*

LabBuddy, The Netherlands

*charita.furumaya@labbuddy.net

Laboratory education plays a vital role in scientific curricula, yet students often struggle due to inadequate preparation, cognitive overload during practical sessions, and a lack of alignment between learning objectives, activities, and assessments. LabBuddy, an e-learning solution developed as part of PhD research (Van der Kolk, 2013), addresses these issues by guiding students through the full laboratory learning process. Grounded in well-established educational frameworks such as the 4C/ID model (Van Merriënboer et al, 2024), Cognitive Load Theory (Sweller, 1994), and principles of multimedia learning (Mayer, 2009), LabBuddy promotes active engagement before class, offers real-time support during experiments, and helps students reflect and process results afterward. It provides interactive questions, experiment design tools, enriched manuals, video instructions, lab journal functionalities, and structured post-lab activities. Across various university implementations, LabBuddy has led to improved student engagement, greater confidence, enhanced preparation, and more effective learning outcomes (Loveridge, 2020; Moelans et al., 2024; Jongsma et al., 2024). Teachers report smoother, more productive lab sessions, while students benefit from the clarity, structure, and autonomy the platform provides. These outcomes demonstrate that LabBuddy effectively overcomes common challenges in lab education and enriches the overall learning experience.

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DIGITAL BADGES: A PEDAGOGIC TOOL TO CHAMPION LAB SKILL DEVELOPMENT AND CELEBRATE ENGAGEMENT ACROSS AN ORGANIC CHEMISTRY MODULE

Frances Heaney^{1*}, Denise Rooney¹, Carmel Breslin¹, Trinidad Velasco-Torrijos¹, Robert Elmes¹, John Stephens¹, Ria Collery-Walsh¹, Anne Cleary¹, Orla Joyce¹, Bernard Drumm², Ronan Bree², Brian Murphy³, Aoife Morrin⁴, Blánaid White⁴, Eric Moore⁵, Christopher Burke⁵

¹*Department of Chemistry, Maynooth University, Ireland*

²*Department of Life & Health Sciences, Dunalk IT, Ireland*

³*Department of Pharmaceutical Science and Biotechnology, TUS: Midlands Midwest*

⁴*School of Chemical Sciences, DCU, Ireland*

⁵*School of Chemistry, UCC, Ireland*

*frances.heaney@mu.ie

The number one theme identified amongst Irish Higher Education students in terms of their perception of success is “developing skills to maximize employability” (National Forum, 2019). Whilst undergraduate chemistry curricula provide numerous opportunities for developing discipline specific and transversal skills and attributes, students do not necessarily identify the full range of their emerging skills portfolio. Therefore, it is important to find a mechanism for guiding students in connecting their in-curriculum skills development to their potential for employment.

The digital badging landscape spans education and workplace settings. (Cumberland et al., 2024) In chemistry, badge use has ranged from visual cues on course materials, (Hill et al., 2020) to digital rewards for skill mastery (Hennah & Seery, 2017). This poster describes a unique hybrid pedagogic approach that purposefully uses badges to foster engagement with, and practice of lab related skills. It will show how a technology-enhanced learning environment was harnessed to overcome the logistical challenges of badging at scale, and will share the student perception of this initiative that recognizes engagement and practical technical skill development.

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DOWN AND ACROSS – SNEAKING IN CHEMICAL CONCEPTS THROUGH CROSSWORDS, PUNS AND PUZZLES

Alicja Kluczyk*

Faculty of Chemistry, University of Wrocław, Poland

**alicja.kluczyk@uwr.edu.pl*

The application of games in chemical education has a long history, a recent review (da Silva et al. 2025) indicates that the first chemistry-related crossword puzzle was published in 1925 (Beardsley, 1925), and the following evolution of games and their impact on learning efficiency is substantial.

A series of courses directed at improving chemistry-related professional English, are offered at the Faculty of Chemistry, University of Wrocław, to facilitate the acquisition of vocabulary and develop the working relationship with resources in English (texts, procedures, webinars, podcasts etc.). The idea is to bridge the linguistic gap as quickly as possible to improve knowledge transfer (Cao et al., 2024).

To increase the interest of students, various games are introduced, for example for practicing element names and properties (Bingo!, puns, crosswords). A combination of Moodle platform activities (glossary and crossword) allows students to select unfamiliar words from journal articles, build a common glossary and practice vocabulary at their own pace. Students find the creative output of developing riddles, rebuses and escape rooms quite exciting and invigorating. When asked to compare the experience of solving a crossword and multiple choice quiz, students indicated crossword as more interesting although not necessarily easier activity.

It was suggested that games provide highly organized knowledge, leading to deeper understanding of chemical terms and definitions (Yuriev et al. 2016). The broad range of resources and the more engaging, immersive, and interactive approach, combining fun and learning, attract attention, improve students' motivation, and are worth promoting (Hermanns & Keller, 2022).

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CHROMATOGRAPHIC METHODS IN STUDENT PROJECTS: FROM RESEARCH TO EDUCATION

Alicja Kluczyk*

Faculty of Chemistry, University of Wrocław, Poland

**alicja.kluczyk@uwr.edu.pl*

Chromatographic methods offer a variety of possibilities for student research projects at different levels of complexity. Considering the availability of equipment and required knowledge, topics for both Bachelor and Master degree students could be selected, with the additional factor of analyzed materials, suitable for broad range of personal interests and course objectives. The required elements of novelty usually associate the projects with current research conducted by the thesis supervisor.

Taking into account some recent experimental BSc and MSc theses in Peptide Engineering Research Group at the Faculty of Chemistry, University of Wrocław, three types of chromatographic methods could be selected: thin layer chromatography (TLC), high performance liquid chromatography (HPLC) with ultraviolet detection, and HPLC coupled with mass spectrometry (LC-MS). Specific cases would be presented and discussed, providing examples and perspectives.

TLC is a relatively simple and inexpensive separation method, which could be used in identification and differentiation of compounds, especially in difficult matrices, studying chemical derivatization and investigation of physicochemical properties. More complicated mixtures or low concentration components require increased resolution and sensitivity or reliable quantitative analysis of HPLC-UV (Palme et al. 2024). The examples of projects, in which both techniques were used include detection of artificial sweeteners in soft drinks, theanine in teas, quinine in hair products or vitamins in food. Identification of specific components frequently requires further studies, providing insight into real scientific investigations. In several cases the preliminary TLC analyses were also used to group and select promising cases for LC-MS studies, for example different types of red ink pen colorants or labile natural products. Advanced projects are usually based on LC-MS studies involving special chromatographic approach, including HILIC separations for nonproteinaceous amino acids or multistep sample preparation in the case of cosmetic peptides (Kluczyk et al. 2021).

The main advantage of chromatography-based projects in education is the direct relation to current research challenges and prospective professional skills.

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PROCESS-BASED LAB ASSESSMENT STRATEGIES IN THE AGE OF AI

Izabela Koter*

Faculty of Chemistry, Nicolaus Copernicus University in Torun, Poland

**ikoter@umk.pl*

The rapid advancement of generative artificial intelligence presents both unprecedented challenges and opportunities in scientific education (Lee et al., 2024). As GenAI tools become widely available, students can now generate seemingly correct explanations without truly understanding the concepts. This creates a challenge for educators: how do we assess real learning when AI can produce perfect-looking answers?

A typical assessment of a student's work in a laboratory consists of an evaluation of the report prepared by the student on the task. This poster presents a practical approach to assessment in selected chemistry courses that focuses on how students think, not just what answers they produce. This approach has been applied to physical and nuclear chemistry as they combine abstract theory, complex math, precise measurements, and technical equipment, making it challenging to connect concepts with hands-on practice. The method has two main parts: pre-lab conceptual diagnostic and reflective lab reports. Before lab work, students complete assessments that reveal their current understanding and misconceptions. This helps instructors see how students are thinking about chemistry concepts and address problems early. After experiments, students write about not just their results, but their thought process—including what confused them, how their understanding changed, and how they reached their conclusions.

By focusing on students' thinking processes rather than just their final answers, this approach is designed to develop deeper understanding in chemistry. It allows students to demonstrate their knowledge in ways that AI cannot easily imitate (Humphry and Fuller, 2023). The method also gives teachers better insight into what students actually understand versus what they can produce with technological assistance. It is not intended to discourage students from using GenAI tools, but rather to make students aware of their limitations and increase their informed use.

Teacher observations and student surveys will be presented to evaluate the effectiveness of this approach.

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NOTES

IN THE EYE OF THE LEARNER: BUILDING BETTER CHEMISTRY TOOLS

Radana Koudelíková^{1*}, Pavel Štarha^{2*}

Faculty of Science, Palacký University Olomouc, Czech Republic

^{1*}radana.koudelikova@upol.cz

^{2*}pavel.starha@upol.cz

In contemporary science education, the integration of multimedia tools plays a significant role in enhancing students' understanding of science education. A central question remains whether video tutorials, when developed in line with multimedia learning principles, can effectively support knowledge acquisition in STEM fields.

Eye-tracking technology offers valuable insights into students' visual attention and cognitive engagement while interacting with instructional content. It helps uncover how learners perceive and prioritize key elements within the materials, offering a window into their cognitive needs and expectations. These insights form the basis for optimizing video-based materials to better reflect students' natural learning processes, with an emphasis on clarity, focus, and guided visual input.

It is assumed that a thoughtful comparison between video and traditional text-based formats can reveal critical design elements that influence the quality of learning. Such findings may contribute to the creation of pedagogically grounded educational resources that enhance both procedural understanding and long-term retention in science education.

Keywords:

multimedia learning, video tutorials, science education, eye tracking, instructional design

NOTES

BIOCHEMISTRY STUDY PROGRAMS AT THE FACULTY OF SCIENCE: FROM BACHELOR'S TO DOCTORAL STUDIES

Maria Kožurková, Zuzana Vargová*

Faculty of Science, Pavol Jozef Šafárik University in Košice, Slovakia

**zuzana.vargova@upjs.sk*

The Department of Biochemistry at the Faculty of Sciences of the Pavol Jozef Šafárik University in Košice teaches bachelor's, master's and doctoral study programs based on a credit system. A specialized post-graduate study program in the field of the structure and function of biomacromolecules is also offered by the Department. A substantial part of the content of the doctoral study program is devoted to familiarising students with the latest scientific findings in biochemistry, molecular biology, biophysical chemistry, bioinformatics and the conformational stability of biomacromolecules. Graduates can go on to develop their careers at foreign research institutions, and the doctoral program provides them with the necessary skills to teach specialized chemistry subjects at universities and conduct independent research.

The bachelor's degree is only offered in Chemistry. In an effort to strengthen undergraduates' basic knowledge of biochemistry and develop a better foundation for studying biochemical subjects at the master's and doctoral levels, a new bachelor's degree in biochemistry was developed within the framework of KEGA Project 007UPJŠ-4/2024: "2024 Preparation and formation of a new bachelor study program in Biochemistry at UCHV PF UPJŠ in Košice". In comparison to the bachelor's degree in chemistry, the only study program of its kind currently offered at our Faculty at this level, the new bachelor's program in biochemistry will offer more subjects and practical exercises in biology, covering subjects such as general zoology, genetics and many more. In this contribution, we present the content of these new subjects focused on the use of knowledge at the M.Sc. and Ph.D. levels of study.

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Acknowledgement:

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This image shows a full page of dot grid paper. The dots are arranged in a precise, repeating grid pattern across the entire surface. There are no margins, text, or other markings present.

FEEDBACK AS A TOOL OF SUCCESS: HOW TO EFFECTIVELY SUPPORT STUDENT DEVELOPMENT?

Małgorzata Krzeczowska^{1*}, Tetiana Matuselych²

¹*Faculty of Chemistry, Jagiellonian University in Cracow, Poland*

²*Institute of Philosophy and Education Policy, Dragomanov Ukrainian State University*

*malgorzata.krzeczowska@uj.edu.pl

Modern approaches to didactics place great emphasis on feedback, which is a key element in supporting the learning process. And this does not only apply to student learning, but also to student teaching.

The post will present a scenario of original classes that enable students - future teachers - to understand and practice effective feedback. The 90-minute class is designed to be interactive, engaging students in a variety of activities designed to develop their ability to analyze, evaluate and formulate constructive information. The lesson scenario includes personal reflection, analysis of real-life examples of feedback, a feedback transformation exercise, a digital experiment using AI tools, and practice in feedback formulation groups.

In addition, examples of specific student feedback directed to school students writing a chemistry revision test and their analysis will be presented.

Future teachers need to be aware from the outset that feedback is a key element in supporting students' development as independent learners, enabling them to monitor, assess and regulate their own learning (Md. Mamoon-Al-Bashir, et al., 2016). School teachers, university teachers should possess and develop this skill; only then will feedback fulfill its purpose in the educational process.

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MICRORELATIONSHIPS, MACRO EFFECTS – ABOUT TUTORING NOT ONLY FOR CHEMISTRY STUDENTS

Małgorzata Krzeczowska^{1*}, Natalia Bokla²

¹*Faculty of Chemistry, Jagiellonian University in Cracow, Poland*

²*Department of Computer-Aided Design, Lviv Polytechnic National University, Ukraine*

*malgorzata.krzeczowska@uj.edu.pl

Modern higher education is facing the challenges of increasing diversity of student needs and the need to personalize educational pathways. One of the responses to these needs is the implementation of academic tutoring - a teaching method based on a direct master-student relationship (Wakelin, 2021). The poster will present the potential of tutoring in the context of supporting the development of students' cognitive, social and metareflective competencies.

The Lviv Polytechnic National University has launched the “First-Year Student Tutoring” program, as part of the PROMENT project supported by the Erasmus+ program, to help incoming students transition to university life. This initiative aimed to address common academic and social challenges faced by first-year students, in particular when adjusting to the academic expectations and workload of the university.

The main objective of this scheme was to assist first-year students in their academic and social transition to university life. The program aimed to provide individual academic support, improve study skills, and help students adapt to the expectations of the university. By pairing new students with experienced mentors, the program sought to provide personalized academic support, facilitate the development of study strategies, and offer guidance on navigating the university environment. The results of the pilot study conducted among tutors and tutees will be presented.

In addition, a specific case of tutoring application among students of the Faculty of Chemistry at the Jagiellonian University in Kraków will be also presented and discussed.

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A PROJECT BASED LEARNING APPROACH FOR BASIC ORGANIC CHEMISTRY TEACHING & LEARNING

Àngels Leiva-Presa*

*Faculty of Sciences, Technology and Engineering,
University of Vic – Central University of Catalonia, Spain*

**angels.leiva@uvic.cat*

Project Based Learning (PBL) in education of sciences has increased a lot in recent years due to its advantages to, not only promote knowledge acquisition, but also to develop key competences, attitudes and values for the XXI century (Geisinger, 2016). Despite the benefits of PBL, it has also been reported to entail several teaching implementation difficulties, and this has been leading to a variety of teaching approaches. The present work shares a proposal for Basic Organic Chemistry teaching based on PBL.

A project, developed in seven steps, has been established for teaching the Organic Chemistry curriculum of the subject Chemistry II (first course of Biotechnology and Biology degrees). The first step of the project includes grouping of the students and searching of information. This step covers the selection of a complex organic molecule, which must meet conditions of functional groups containing, structure and isomerism possibilities. This molecule is validated for each group and used to study the topics of the curriculum. The following steps expand on IUPAC nomenclature of the molecule, all types of isomerism, physical and chemical properties of the molecule and an oral presentation of the whole project. The selected molecules are built with molecular models and represented with an online program for drawing and editing chemical structures. All the steps of the project combine short theoretical sessions, which introduce general aspects of the topics, practical sessions in the lab or with the molecule, and teamwork.

As a result of the process, students have increased the perception of relevance of the studied topics and have shown better performance in the application of key concepts of Organic Chemistry. Creativity, teamwork and decision-making competences have been highlighted as crucial to develop the project. Development of the project have enhanced student engagement, motivation and willingness to learn Organic Chemistry topics.

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THE DICTIONARY AS A CATALYST FOR UNDERSTANDING IN CHEMISTRY EDUCATION

Denis Zhilin^{1*}, Iwona Maciejowska², CCE IUPAC project team

¹*Faculty of Chemistry, Jagiellonian University in Krakow, Poland*

²*Committee on Chemistry Education, IUPAC*

*zhila2000@mail.ru

In the increasingly globalized context of chemistry education, effective communication between educators from different linguistic and pedagogical backgrounds is vital. The IUPAC-endorsed project "Multi-language Dictionary of Terms in Chemistry Education" responds to this need by compiling key educational terminology used in the teaching and learning of chemistry across multiple languages (<https://iupac.org/project/2023-031-3-050/>).

The dictionary serves as a dynamic, open-access resource developed collaboratively by contributors from over 15 countries. Each term is provided in English and translated into national languages, accompanied by context-specific definitions and examples. Beyond simple translation, the project addresses the conceptual and cultural nuances that hinder mutual understanding—e.g., the term *constructivism* interpreted outside pedagogical contexts.

Currently, the English master list is being finalized, including terms such as *conceptual understanding*, *balancing equations*, *scaffolding*, *threshold concepts* and *cognitive overload*. These will form the backbone for translation into national terms, including cases where no direct equivalents exist. The final resource will be semantically structured, cross-referenced, and hosted in an open, digital format in collaboration with the IUPAC Committee on Publications and Cheminformatics Data Standards.

This poster presents the current state of the project and invites feedback, collaboration, and contributions from chemistry educators worldwide. The dictionary aims to facilitate competence-based education, improve international cooperation, and support the professional development of university teaching staff.

NOTES

IMPACT OF NEW CHEMICAL FINDINGS ON EDUCATION CURRICULA

Vladimír Mañas*, Bohuslav Drahoš, Iveta Bártová, Jana Prášilová

Faculty of Science, Palacký University Olomouc, Czechia

*vladimir.manas01@upol.cz

This study explores the impact of recent advancements in chemical knowledge on secondary education curricula. Through a comprehensive literature review, we identified key new scientific findings, such as hydrogen economy, nanotechnology, green chemistry, microplastics, and modern gastronomy. We also explored potential pathways for their integration into secondary school teaching. Our research analyzed a range of educational resources, including Czech and international secondary chemistry textbooks, Czech national curriculum documents, programs offered by centers of informal education, and professional development courses for teachers.

The analysis aimed to determine emerging scientific concepts and assess the feasibility and methods of their transfer into the secondary education system, considering pedagogical approaches like inquiry-based learning, individualized learning, cooperative learning, manipulative, model and multiple representations learning, multimedia-based learning, etc. (Sugano et al., 2019; ter Horst et al., 2024). The findings highlight specific new chemical discoveries and suggest practical strategies for their incorporation into existing curricula and teaching practices, utilizing diverse pedagogical methods.

To summarize, this research aims to provide valuable insights for curriculum developers and educators seeking to modernize chemistry education and equip students with the knowledge and skills necessary to engage with contemporary scientific challenges and advances.

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IMMERSIVE VR CHEMISTRY LABS – ADDRESSING DIVERSE PRIOR EXPERIENCES WITH HANDS-ON INTERACTIONS

Leander Mecklenburg^{1*}, Stefanie Lenzer^{1,2}

¹*Institute of Inorganic Chemistry, Kiel University, Germany*

²*Department of Chemistry Education, Leibniz Institute for Science and Mathematics Education, Germany*

*lmecklenburg@ac.uni-kiel.de

University chemistry lab courses play a crucial role in students' education, providing opportunities to develop both hands-on skills and procedural knowledge (Seery et al., 2019). However, first-year students – particularly those with less prior lab experience – often struggle adapting to the new lab environment due to the complexity of integrating these skills and knowledge. To address these challenges, educators have developed various interventions for lab courses (Seery et al., 2019). Among these, immersive Virtual Reality Chemistry Labs (iVRCLs) offer a promising approach by enabling students to engage in interactive simulations that integrate hands-on skills with procedural knowledge. Prior research suggests that iVRCLs can enhance self-efficacy and reduce chemistry anxiety, preparing students for the physical lab (Gungor et al., 2022). Despite these advantages, many existing interventions do not sufficiently consider students' prior experience or incorporate their perspectives into the development process.

In this contribution, we introduce an iVRCL to simulate an inorganic chemistry laboratory for first-year students with varying levels of prior experience. The iVRCL allows students to explore the lab, conduct experiments, develop hands-on skills and procedural knowledge in preparation for the physical lab. The development process follows a design-based research approach (Anderson & Shattuck, 2012) and includes iterative usability testing to ensure an effective learning experience.

We outline the development process, highlight key iVRCL features—including embedded guidance, realistic environment, and reflection opportunities—and present preliminary findings from usability testing. These results provide insights into the potential of iVRCLs to enhance hands-on skills and procedural knowledge among students with diverse prior experiences, aiding their preparation for the physical lab.

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OXIDATIVE STRESS: EXPERIMENTS FOR SCHOOL STUDENTS IN THE FRAME OF A STUDENT LABORATORY

Jannis Memmen*, Denis Schiffelbaum, Philipp Maier,
Ivana Ivanović-Burmazović, Silviija Markić

Department of Chemistry and Pharmacy, Ludwig Maximilian University of Munich, Germany

**jannis.memmen@lmu.de*

Experiments on redox reactions for school students are often associated with batteries, galvanic cells, and other topics in electrochemistry. Moreover, biochemical experiments should be considered as additional approaches to oxidations and reductions. These experiments can often be situated in the contexts of medicine, the human body, or diseases, which have been identified as highly engaging – especially for girls, who have shown less interest in typical contexts for redox reactions like physics or technology (e.g. Holstermann & Bögeholz, 2007).

The topic of oxidative stress is an especially suitable context for this endeavor, as oxidative stress is connected to age-related diseases, such as cardiovascular and neurodegenerative diseases (Chandrasekaran et al., 2017). Oxidative stress can be defined as the “disturbance in the balance between the production of reactive oxygen species (free radicals) and antioxidant defenses” (Betteridge, 2000, p. 3). These reactive oxygen species (ROS; e.g. hydrogen peroxide, superoxide, hydroxyl radical) are often byproducts of reactions in the human body as well as of oxidation processes involving molecular oxygen in general, such as combustion reactions. As ROS have the potential for tissue damage, the human body has developed defenses against these reactive species (Betteridge, 2000).

These redox processes bring numerous opportunities for simulations and experiments in the student laboratory. The following experiments were selected to give school students an overview of oxidative stress and allow them to experience a multitude of practical methods: i) Pyrogallol-assay for investigating the antioxidant activity of different samples (e.g., fruit juices), ii) Detection of ROS formation by xanthine oxidase using methylene blue, iii) Blue Bottle and Baumann experiment as model experiments for the respiratory chain – a source of ROS, and iv) Detection of ROS in a model system using yeast cells and fluorescence spectroscopy with H₂DCFDA.

This poster presents the experiments for the student laboratory. Further, videos will be shown on an iPad at the poster to immerse the viewer in the experiments on oxidative stress and allow for further discussion in the school context.

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ELECTRONIC PROTOTYPING IN STEM EDUCATION: DIFFICULTIES FACED BY CHEMISTRY PRE-SERVICE TEACHERS

Cidália André¹, Carla Morais^{1*}, Gildo Giroto Junior²

¹CIQUP, Faculty of Sciences, University of Porto, Portugal

²Chemistry Institute, State University of Campinas, Brasil

*cmorais@fc.up.pt

Integrating single-board computers, such as Arduino, can be an asset in implementing a Science, Technology, Engineering and Mathematics (STEM) approach within chemistry laboratories, enabling real-time data acquisition and analysis. Such technology-enhanced practices increase students' interest in STEM careers while fostering their digital literacy and strengthening essential STEM-related skills (Araújo & Morais, 2024). However, future chemistry teachers can face significant challenges in the integration of these technologies. This study investigates the difficulties faced by 10 Portuguese pre-service chemistry teachers during an introductory training session in which they worked in groups to assemble and code circuits with sensors (e.g. DS18B20 Temperature sensor) connected to Arduino. Using a qualitative methodology, data were collected through a set of open questions related to the difficulties faced during the process of electronic prototyping and analyzed through content analysis. The results indicate that the pre-service teachers encountered a set of difficulties during the prototyping activities. Challenges in assembling circuits and integrating sensors were common, often stemming from a lack of familiarity with electronic components, which led to confusion about wiring, polarity, and layout. Programming the Arduino board also proved difficult, particularly in grasping code syntax, uploading programs, and handling external libraries required for sensor operation. These hurdles were exacerbated by limited prior experience with coding. To overcome these obstacles, participants frequently turned to online tutorials, generative AI tools, and trainer support to complete their tasks. These findings suggest that with adequate training and support, future chemistry teachers can successfully implement STEM laboratory activities using this type of technology, contributing to the development of teaching strategies that effectively integrate electronics and coding into STEM education.

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Acknowledgments

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STEM-BASED LABORATORY ACTIVITY IN CHEMISTRY EDUCATION: INSIGHTS FROM PRE-SERVICE TEACHERS

Carla Morais^{1*}, Cidália André¹, Gildo Giroto Júnior², Joana Alves¹

¹CIQUP, Faculty of Sciences, University of Porto, Portugal

²Chemistry Institute, State University of Campinas, Brasil

*cmorais@fc.up.pt

Science, Technology, Engineering and Mathematics (STEM) education becomes increasingly central to science curricula, there is a growing need to understand how initial teacher training can better prepare future educators to meet its demands. This includes fostering the skills and confidence required to design and implement engaging, interdisciplinary learning experiences in the classroom (Morais et al., 2024). This study investigates how a STEM-based chemistry laboratory activity, integrating experimental work with Arduino prototyping, supports the professional knowledge development of 20 Portuguese pre-service chemistry teachers. Through a hands-on activity using investigative strategy, pre-service chemistry teachers engaged with chemistry concepts and technological tools, enhancing their understanding of STEM integration in the classroom. Pre- and post-activity tests, incorporating closed and open-ended questions, were used. Data analysis included quantitative assessment of closed questions and qualitative content analysis of reflective responses. The results suggest that the activity promotes a reflective process among trainee chemistry teachers, enabling them to integrate STEM components with a contextual socio-scientific approach. Although this approach significantly extends pedagogical effectiveness, there are still challenges in identifying engineering-related elements and the use of prototyping with Arduino. Findings indicate that the activity helps pre-service chemistry teachers bridge theoretical and practical aspects of teaching, promoting a deeper appreciation of inquiry-based and technology-enhanced learning. Additionally, it highlights the potential of laboratory-based STEM activities in teacher education to foster innovative teaching practices.

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TEACHING NUTRITION IN CHEMISTRY: A BLENDED LEARNING APPROACH FOR FUTURE TEACHERS

Laura Naumann*, Lilli-Marie Rink, Silvija Markic

Department of Chemistry and Pharmacy, Ludwig Maximilian University of Munich, Germany

*laura.naumann@cup.lmu.de

In 2020, the COVID-19 pandemic demonstrated how personal health is interconnected with public health and there are even more holistic approaches like the 'One Health' concept that additionally links personal health to planetary health (Missoni, 2024). Despite these broader perspectives, nutrition remains a key pillar of personal health (Rattan & Kaur, 2022). In line with this, for example, the Bavarian Curriculum emphasizes health education in its transdisciplinary educational goals, focusing on skills for a healthy and responsible lifestyle, which includes a sense of responsibility for one's health and the environment. In the chemistry curriculum, the aspect of nutrition in health education is further emphasized in the topic of food chemistry, e.g. focusing on the experimental analysis of food composition as well as the evaluation of dietary trends based on their nutrition and environmental impact (ISB, n.d.).

However, food chemistry is rarely in the focus of university teacher education. To address this, we developed a lesson sequence to enhance chemistry student teachers' pedagogical content knowledge on this topic using a flipped classroom approach. First, participants evaluate on different diets under the aspects of nutrition, health implications and factors influencing diet choices. Then, the gained knowledge is extended by content knowledge on macronutrients like carbohydrates and proteins. In the next phase, participants consolidate the theoretical knowledge in an experimental phase through qualitative and quantitative experiments. The experiments revolve around a comparison of cow and soy milk, as representatives of the vegetarian or vegan diet. In the last phase, participants develop a digital learning app designed to introduce aspects of health education from a chemistry perspective to their future school students. The creation of this teaching material encourages student teachers to translate the acquired knowledge into practical teaching ideas.

The poster will present the seminar unit and showcase created learning apps via QR codes, allowing participants to engage with the topic interactively.

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SCOPE STUDENT PARTNERSHIP WITH CHEMISTRY AND BIOCHEMISTRY FACULTY AT WORCESTER POLYTECHNIC INSTITUTE

Raul Orduna Picon^{1*}, Cody DiBonaventura^{2,3}, Jessica C. Hill⁴

¹Assistant Professor of Teaching, Chemistry and Biochemistry, WPI, USA

²Student, The Business School/Management Engineering, WPI, USA

³SCOPE Undergraduate Coordinator, Morgan Teaching and Learning Center, WPI, USA

⁴Director, Morgan Teaching and Learning Center, WPI, USA

*rpicon@wpi.edu

The students-as-partners model, in which faculty and students collaborate to enhance teaching and learning, posits that students are essential contributors and communicators as both "knowledge-holders and knowers" (Matthews, 2024). Typically, faculty, and educational developers engage with student partners to improve the student experience (Reid et al., 2024). At Worcester Polytechnic Institute (WPI), faculty need timely guidance to enhance their teaching due to the 7-week term system as current teaching evaluation methods (e.g., end-of-course surveys) are disconnected from real-time challenges that both faculty and students encounter in the classroom (Wieman, 2015). To address this need, WPI's Chemistry and Biochemistry Department (CBC) have engaged with the Student Consultants on Optimizing Excellence (SCOPE) program housed in the Morgan Teaching and Learning Center (MTLC). This student partners model was co-created by the MTLC Director and an undergraduate Management Engineering student (third and second author of this abstract respectively) to improve pedagogy at WPI in a more inclusive and student-centered way (Cook-Sather et al., 2018; Drake, 2024). This poster aims to shed light on the context in which student partners and faculty work together to increase teaching effectiveness and improve learning outcomes in chemistry college classrooms.

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WHAT ARE THE TYPICAL CHARACTERISTICS OF CHEMISTRY TEACHERS WHO USE DIGITAL ASSESSMENT TOOLS?

Patrik Pospíšil^{1,2*}, Veronika Švandová², Bohuslav Drahoš¹

¹Faculty of Science, Palacký University Olomouc, Czech Republic

²Faculty of Science, Masaryk University, Brno, Czech Republic

*pospisilpatrik@email.cz

The primary role of assessment in education is to provide feedback for both sides of the teaching-learning process. In order to achieve this, teachers need efficient tools for evaluating educational outcomes (Fuentealba, 2011; Stowe & Cooper, 2019). Especially for large groups of students, it is challenging to properly evaluate academic performance as an individualized approach would be time-consuming. The solution can be based on introducing digital assessment tools (DATs) such as *Socrative*, *Quizizz*, *Kahoot*, *Google Forms*, *Microsoft Forms*, *Plickers*, or *WordWall*. These online applications can process evaluation automatically, immediately, and simultaneously for all involved students (Andriani et al., 2023; Kocak, 2022).

Our study deals with the implementation of DATs in upper-secondary chemistry education. Specifically, the fundamental objective was to map the experience and user preferences of grammar school chemistry teachers in the Czech Republic regarding the use of DATs in their classes. It includes which particular DATs teachers use, for what purposes, and with what frequency.

The follow-up aim was to determine which personal characteristics of the teachers (such as gender, age, or education) influence their experience with DATs and which characteristics are not relevant. The relational analysis description is the main content of the presented poster.

The form of research was a questionnaire survey involving more than 250 teachers, i.e., approximately one-fifth of the overall number of grammar school chemistry teachers in Czechia. To summarize the results of relational analysis, several connections between monitored variables were found. As anticipated, the substantive personal characteristics of respondents were age, length of practice, and region of activity (for instance, the difference between the cities with universities and other localities). However, with regard to the frequency of using DATs, gender was also found to be a relevant personal characteristic, which could be surprising.

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TRANSFORMING CHEMISTRY LABORATORY WORK THROUGH AUGMENTED REALITY TECHNOLOGY

Luka Ribič^{1*}, Klen Čopič Pucihar², Matjaž Kljun², Miha Slapničar¹, Luka Vinko¹, Maheshya Weerasinghe², and Iztok Devetak¹

¹University of Ljubljana, Faculty of Education, Kardeljeva ploščad 16, 1000 Ljubljana, Slovenia

²University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies, Glagoljaška 8, 6000 Koper, Slovenia

*Luka.ribic@pef.uni-lj.si

Chemistry is a subject that students often find challenging due to the complex, multi-layered nature of chemical phenomena (Johnstone, 1991). Augmented reality (AR) is a novel technology that facilitates interactive learning by overlaying computer-generated elements on the real world (Mazzuco et al., 2022).

Pre-service primary school teachers in particular often struggle with misconceptions about the triple nature of chemical phenomena (Juriševič et al., 2008). The integration of AR technology has been shown to enhance students' situational interest in learning (Zhang et al., 2020), although its effectiveness may depend on factors such as technology acceptance (Tarng et al., 2022).

In this pilot study, quasi-experimental research design with descriptive methods was used. A total of 10 students participated, of which 5 students used AR glasses, and 5 students used tablets. Participants completed two paper-based questionnaires to assess their technology acceptance and situational interest.

The results show that students using AR glasses reported a slightly higher level of situational interest ($M = 42.2$; $SD = 4.9$) than students using tablets ($M = 41.6$; $SD = 5.0$). In terms of technology acceptance, students using tablets showed higher perceived usability ($M = 32.0$; $SD = 2.45$), higher perceived ease of use ($M = 55.60$; $SD = 5.3$), and higher attention to use ($M = 24.8$; $SD = 4.8$) than students using AR glasses.

These results indicate that although AR technology can increase students' situational interest, this effect may be influenced by the novelty of the technology. Additionally, students tend to prefer using tablets for interactions with animations on sub-microlevel, which is likely due to their greater familiarity with tablet-based interfaces.

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TRAINING TOMORROW'S LABORATORY PROFESSIONAL – COMBINING RESEARCH AND EDUCATION TOWARDS THE ENERGY-, AND MATERIAL TRANSITION

Jasmijn Ruijgrok^{1,2*}, Bart van den Bosch¹, Rogier Nijssen², Anass Znabet¹

¹*Chemistry Department, UAS Inholland, Amsterdam, the Netherlands*

²*Professorship of Smart Materials for the Energy Transition, UAS Inholland,
Alkmaar, the Netherlands*

*jasmijn.ruijgrok@inholland.nl

Addressing the global challenges of sustainability and the energy transition demands a new generation of chemistry professionals equipped with both theoretical insight and practical experience. At Inholland University of Applied Sciences, we integrate cutting-edge applied research directly into our chemistry curriculum to meet this need.

Students follow a dedicated specialization in *Energy and Next Generation Materials*, where they combine coursework in electrochemistry and material sciences with hands-on research projects. These projects are not simulations—they are real, ongoing investigations into sustainable solutions, such as chemical recycling of complex polymeric materials used for wind turbine blades and hydrogen storage systems or synthesis of polymeric building blocks from waste material. While learning techniques like cyclic voltammetry, electrochemical synthesis, and polymer analysis, students actively contribute to research on novel recycling methods, circular building blocks and green electro synthesis.

This seamless integration of research and education ensures that students develop a strong theoretical foundation while gaining the skills and mindset needed to tackle 21st-century sustainability challenges.

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LEARNING STRUCTURE OF MOLECULES THROUGH VIRTUAL REALITY - "IN SITU" EXPERIENCE

Petr Šmejkal^{1*}, Luděk Míka¹, Carlo Pirola², Alessandro Pedretti², Claude Jolival³

¹*Faculty of Science, Charles University, Czech Republic*

²*Department of Chemistry, University of Milan, Italy*

³*Faculty of Science and Engineering, Sorbonne University, France*

*psmejkal@natur.cuni.cz

Virtual reality (VR) is "A computer-generated environment that allows one to perceive this environment like real experience." Virtual reality's important and natural aspect is the user's (students') ability to interact with the computer-generated environment. Considering its characteristics, VR seems to be a promising way of teaching chemistry, especially in themes, where spatial imagination is required and/or it is difficult to get into the real environment, either because this environment is, i.e. dangerous, or because its objects are on a different scale than the ones we are used to (Pirola, 2020). A typical example of a topic in chemistry where it makes sense to use VR in its teaching is the topic of the structure of molecules and substances, in conjunction with their properties. Accordingly, in this study, we focused on the investigation of the advantages and limitations of VR in education, e.g., the appropriate time of use, possible problems with the software used, health problems, etc. For this study, we prepared several student-centered educational units in SW Nanome, which were implemented to teach students the above theme in selected secondary schools and universities.

Investigation of students' motivation showed that VR generally increases their motivation, and they perceive this learning as interesting, fun, and beneficial. Similarly, students' performance on tasks linked to the content of the learning units was very satisfactory. On the other hand, unfortunately, teaching in VR brings several technical and organizational difficulties that complicate its use. These include, e.g., the need for a high-capacity wireless connection, or the need to ensure the recharging of the headset and controllers in longer lessons. In addition, there may be various health issues, such as headaches, nausea, etc. Fortunately, appropriate technical interventions and/or instruction organization can significantly minimize these difficulties. With this in mind, and based on data and information obtained from students who participated in our survey, for example, the appropriate time for VR-based instruction was set at 45 min., a plan for instruction on how to work with VR was established, or the prepared instructional unit assignments were modified in light of students' feedback.

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INTEGRATING ARTIFICIAL INTELLIGENCE INTO CHEMISTRY TEACHERS' EDUCATION IN THE CZECH REPUBLIC: INSIGHTS AND PERSPECTIVES

Veronika Švandová*, Leoš Šáblík, Patrik Pospíšil, Kateřina Klebanová

Faculty of Science, Masaryk University, Brno, Czech Republic

*106381@mail.muni.cz

Generative AI is revolutionising many sectors, including education (Bendel, 2023). Future teachers should learn to use this technology as AI integrates into education (Inamdar, 2024; Iyamuremye et al., 2024).

This contribution describes the use of AI in training chemistry student teachers at Masaryk University in the Czech Republic during spring 2024 and 2025. The related research explored their experiences with AI before and after taking the course "Teaching Materials in Chemistry," focusing on areas of interest, skill development, and opinions on AI's role in the course and education overall. This contribution presents selected research methodology, findings and illustrates examples of how related AI applications were utilised by student teachers. It delves into which tools like text generators (ChatGPT, Copilot, Gemini), graphic applications (Midjourney, DALL-E, Canva), digital assessment platforms (Kahoot, Socrative, Quizizz), lesson preparation apps (Sci-oBot), and presentation apps (Gamma, Prezi AI) were integrated into their teaching practices, showcasing AI's transformative impact on modern education.

The target group consisted of chemistry student teachers enrolled in the course "Teaching Materials in Chemistry" during the spring semesters of 2024 (17 students) and 2025 (10 students). The research methodology was a questionnaire. Quantitative descriptive research was chosen to obtain preliminary insights into issues concerning AI in the training of chemistry student teachers. Additionally, qualitative research methods, such as focus group, were utilised in the 2025 course.

In 2025, most students used AI for lesson planning (compared to less than half in 2024) and designing chemical experiments. This confirms that AI helps students understand (beyond molecular structure, chemical data analysis, and chemical reactivity) right chemistry experiments (Iyamuremye et al., 2024). However, 2025 students lacked experience in creating presentations using AI tools, so applications like Gamma and Prezi AI were included in the course.

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BAKE YOUR OWN RUBY: WHEN CHEMISTRY MEETS THE MICROWAVE

Pavel Svozil*, Peter Antal

Department of Inorganic Chemistry, Palacký University Olomouc, Czech Republic

*pavel.svozil01@upol.cz

Microwave ovens, usually found in kitchens, can do more than heat your lunch. They can be powerful tools for chemistry experiments. What happens when you mix a few simple compounds, like as aluminum and chromium oxides with the pinch of borax, and then hit “start”? This project explores a high-temperature synthesis of synthetic ruby using common precursors and a standard kitchen microwave, modified for safe use in a laboratory setting. The goal was to prepare a compact ruby gemstone using nothing more than household equipment and creativity.

In this project we used the crucibles made from silicon carbide powder, commonly used as abrasive, and ceramic fiber insulating material (Fiberfrax®), used for wide range of thermal insulation application. Several challenges were encountered during the synthesis, including plasma formation, local overheating, and crucible deformation, which were mitigated by optimizing the susceptor geometry and reduction of heat loss (Leyral et al., 2013; Mishra & Sharma, 2016).

This experiment shows how everyday materials and tools can support hands-on, interdisciplinary chemistry education. It links inorganic synthesis, materials science, and pedagogy into one visually striking, curiosity-driven experience. (Kitchen et al., 2013; Hájek, 2003).

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SEEING THINGS INVISIBLE TO THE NAKED EYE – OR HOW TO INCREASE STUDENTS' INTEREST IN THE INFRARED SPECTROSCOPY METHOD, BUT ALSO IN THE STATISTICAL METHODS USED IN IT

Elżbieta Szostak*, Natalia Górską

Faculty of Chemistry, Jagiellonian University, Gronostajowa 2, 30-387 Kraków, Poland

*elzbieta.szostak@uj.edu.pl

Have you ever wondered what the images shown in Fig. 1 have in common? What wonderful technique is behind the unique vision capabilities that go beyond the capabilities of the human eye, and at the same time what exactly distinguishes individual images and how can we determine which one better suits our specific research needs?

Although the idea of using infrared imaging as a tool for visualization, research and discovery in

teaching has already been discussed by Xie et al. (2011) [1-2], the methodological background and statistical processing of spectra, which require more advanced knowledge, still pose a considerable cognitive challenge for students of chemistry.

The poster will present topics covered in the *Instrumental methods in environmental and pharmaceutical analysis* and *Molecular spectroscopy* classes conducted for students of second-cycle chemistry at the Faculty of Chemistry of the Jagiellonian University. The authors of the classes were guided by the idea that students should actively participate in the process of learning the content presented to them. For this purpose, a number of teaching methods were used, including the problem-based method, student discussions, group work and learning by experience. This approach was to be a response to the didactic challenges in the field of IR spectroscopy mentioned in their work by Jablonka, Patiny and Smit (2022) [3], namely that for many students the need to use (new) abstract concepts at the same time can lead to cognitive overload [3]. An equally important aspect was also to stimulate students' inquiry skills and their critical thinking skills based on the identification of possible problems and limitations of the content taught.

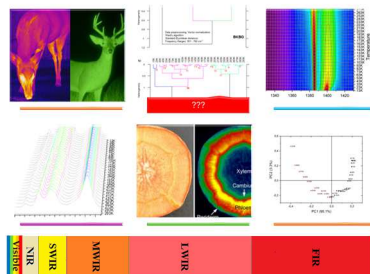


Fig. 1. Science hidden behind the image

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NOTES

CHEMISTRY LABS WITH RELEVANCE: CONTEXTUALIZED EXPERIMENTAL INSTRUCTIONS FOR MEANINGFUL LEARNING

Maximilian Traub^{1*}, Stefanie Lenzer^{1,2}

¹*Institute of Inorganic Chemistry, Kiel University, Germany*

²*Department of Chemistry Education, Leibniz Institute for Science
and Mathematics Education, Germany*

*mtraub@ac.uni-kiel.de

For undergraduate lab courses it is quite common to jointly instruct students with different study profiles and career aspirations, e. g. chemistry teachers and chemists. This is particularly challenging because students come to these labs not only with different educational backgrounds but also with different interests. From recent research we know, that especially motivational-affective characteristics such as interest and perceived relevance can strongly influence students' learning outcomes (Agustian et al., 2022; Andersen, 2020; Kauper et al., 2023). To make laboratory learning more meaningful and to foster students' interest and perceived relevance, context-based learning offers great potential by connecting chemical knowledge and concepts to real-world scientific issues (Parchmann et al., 2015). However, this potential has rarely been exploited for chemistry labs so far. In this contribution, we present the iterative design and development process (Anderson & Shattuck, 2012) of contextualized experimental instructions for a first-semester inorganic chemistry lab course which are intended to improve the perception of relevance for students with diverse interests and career aspirations. The instructions contain content such as battery recycling and professional references for chemistry teachers and chemists. We share insights into the key features of the instructions and first results from the piloting that incorporated both students and educators perspectives. These mixed methods results provide implications for the potential of contextualized experimental instructions to make university chemistry labs more relevant for students with diverse backgrounds.

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POPULARIZATION OF CHEMICAL SCIENCES - NEW PROJECT OF THE PRO CHEMIA FOUNDATION

Renata Wietecha-Posłuszny*, Dorota Majda, Joanna Lewandowska-Łańcucka,
Katarzyna Kurpiewska, Paweł Broś

*Faculty, University, Country (Italic, 9 point, Calibri) Faculty of Chemistry, Jagiellonian University
in Kraków, Gronostajowa St. 2, 30-387 Kraków, Poland*

*Pro Chemia Foundation, Faculty of Chemistry, Jagiellonian University in Kraków,
Gronostajowa St. 2, 30-387 Kraków, Poland*

*renata.wietecha-posluszny@uj.edu.pl

The Pro Chemia Foundation was established to support the Jagiellonian University Chemistry Department in carrying out its statutory activities, including academic teaching and popularization of science. In recent years, the Foundation has been implementing the project "Feel chemistry for the chemistry", aimed mainly at secondary school students preparing for university education.

The project offers young people a variety of educational forms, based on a modern pedagogical model in which learning is based on one's own experience and the knowledge gained can be immediately use to solve new scientific problem.

1. Open chemistry laboratory - laboratory activity for secondary school students. During the 18 hours of classes, each participant has the opportunity to work independently in the laboratory and solve a chemical problem through experiments. The program is tailored to the abilities of the participants, and usually includes qualitative analysis of cations of groups I-V or solving tasks from the Chemistry Olympiads for more advanced participants.

2. The passions of the modern chemist - a study activity or working with a scientist. The two-hour activity takes place in small groups of up to six people. Participants take part in research using Atomic Force Microscopy (AFM) and Optical and Fluorescence Microscopy.

3. See to understand - this part of the project consists of five different demonstrations of chemical experiments. The show lasts approximately 90 minutes and involves interaction with participants:

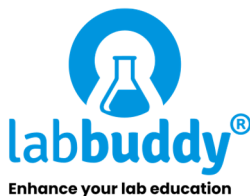
- "Cryogenic demonstrations" - the demonstrations consist of a short lecture on the history of gas liquefaction and the applications of cryogenics, and a series of experiments showing the unusual properties of substances at low temperatures.
- "Chemistry and Light" - the show presents interesting experiments in various experiments related to light, preceded by a lecture discussing the processes observed.
- "Chemist at the crime scene" - the performance that shows how can chemical expertise help to apprehend a criminal.
- "Chemical Escape Room" - the show using gamification elements. Together we move into an auditorium full of mysteries and clues. In order to leave the room, we have to solve puzzles and find ciphers to the hiding places, which will be achieved

- More information can be found on the website: prochemia.org.

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INFORMATION ABOUT SPONSORS



LabBuddy provides an e-learning solution to supplement traditional laboratory education by creating a form of blended learning. LabBuddy helps students prepare before the start of the laboratory work, supports them while working in the laboratory, and guides them during the processing of their results after the practical work.

In this example, students design their workflow (left) and prepare their protocols by answering questions (right), both guided by feedback.

The screenshot displays the LabBuddy interface. On the left, a workflow diagram shows the process: starting with '2,4,6-tribromophenol', 'Oxalyl chloride', and 'Triethylamine' (all marked 'Out'), leading to 'Perform synthesis reaction' (marked 'In'). From there, the process splits into 'Thin layer chromatography' (marked 'Out') and 'Vacuum filtration (glass filter)' (marked 'In'). The 'Vacuum filtration' step leads to 'Residue' and 'Filtrate'. The 'Filtrate' then goes to 'Acid/base extraction' (marked 'In'), which further splits into 'Aqueous' and 'Organic' phases.

On the right, the 'Perform synthesis reaction' protocol form is shown. It includes a 'Protocol' section with two steps:

- 1 Prepare the ice bath and cooler.
Answer question
- 2 Dissolve the appropriate amount of your phenol of choice in an appropriate organic solvent.
Add note

Step 2 includes a dropdown menu for 'Which phenol did you choose?' with '2,4,6-tribromophenol' selected. Below this, it asks: 'Review the reaction in the introduction. 10 mmol oxalic acid is used for the reaction, how much of your phenol should be added? For 5 mmol of this phenol, weigh 4 g.'

A pink box contains a warning: 'Review the reaction equation, in what ratio do the compounds react to each other? So how many mmol of your phenol should you add?'

At the bottom, there are 'Submit answer' and 'Reset' buttons.

You're invited to participate in our workshop about innovating laboratory education with blended learning. You can also find our poster and stop by our stand to talk about lab education!

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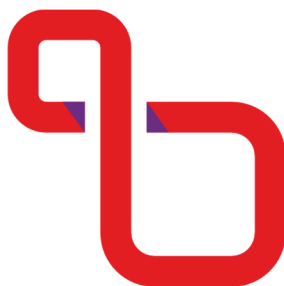
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