ECRICE 2024

16 European Conference on Research in Chemical Education

NOVA SCHOOL OF SCIENCE AND TECHNOLOGY · CAMPUS DA CAPARICA, LISBON

September 05 - 07, 2024

Book of Abstracts

EuChemS
European Chemical Society

SOCIEDADE PORTUGUESA DE QUÍMICA

NOVA
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Book of Abstracts of ECRICE 2024, the 16 European Conference on Research in Chemical Education

Editors: A. Jorge Parola, Isabel Ribau

Caparica, Portugal, 2024

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FOREWORD

Dear Colleagues,

We are happy to welcome you to the ECRICE 2024, the 16 European Conference on Research in Chemical Education, to be held at NOVA School of Science and Technology, Campus da Caparica, Lisbon, September 5-7, 2024.

This conference on research in chemical education, recognised by EuChemS, is an important event to disseminate new research and developments. It is important to know how learners acquire knowledge, how to facilitate this acquisition and trigger it. It is relevant to examine different learning environments, new educational tools, and new ways in which neuroeducation, technology and artificial intelligence, can be integrated into chemical education, and promote the engagement of students in the learning process. But nowadays this is not enough. It is necessary to do this through the lens of sustainability, having in mind the 17 SDGs. Therefore, ECRICE 24's theme is "Chemical Education for Sustainable Development: Empowering Education Communities"

The ECRICE24 Committees of this International conference invite all chemistry education researchers and teachers to come to the conference and challenge them to showcase presentations, submit abstracts, and present work, regarding new developments in Chemical Education, through the lens of sustainable goals, and participate in the ECRICE 2024 meeting.

We are looking forward to welcoming you in Lisbon.

Enjoy the conference!

Sincerely,

On behalf of the Scientific and Organizing Committee,

Isabel Ribau, ECRICE24 conference chair
A. Jorge Parola, Secretary General of the Portuguese Chemical Society
Joaquim Luís Faria, President of the Portuguese Chemical Society

Caparica, September 2024

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DETAILED PROGRAMME

5 September

9.00-19.00	Welcome Desk: Information and Registration
9.00-9.20 **Room 204**	Opening session
9.20-10.00 **Room 204**	**Keynote 1** Moderator: João Paulo Leal **Silvija Markic** Ludwigsburg University of Education ***Diversity and Inclusion in Chemistry Education***
10.00-10.20	**Coffee break / poster session**
10.20-12.00	**Workshops** **W1 -**How to Publish in Chemistry Teacher International (Room 203) **W2 -** AI. How can we use it to teach and learn? (Room 107) **W3** - 3D Printing and LASER cutting models to lear Chemistry at Secondary School. Periodic table and electrons, and shape of molecules and ions pollutants of air and water. (Room 115)
12.00-12.40 **Room 204**	**Keynote 2** Moderator: Adelino Galvão **Dragica Trivic** University of Belgrade ***Chemistry and Cultural Heritage Integration in a Sustainable World***
12.40-14.00	**Lunch**
14.00-16.00 4 Parallel sessions | 2 Workshop	**Parallel Sessions** **Room 110** **Moderator: Ron Blonder** OP1- The influence of authentic advanced lab experiences on students' NOS understanding - Iris Shinar OP5- Laboratory Work for 1st year undergraduates – are we making the most of the opportunities? - Odilla Finlayson

OP9- Immersive Technology for Teaching Undergraduate Analytical Chemistry in the Laboratory - Denise Rooney

OP13- Virtual Laboratories: A Blended and Sustainable Pedagogic Approach to Teaching and Learning of Practical Chemistry - Frances Heaney

OP17- The Arsenator – Using Coca-Cola to Analyse Arsenic in Rice - Johannes Passler

OP21- Environmental Education Challenges: Understanding Bio-Geo-Chemical Cycles Among Slovenian Pre-Service Teachers - Luka Ribič

Room 107

Moderator: Isabel Ribau

OP2- Fostering Critical Thinking in Science Education: Definitions, Assessments, and Implications for Sustainable Decision-Making - Luc B. Albrecht

OP6- Measuring Success in Chemistry Practical Work: A Comprehensive Review - Dominika Koperová

OP10- Promoting Sustainability in Chemistry through Systems Thinking for Student Teachers - Krenare Ibraj

OP14- STEM-Lab electrochemistry activity through a contextualized approach - Cidália André

OP18 Important Moments among Chemistry Teachers in a Collaborative and Dynamic Learning Environment - Shirly Avargil

OP22- A Case Study on Integrating Sustainability and Project-Based Learning in Chemistry Teacher Education - Outi Haatainen

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Room 115

Moderator: Teresa Santos Silva

OP3- A pedagogical strategy centred on water analysis in the community for a sustainable world: incorporating different elements of teamwork. - Carmel B. Breslin

OP7- Upper secondary students and teachers' experience with a teaching unit on organic synthesis with emphasis on green chemistry - Svein Tveit

OP11- Material Stewardship: Framing Education about Chemistry's Mission in Sustainability - Stephen Matlin

OP15- From Knowledge to Hope: Assessing High School Students' Knowledge of Climate Change, Mitigation, and Adaptation in the Context of Constructive Hope - Najl Kortam

OP19- Integrating Systems Thinking Approaches in Chemical Education for Sustainable Development: Exploring the Status Quo - Elisabeth Hofer

OP23- Embedding Systems Thinking into Sustainable Chemistry Course for Pre-Service Teachers. - Emmi Vuorio

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Room 203

Moderator: Adelino Galvão

OP4: To stay or not to stay in reality: Insights from Cognitive Load Measurements via Electroencephalography and Heart Rate Variability - Mária Babinčáková

OP8- Exploring the Role of Non-textual Components in Chemistry Learning - Lucie Hamerská

OP12- Exploring Sustainable Chemistry Discourse in Serbian Chemistry Textbooks - Dušica D. Rodić

OP16- The Evaluation of History of Chemistry Chapter in textbooks in Turkey - Ilknur şahin

OP20- The Adoption of Green Chemistry in Brazilian Higher Education - Gildo Girotto Junior

OP24- Teachers' role in developing students' agency for SDGs - Ayshi Sindiani- Bsoul

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Workshops

W4 - Computer Lab Assignments with tools for Visualizing Chemical Phenomena (Room 204)

W5 - Sustainable Chemistry in the School Laboratory (Lab 417 – Chemistry Department)

16.00-17.40 **Parallel Sessions**

Room 110

4 Parallel sessions | 2 Workshop

Moderator: Teresa Santos Silva

OP25-Impact of Team-Based Learning on Student Engagement and Learning Outcomes in Physical Chemistry - Heili Kasuk

OP29- Promoting classroom emotional climate for meaningful science learning: Findings from an ADDIE approach - Tapashi Binte Mahmud Chowdhury

OP33- Science Lessons from the eternal Ice: Glaciers as a Gateway to an education for sustainable development - Philipp Spitzer

OP37- Engaging students in the exploration of Antibiotic Coordination Frameworks (ACFs) using sustainable methods - Patricia Rijo

OP41- A Role-Playing Tabletop Game on Laboratory Techniques and Chemical Reactivity: Gamifying Organic Chemistry Education - João Avó

Room 107

Moderator : Isabel Ribau

OP26- The Norms of Chemistry and How Students Figure Them - Jonas Niemann

OP30- Computational Methods of Varying Complexity in High School Chemistry - Fredrik L. Holmelin

OP34- Pedagogical Content Knowledge and the implementation of a Multistrategic Didactic Unit on the theme of Green and Sustainable Chemistry: first approximations - Gildo Girotto Junior

OP38- Nanotechnology Education as a Gateway for Promoting Sustainability - Riam Abu Much

OP42- Unlocking Knowledge: Can Nanochemistry Escape Rooms Promote Learning? - Shelley Rap

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Room 202

Moderator : Madeleine Schultz

OP27 First Hungarian Results of the IUPAC Teacher Survey on Green and Sustainable Chemistry Practical Activities. - Murányi Zoltán

OP31 Green and sustainable practical activities in Serbian secondary schools: The analysis of open-ended IUPAC teacher survey questions - Tamara Rončević

	OP35- To do or not to do practical activities: Turkish chemistry teachers' experiences and views on practical activities and green chemistry reported on IUPAC global survey - Sevil AKAYGUN OP39- Practical (green) chemistry in Czech schools: A myth or reality? - Martin Rusek" OP43-Environmental literacy of Slovenian chemistry teachers in the context of hydrosphere pollution. - Luka Vinko
	Room 203 **Moderator : Adelino Galvão** OP28- Enhancing Diversity and Inclusion in Science Teacher Education: Insights from a Diagnostic Study. - Laura Naumann OP32- Universal Design for Learning - Building a University Culture of Inclusion - Denise Rooney OP36- Sima Lozanić's secondary school chemistry textbooks as artifacts: changes in the Periodic table in late 19th and early 20th century editions - Vesna D. Milanovic Mastrapovi OP40- Drawing Cartoon Strips as a Visualization Tool in Pre-service Chemistry Education - Jouni Välisaari OP44- The Effect of In-Service Education on Chemistry Teachers' Understanding of Nature of Science - Suat CELIK
	Workshops
	W6 - Computational Thinking and Modelling in Science Education (Room 204) **W7** - Química para os mais novos: THE CHALLENGE (Lab 417 – Chemistry Department)
17.40-18.00	**Coffee break/poster session**
18.00-19.40	**Symposium 1**
Room 204	**Empowering Agency: Research, Development, and Implementation in Chemistry and SDGs Education** Organizer: Ron Blonder Chair: Rachel Mamlok-Naaman Speakers: Debora Marchak, Inna Shvarts-Serebro, Shelley Rap, R.Mamlok-Naaman Discussant: Ron Blonder
19.40-20.10	**Welcome Reception**

6 September

9.00-19.00	Welcome Desk: Information and Registration
09.30-10.10	**Keynote 3**
Room 204	Moderator: Isabel Ribau
	Agustian Hendra
	University of Copenhagen
	Explore work in the chemical laboratory
10.10-10.30	**Coffee break/poster session**
10.30-12.10	**Symposium 2**
Room 204	**International teacher survey on green and Sustainable Chemistry Practical Activities**
	Organizer: Madeleine Schultz and Seamus Delaney
	Chair:Madeleine Schultz
	Speakers: Seamus Delaney, Madeleine Schultz, Iztok Devetak:, Dusica Rodic, Marina Stojanovska
	Discussant: Madeleine Shultz
	Workshops
	W8 - The cold Pack: Laboratory work with elements of formative assessment for lower secondary school (Room 110)
12.10-13.30	**Lunch**
13.30-14.10	**Keynote 4**
Room 204	Moderator: Teresa Santos Silva
	Ana Isabel Aguiar-Ricardo
	NOVA Lisbon University
	Catalyzing Change: Teaching Chemistry for Sustainable Development
14.10-15.50	**Symposium 3**
	Chemistry Education in the digital age-(missing) expectations, opportunities and challenges
	Organizer: Carolin Flerlage
	Chair: Shelley Rap

Speakers: Itsik Aroch, Ron Blonder, Karolina Broman, Carolin Flerlage, Stefanie Lenzer, Ilka Parchmann

Discussant: Ilka Parchmann

Room 202

Symposium 4

Portuguese online platforms that facilitate the teaching and learning of Sustainable Chemistry

Organizer and Chair: Carla Morais

Speakers: Andreia S. Sósinho, Paula Cotter Cabral, Cláudia Capela, Inês Santos and João Tavares

Discussant: Carla Morais

Room 204

Workshops

W9 - An Arts-Integrating Approach to Bring neuroeducation to The Chemsitry Classroom (Lab 417 – Chemistry Department)

W10 - Technology Enhanced Problem-based Learning in the Chemistry Classroom (sala 110)

15.50-16.10 **Coffee break/poster session**

16.10-17.50

4 Parallel sessions | 2 Workshop

Parallel Sessions

Room 115

Moderator : Isabel Ribau

OP45- Challenges in drawing students to pursue Chemistry in Higher Education. - Isabel Ribau

OP49- Students' and scientists' conceptions of the supply risk dimension of critical raw materials - Yannick L. Legscha

OP53- Developing an operational model to address attractiveness of Science Career Awareness. - Jack Holbrook

OP57- Fast and Furious? Students' Quality Demands for Successful Science Communication on Social Media - Alina Majcen

OP61 -Empowering Green Changemakers: The All Aboard Project's Journey Towards Sustainable Education - Ângela Gordino

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Room 110

Moderator : João Mouro

OP46- Classroom implementation of an AI voice assistant for chemistry lab learning in secondary school. - Marvin Rost

OP50-Digital and complexity-differentiated learning modules – a step towards adaptive learning? - Nicolai ter Horst

OP54- Integrating AI into Chemistry Education: Experiences and Concerns of Chemistry Preservice Teachers Using AI Tools During Their Teaching Practicum - Elif Özdengelen

OP58- Generative Artificial Intelligence (GenAI) as the Artist of Chemistry Visuals: Chemistry Preservice Teachers' Reflections on Visuals Created by GenAI - Sevil AKAYGUN

OP62- Interactive online learning environment for self-regulated learning in chemistry - Florian Trauten

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Room 107

Moderator: Rachel Mamlok Naaman

OP47- A Web-Based Tool to Promote Self-Regulated Problem-Solving in Chemistry Lessons - Leonie Jasper

OP51- Delicious: Promoting students assessment competencies through an inquiry-based learning student laboratory on food chemistry - Jannis Memmen

OP55- Exploring the impact of an intervention on plastics and bioplastics on Israeli pre-service science teachers' green chemistry and sustainability awareness and their attitudes towards environmental education - Ahmad Basheer

OP59- New results in improving experimental design skills - Luca Szalay

OP63- Enhancing Diversity and Inclusion in Science Teacher Education: Insights from a Diagnostic Study. - Laura Naumann

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Room 201

Moderator : Teresa Santos Silva

OP48- Investigating students' conceptions on molecular orbital theory via concept map analysis - David Johannes Hauck

OP52- Advancing Laboratory Education in Chemistry via Mapping Students' Expectations and Actual Experience - Tadeas Matecha

	OP56- Difficulties of first-semester students in redox- and electrochemistry - Jasmin Kneuper OP60- Analyzing Students' Conceptual Progression of Chemical Reactions: A Cross-age Study - Emine Adadan
	Workshops
	W11 - "Chemistry, climate & and the numbers in between": Skills-centred Climate Chemistry Education (Room 204) **W5** - Sustainable Chemistry in the School Laboratory (Lab 417 – Chemistry Department)
Sightseeing (Walking on the beach and surfing)	
20.30-22.30	**Conference Dinner**

7 September

9.00-13.30	Welcome Desk: Information and Registration
09.00-10.40	**Symposium 5**
Room 204	**Promoting relevant Education in Science for Sustainability** Chair and Organizers: Ingo Eilks Speakers: M. Aksela, Vania Zuin Zeidler, G. Guerrero, Nadja Belova Discussant: Ron Blonder
10.40-11.00	**Coffee break/poster session**
11.00-12.40	**Symposium 6**
Room 204	**Professional development of chemistry teachers for sustainability** Organizer and Chair: Avi Hofstein Speakers: Ingo Eilks, Muhamad Hugerat, Miia Rannikmae, Avi Hofstein Discussant: Rachel Mamlok Naaman
12.40-13.20	**Plenary Lecture**
Room 204	Moderator: Ana Isabel Aguiar-Ricardo **Martyn Poliakoff** University of Nottingham *Teaching for a Sustainable Future*
13.20-13.30	**Closing session**

ECRICE 2024

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September 05 - 07, 2024

Symposia

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Sociedade Portuguesa de Química

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Symposium 1: Empowering Agency: Research, Development, and Implementation in Chemistry and SDGs Education

Organizer: Ron Blonder

Chair: Rachel Mamlok-Naaman

Speakers: Debora Marchak, Inna Shvarts-Serebro, Shelley Rap and Rachel Mamlok-Naaman

Discussant: Ron Blonder

Symposium
1. Chemical Education for Promoting Sustainability and Climate Awareness
3. Research in Students Learning in a Sustainable World
4. Innovative Teaching and Pedagogies for a Sustainable World
6. Engaging Students in a Sustainable World with Chemistry
7. Neuroeducation - Strategies and Projects to Support Chemistry Education in a Sustainable World

S1.1 – Empowering Agency: Research, Development, and Implementation in Chemistry and SDGs Education.

Ron Blonder [a)], Rachel Mamlok-Naaman [a)], Debora Marchak [a)], Shelley Rap [a)] and Inna Shvarts-Serebro [b)]
a) Department of Science Teaching, Weizmann Institute of Science, Israel
b) Faculty of Education, Bar-Ilan University, Israel

Introduction and Final Discussion:

Ron Blonder

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

* Corresponding author: ron.blonder@weizmann.ac.il

The symposium explores new methods and interdisciplinary strategies to empower students and educators in chemistry education. As we face global challenges, the role of education, especially in science, is crucial. This symposium highlights the intersections between chemistry education and the Sustainable Development Goals (SDGs). It focuses on fostering student agency, promoting collaborative learning, supporting novice teachers, and integrating sustainability into curricula. Our goal is to create educational experiences that are intellectually enriching and socially relevant. By using innovative teaching practices and real-world applications, we aim to educate students to become scientifically literate, socially responsible individuals; skilled individuals who are able to make informed decisions and contribute positively to societal challenges. The symposium includes examples of activities aimed at promoting education for sustainable development on the framework of a European project: *Scientific Career Awareness (SciCar)*.

S1.2 – Developing Students' Agency to Address SDG3: The Case Study of COVID-19 Pandemic

Shelley Rap * [a], *Debora Marchak* [a], *Moran Bodas* [b] *and Ron Blonder* [a]
a) Weizmann Institute of Science, Israel
b) Tel Aviv University, Israel
* Corresponding author: shelley.rap@weizmann.ac.il

The COVID-19 pandemic posed significant challenges in ensuring public compliance with health regulations, particularly regarding mask-wearing. Despite expert recommendations emphasizing its effectiveness in curbing transmission, convincing individuals to adopt this preventive measure proved difficult. Behavioral science studies have underscored the gap between knowledge and behavior, highlighting the need for innovative approaches to bridge this divide (Paton, 2019). This study investigates the efficacy of integrating public health knowledge with scientific education to influence adolescents' behavior regarding mask-wearing during the pandemic.

A multidisciplinary teaching unit was designed to actively engage chemistry students in learning nano-chemistry concepts and their application to public health issues, specifically focusing on the structure and effectiveness of masks. Drawing from neuro-pedagogical principles and active learning strategies, the unit aimed to enhance students' understanding and retention of relevant content. Emphasis was placed on creating a learning environment conducive to social interaction (Markant et al., 2016), personal meaning attribution, and excitement to facilitate long-term memory formation (Eison, 2010).

The research population comprised 120 high-school students majoring in chemistry in 10th-12th grades. Structured interviews were conducted with six students, 8-12 months post-unit completion (Shkedi, 2011), to assess the impact of the intervention on their knowledge, emotions, and behavior related to COVID-19 issues, particularly mask-wearing.

The study revealed a notable impact of the integrated teaching unit on students. Emotionally, students found the learning experience enjoyable and interactive, diverging from traditional methods. They expressed increased interest, noting the relevance of chemistry to real-world challenges like COVID-19. This emotional engagement intertwined with cognitive effects, as students reported better understanding and retention of the material. They integrated nano-chemistry concepts into discussions on mask structures and virus interactions, demonstrating a deeper grasp of the subject matter. Visual literacy played a crucial role, aiding students in comprehending complex ideas and retaining information. Most students accurately recalled visual representations and associated them with conceptual and mechanistic levels. This retention persisted months after the unit, indicating a lasting impact. In terms of

behavioral changes, students shifted from viewing mask-wearing as mere compliance to understanding its role in preventing infection. They became proactive in sharing knowledge and advocating for informed decision-making, illustrating a newfound commitment to public health.

This study highlights that integrating science with real-world issues empowers informed decision-making and action. Combining active learning and visual literacy (Vekiri, 2002) was found to equip students to address global challenges effectively, fostering agency in shaping a better future. This approach cultivates scientifically literate citizens capable of making meaningful contributions to health, social, and environmental issues.

References:

Eison, J. (2010). Using active learning instructional strategies to create excitement and enhance learning. Jurnal Pendidikantentang Strategi Pembelajaran Aktif (Active Learning) Books, 2(1), 1-10.

Markant, D. B., Ruggeri, A., Gureckis, T. M., & Xu, F. (2016). Enhanced memory as a common effect of active learning. Mind, Brain, and Education, 10(3), 142-152. doi:10.1111/mbe.12117

Paton, D., (2019). Disaster risk reduction: Psychological perspectives on preparedness. Australian Journal of Psychology, 71(4), 327-341. doi: 10.1111/ajpy.12237

Shkedi, A. (2011). The meaning behind the words: Methodologies of qualitative research: Theory and practice. Tel Aviv: Ramot (In Hebrew).

Vekiri, I. (2002). What is the value of graphical displays in learning? Educational psychology review, 14(3), 261-312.

S1.3 – Offering Chemistry Students Creative Contexts to Exercise Co-Agency in the Classroom

*Debora Marchak * [a], Miri Kesner [a], Inna Shvarts-Serebro [b] and Ron Blonder [a]*
a) Weizmann Institute of Science, Israel
b) Faculty of Education, Bar-Ilan University, Israel
* Corresponding author: marchak@weizmann.ac.il

In the OECD Learning Compass 2030 context, “agency” is defined as the capacity to set a goal, reflect, and act responsibly to effect change. It relates to all fields of life, including learning. In the educational context, "co-agency" refers to the capacity to co-create knowledge and gain skills through collaborative and interactive relationships with peers, teachers, parents, and the wider community to progress towards shared educational goals. Co-agency is thus based on foundational skills such as the capacity to act, set personal goals that align with collective goals, and reflect and support a decision at cognitive, social, and emotional levels.

Educational contexts that encourage student agency and co-agency should offer suitable instruction and evaluation strategies. These strategies should allow students to undergo a learning experience through which foundational skills can be acquired in parallel to knowledge and where peer students and teachers can be engaged in a collaborative process. Offering chemistry students creative contexts to engage in guided collaborative active learning that also provide high degrees of choice might be a suitable strategy to promote co-agency in the chemistry classroom.

This presentation introduces two such creative learning contexts: 1) an arts-integrated approach to teaching and learning chemistry (Marchak et al., 2021), and 2) a national projects competition (Shwartz et al., 2020). These contexts are examined under the lens of the OECD 2030 framework and mapped out to identify how their implementation can help promote the core skills needed to exercise co-agency. In addition, insights from years of implementing these contexts will be presented underlying the importance of professional development and continuous teacher support to aid teachers in being effective co-agents (Marchak et al., 2023).

References:

Marchak, D., Shvarts-Serebro, I., & Blonder, R. (2021). Teaching chemistry by a creative approach: adapting a teachers’ course for active remote learning. Journal of chemical education, 98(9), 2809-2819.

Shwartz, Y., Eidin, E., Marchak, D., Kesner, M., Green, N.A., Marom, E., Cahen, D., Hofstein, A. and Dori, Y.J. (2020). A holistic approach to incorporating sustainability into chemistry education in Israel. In Chemistry Education for a Sustainable Society Volume

1: High School, Outreach, & Global Perspectives; (Eds. Obare, Sh.O., Middlecamp, C. H., Peterman, E.), American Chemical Society (pp. 125-160).

Marchak, D., Kesner, M., and Frailich, M. (2023) Integrating web-based learning to make industrial and everyday life chemistry accessible to high-school chemistry students. In Digital Learning and Teaching in Chemistry; (Eds. Y. Dori, C. Ngai, and G. Szteinberg), The Royal Society of Chemistry (ch. 11, pp. 127-140).

S1.4 – Developing Students' Agency to Address SDG3: The Case Study of COVID-19 Pandemic

Inna Shvarts-Serebro * [a)]
a) Faculty of Education, Bar-Ilan University, Israel
* *Corresponding author: shvartsi@gmail.com*

Neuropedagogy is a novel field that integrates accumulated knowledge from neuroscientific, psychological, and educational research, with the purpose of deepening and refining the theoretical and applied understanding of teaching-learning processes, aiming to help every child realize their full potential (Devonshire & Domett, 2010; Nouri, 2016; Rodgers, 2015; Carew & Magsamen, 2010).

Neuropedagogical competence among teachers equips them with applicable, evidence-informed tools from brain research to develop student agency (OECD, 2018) in a way that accommodates students' diversity in the classroom and enables the design of solutions for challenges arising throughout the educational journey.

The first five years for novice teachers in the educational system worldwide are very challenging, with a high percentage of teachers exiting the profession within this period (Fantilli & McDougall, 2009; Donna & Roehrig, 2024). Among the major challenges faced by novice teachers is the difficulty in coping pedagogically with the heterogeneous cognitive, emotional, and behavioural needs of students in the classroom (Donna & Roehrig, 2024).

In the lecture, I will highlight the importance of incorporating neuropedagogy into teacher training process and its contribution to the development of teachers' ability to navigate the complexities of entering teaching in the initial years.

References:

Carew, T. J., & Magsamen, S. H. (2010). Neuroscience and education: An ideal partnership for producing evidence-based solutions to guide 21st century learning. Neuron, 67(5), 685-688.

Devonshire, I. M., & Dommett, E. J. (2010). Neuroscience: Viable application in education? Neuroscience and Society, 16, 349-356.

Donna, J. D., & Roehrig, G. H. (2024). Moving from surviving to thriving: a taxonomy of beginning science teacher challenges. Disciplinary and Interdisciplinary Science Education Research, 6(1), 9.

Fantilli, R. D., & McDougall, D. E. (2009). A study of novice teachers: Challenges and supports in the first years. Teaching and teacher education, 25(6), 814-825.

Organisation for Economic Co-operation and Development (OECD). (2018). The future of education and skills: Education 2030. OECD education working papers.

S1.5 – Education for Sustainable Development in the framework of SciCar: Guiding Science Educators towards Becoming Agents of Change

Rachel Mamlok-Naaman * [a]

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Incorporating sustainable development issues is recommended as a contextual approach to make chemistry education more relevant. Over the past 30 years, chemistry educators in Israel have developed and researched learning materials that integrate socio-scientific issues from the chemical industry and green chemistry into high school chemistry curricula. The goal was to educate students on sustainable development and environmental awareness through an inquiry-based science learning approach, involving skills such as questioning, hypothesizing, drawing conclusions, and argumentation (Cai & Mamlok-Naaman, 2020). These learning materials, designed for both students and science educators, interweave chemistry concepts with environmental, health, economic, and societal dimensions. They include textbooks and learning module booklets. However, science educators and science teachers are the key to the implementation of new ideas, reforms and innovations – agents of change. They should receive sustained support in order to gain knowledge of different, which incorporated sustainable development issues (Mamlok-Naaman & Mandler, 2020) showed that teaching strategies and of assessment skills. This can be done by attending workshops that deal with those topics, which will consequently stimulate their creativity and diversify their instructional strategies in the classroom. A study that was conducted in Israel regarding the implementation of a curriculum showed that these learning materials effectively motivate and promote chemistry learning while concurrently fostering sustainable educational skills. The current presentation includes examples of activities aimed at promoting education for sustainable development on the framework of a European project: Scientific Career Awareness (SciCar).

References:

Cai, J., & Mamlok-Naaman, R. (Eds.). (2020). Posing Researchable Questions in Mathematics and Science Education (Special issue). International Journal of Science and Mathematics Education, 18(1).

Mamlok-Naaman, R., & Mandler, D. (2020). Education for sustainable development in high school through inquiry-type socio-scientific issues. In: S. Obare, C. Middlecamp and J Peterman (Eds). Chemistry Education for a Sustainable Society, (Vol 1, pp. 69-78). ACS publication.

Symposium 2: International teacher survey on green and Sustainable Chemistry Practical Activities

Organizer: Madeleine Schultz and Seamus Delaney

Chair: Madeleine Schultz

Speakers: Seamus Delaney, Madeleine Schultz, Iztok Devetak:, Dusica Rodic, Marina Stojanovska

Discussant: Madeleine Shultz

S2.1 – International Teacher Survey on Green and Sustainable Chemistry Practical Activities

Madeleine Schultz * [a], *Iztok Devetak* [b], *Dusica Rodic* [c], *Marina Stojanovska* [d], *Seamus Delaney* [e]

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Chemistry teachers worldwide engage students in practical activities in different ways and for different reasons. In most countries, little is known about what teachers do during their laboratory sessions and whether they are using activities related to green chemistry or sustainability. To fill this gap, a major international survey was recently developed to collect a large baseline of data by surveying high school teachers about the frequency and type of practical activities that they use with their classes and their use of activities related to green or sustainable chemistry. This Symposium will describe the design, implementation and some results of the survey.

Madeleine Schultz will introduce the project, including the design of survey questions and the logistics required to run it in many languages and contexts.

Iztok Devetak will present the survey results from Slovenian in-service lower and upper secondary school chemistry teachers. Results indicate that 72% of in-service teachers think that the main reason for not implementing experimental work more into their teaching is the lack of time during chemistry lessons. Almost all teachers (92%) believe that experimental work is an important vehicle to introduce green and sustainable chemistry to students, but only 26% of them also conduct such experiments in school.

Dusica Rodic will describe the importance of this survey in the Republic of Serbia, related to a national objective dedicated to enhancing the quality of education, specifically targeting knowledge and skills pertinent to sustainable development. Insights gleaned from teachers who are integrating this transformation into their approach will be explored and discussed.

Marina Stojanovska will present the results of the survey in North Macedonia (in Macedonian and Albanian) and activities that have followed on from this. The survey results served as a foundation for further investigation within a master's thesis focused on developing and implementing activities aiming to foster eco-friendly habits among students, particularly as the activities involved outdoor learning in real-world environments outside the school premises.

Finally, *Seamus Delaney* will round off the symposium with a preliminary analysis of the full set of results across all countries so far involved (as of March 2024, 46 countries and in 37 languages). The feasibility of how the findings could be used to inform teacher

practice, professional learning programs and innovation in curriculum will be critiqued and discussed.

Acknowledgements: The IUPAC Task Group chairs (Madeleine Schultz, Seamus Delaney, Iztok Devetak, Supawan Tantayanon) wish to acknowledge that this project would not be possible without the extraordinary effort and commitment from over 70 country coordinators. This invited symposium presents just a small sample of the amazing collaborative team.

This research was conducted within the project "International Teacher Survey on Green and Sustainable Chemistry (GSC) Practical Activities" which has received funding from the IUPAC Committee on Chemical Education (No.: 2023-002-2-050). The presentation of this work received additional financial support from the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia (Grants No. 451-03-66/2024-03/200125 & 451-03-65/2024-03/200125), and from the School of Education, Deakin University, Australia.

Symposium 3: Chemistry Education in the digital age-(missing) expectations, opportunities and challenges

Organizer: Carolin Flerlage

Chair: Shelley Rap

Speakers: Itsik Aroch, Ron Blonder, Karolina Broman, Carolin Flerlage, Stefanie Lenzer, Ilka Parchmann

Discussant: Ilka Parchmann

Symposium
2. Artificial Intelligence, Innovative Technologies, and the Impact on Chemical Education
4. Innovative Teaching and Pedagogies for a Sustainable World
6. Engaging Students in a Sustainable World with Chemistry
9. Professional Development of Chemistry Teachers in a Sustainable World

S3.1 – Chemistry Education in the digital age – (missing) expectations, opportunities and challenges

Itsik Aroch [a)], Ron Blonder [a)], Karolina Broman [b)], Carolin Flerlage [c)], Stefanie Lenzer [c)], Ilka Parchmann [c)]*

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Introduction and Final Discussion

Potentials for digitalization in chemistry education have been discussed at every conference in the last years. Two approaches have been in focus not only lately: opportunities for visualization of molecules and reactions, and trainings as well as analyses of lab practices. In addition to such chemistry content and chemistry learning related opportunities, however, further questions have to be discussed to enable successful implementations of digital as well as other developing resources and approaches: How can we best include teachers and take their expectations as well as preconditions into consideration? How can student learning be contextualized to better connect learning to students´ habits in the digital age? How can textbooks and media be adapted and enhanced as interactive sources? How can artificial and human intelligence be connected as partners in learning and orchestration? The symposium will reflect on these questions with examples from three different countries and invite the audience to discuss their own experiences and questions related to such impulses.

S3.2 – Profiles of Student Teachers Demands and Expectations as Starting Points for Transfer and Implementation

Carolin Flerlage [*a)], Stefanie Lenzer [a)], Andrea Bernholt [a)], Ilka Parchmann [a)]*
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There is a wide range of innovative digital learning opportunities that can support and enhance chemistry education, especially for visualization and lab practices. However, these innovative approaches rarely find their way into teaching practice. To achieve a more sustainable development and implementation of digitally-supported learning opportunities, the question arises: How can teachers, with their diverse expectations and preconditions, be best involved in the process of developing and implementing digitally- supported learning offerings? Various studies suggest that teachers are more likely to integrate digital media into their teaching if they maintain a positive attitude (e.g., Celik & Yesilyurt, 2013; Endberg et al., 2015) and perceive their own (digital) competencies as sufficiently high (e.g., Drossel et al., 2017; Siyam, 2019). Regarding the latter, Schulze-Vorberg et al. (2021) were able to identify three teachers profiles (digitally distanced, digitally accompanying, and digitally pioneering), which, in turn, impact the need for professional development and the implementation of digital media in teaching.

Building upon a study presented at the last ECRICE on the expectations and motivation of STEM students in the context of digital educational content (Flerlage et al., 2023), the presentation will offer more differentiated analyses of student teachers´ profiles from Germany. The focus is on the in-depth analysis of the preconditions and motivations of this cohort with regard to possible use cases of digital learning opportunities and the need for professional development. Combined with the findings from the literature, the talk apply the results presented to discuss further implications, potential scenarios for the use of digital learning opportunities, and considerations for transfer and implementation processes.

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S3.3 – Characterization of chemistry teachers' concerns profiles regarding technology adoption

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Contexts such as health, energy and climate are highly relevant to our everyday lives as they are associated with major challenges. Although chemistry education can make a key contribution to dealing with these challenges, the perception of the relevance of chemistry seems to be decreasing. To highlight the importance of chemistry in our daily lives, context-based teaching and learning is an established and effective approach (Sevian, Dori, and Parchmann, 2018). However, due to the rapid and fundamental changes in learning brought about by digitalisation, it is necessary to question existing approaches, suchas context-based learning. Is this approach still useful in an age where communication and information acquisition about scientific phenomena are dominated by digital and social media? Besides traditional learning in the chemistry classroom, students' learning has also shifted to informal digital spaces such as Instagram, TikTok, and YouTube (Allgaier, 2019; Kim, Sin, & Yoo-Lee, 2014). To better understand how traditional approaches must adapt, researchers have investigated and discussed students' social media habits in the context of science education (e.g., Höttecke & Allchin, 2020; Kresin, Kremer, & Büssing, 2024). The presentation will use such studies as starting points to reflect on how well-established approaches like context-based learning can be enlarged and connected to both, the authenticity of students´ worlds and habits, and authentic science of today. Additionally, a model for planning and reflecting on context-based learning in the digital age will be presented. This model connects the two perspectives of context-based learning and digital media along the SAMR model (Puentedura, 2006). This model can serve as tool to encourage developing more authentic, motivating and collaborative context-based learning materials.

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S3.4 – Profiles of Student Teachers Demands and Expectations as Starting Points for Transfer and Implementation

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Contexts such as health, energy and climate are highly relevant to our everyday lives as they are associated with major challenges. Although chemistry education can make a key contribution to dealing with these challenges, the perception of the relevance of chemistry seems to be decreasing. To highlight the importance of chemistry in our daily lives, context-based teaching and learning is an established and effective approach (Sevian, Dori, and Parchmann, 2018). However, due to the rapid and fundamental changes in learning brought about by digitalisation, it is necessary to question existing approaches, suchas context-based learning. Is this approach still useful in an age where communication and information acquisition about scientific phenomena are dominated by digital and social media?

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S3.5 – Pioneering a Digital Teaching Resource for Authentic Science and Sustainability – the example of DinKemi

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In various countries worldwide, educational context-based approaches have been employed to enhance student engagement and learning, as highlighted by Sevian, Dori, and Parchmann (2018). One challenge has been creating appropriate teaching resources that cater to both the affective and cognitive aspects of learning, making chemistry interesting and relevant to students (Broman, Bernholt, & Christensson, 2022). Stuckey *et al*. (2013) elaborated on relevance, breaking it down into three dimensions: individual,societal, and vocational, which are problematised in the presentation in relation to the teaching resource, and experiences from previous research (*e.g.*, Wei & Long, 2021). In Sweden, where this project is implemented, there is no formally established context-based curriculum, and there are no chemistry textbooks explicitly derived from real-world situations. As a consequence, a five-year initiative has provided the opportunity to develop a novel context-based chemistry teaching resource in the form of a digital textbook designed for lower secondary level (students aged 13-15 years). The project's cornerstone was the creation of relevant teaching material that resonate with students' everyday life, and with an aim to understand how digital opportunities help to link context-based learning approaches to authentic science insights and societal engagement, closely connected to the 17 sustainable development goals.

To create the new teaching resource titled "DinKemi" (*Your Chemistry* in English, accessible at www.dinkemi.com), a collaborative effort involving various competencies was essential. The project group, comprising the authors of this abstract, has been working together since 2018. To ensure accuracy and currency in the content, 40 chemistry researchers generated drafts covering different contexts suggested by the project group. Subsequently, the project group tailored the drafts to the specified school level, incorporating animations, photos, films, quizzes, and tasks. The teaching material encompasses multiple contexts with a focus on sustainability. In the presentation, the project itself will be explored, in relation to survey data with the chemistry researchers' experiences when writing the drafts. Moreover, the necessity for diverse competencies from both researchers as draft authors, and the project group with a broad background in chemistry content knowledge, chemistry education research, and teaching experiences from relevant school level, will be elaborated.

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S3.6 – ChatGPT and GenAI in Chemistry Education: A vision for now and future learning

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In recent years, artificial intelligence (AI) has made significant advancements, permeating various domains, including chemistry research and industry. Its integration into education, particularly within the field of chemistry, has garnered attention. Notably, the rise of generative AI (GenAI) tools, such as ChatGPT and DALL-E, has fueled this interest. GenAI encompasses AI systems capable of creating novel content, spanning words, images, music, code, and video, and DALL-E, generates realistic images and art based on textual prompts, gained widespread popularity after their public release in 2022. Theseapplications democratized access, enabling not only experts but also the general public to engage with AI- generated content.

Within the educational landscape, particularly in science education, numerous articles have surfaced over the past year. These articles showcase research that provided diverse perspectives. Fundamental questions regarding the integration of GenAI tool in chemistry education and regrading the knowledge and skills that are essential for safe use of GenAI are discussed.

In this presentation, I will share my perspective on the impact AI tools have and may have in the future on chemistry teachers and on their students. Based on our initial experience and on the UNESCO Guidance for generative AI in education and research, I will refer to questions as: What knowledge should chemistry educators have to effectively use AI based generative applications like ChatGPT? What are the essential skills to ensure they receive valuable insights from them? What are the ethical aspect that should be considered in order to avoid potential pitfalls?

Symposium 4: Portuguese online platforms that facilitate the teaching and learning of Sustainable Chemistry

Organizer and Chair: Carla Morais

Speakers: Andreia S. Sósinho, Paula Cotter Cabral, Cláudia Capela, Inês Santos and João Tavares

Discussant: Carla Morais

S4.1 – Portuguese online platforms that facilitate the teaching and learning of Sustainable chemistry

Carla Morais * [a], *João Nuno Tavares* [b], *Rui Pacheco* [c], *Andreia Sosinho* [d], *Paula Cabral* [d], *Cláudia Capela* [e]
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Computer-based technologies have opened new avenues in chemistry teaching and learning, serving multiple tasks in education such as productivity, creativity, communication, information, and resources. Chemistry, with its abstract and complex concepts, relies heavily on models. These models help reconceptualize observed phenomena not only at the macroscopic level but also in terms of theoretical models of matter structure at the submicroscopic level (de Jong & Taber, 2014). Computer simulations and animations offer a wide range of possibilities for modeling concepts and processes, enabling students to better grasp chemical concepts through interactive learning, visualization, and modeling. Digital tools enhance classroom dynamics and engagement, but their selection requires careful consideration. Teachers, identified as crucial gatekeepers (Wohlfart & Wagner, 2022), play a vital role in fostering this digital transformation within classrooms. Successful implementation of digital tools by teachers depends on various factors, including access to tools and time for exploration. Over the past decades, there has been an expansion of platforms and repositories of digital educational resources, funded and encouraged by governments, non-profit institutions, or publishers, for collecting, distributing, and preserving resources. Reflecting this trend, Portugal has established repositories at elementary and secondary education levels, covering several areas of the curriculum or focusing on specific domains such as natural and exact sciences. This symposium will present four Portuguese platforms and their repositories as they are the most visible and well-established. Given the complex and essential role of teachers in the digital resources use the articulation of teachers' digital competencies and professional knowledge will be also discussed.

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Symposium 5: Promoting relevant Education in Science for Sustainability

Chair and Organizers: Ingo Eilks

Speakers: Maija Aksela, Vania Zuin Zeidler, Gonzalo Guerrero Hernandez and Nadja Belova

Discussant: Ron Blonder

S5.1 – Promoting Relevant Education in Science for Sustainability via Teacher Education and Professional Development – The PRESS Project

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The presentation introduces the project Promoting Relevant Education in Science for Sustainability (PRESS). PRESS is funded for the period from 2022 to 2025 under the ERASMUS+ program of the European Union, following the action of Capacity Building in Higher Education (CBHE). As a cross regional project, PRESS brings together higher education institutions from Germany, Austria, Finland, Georgia, Israel, and Indonesia.

PRESS invests in the capacity of HEIs to better educate teachers for education for sustainable development (ESD). The aim of the project is to prepare and implement courses for teacher education in science with a focus on promoting ESD. Courses will be developed and implemented to allow partners to strengthen science teacher education with a focus on ESD (PRESS, 2024).

Responsible and sustainable action in society needs participation skills which are (in our contemporary society) inseparably bound to self-determination coverage of media. For ESD, critical scientific media literacy and communication skills with societal stakeholders are suggested as important goals in education, in general and in science education in particular. That is why the PRESS courses on ESD will include a special focus on critical scientific media education and science communication skills to the wider public, both concerning traditional as well as digital/social media.

Courses will also include training teachers for integrating school science learning with partners from businesses (SMEs/industry) and the wider public in small educational projects in connection to the non-formal educational arena. For stronger effects, PRESS will also use developed materials in continuous professional development measures.

The presentation will give insights into the PRESS curriculum and report first experiences and feedback from piloting the courses in partner institutions in Georgia, Israel and Indonesia.

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S5.2 – Promoting system thinking in practice through chemistry education

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System thinking has been seen as one of the main competencies identified by UNESCO for a sustainable future. It is defined, for example, as a tool and learning strategy for understanding and interpreting complex systems (Bielik et al., 2023). During the last few years, it has been seen increasingly as an important part of chemistry education around the world (e.g. Reynders et al., 2023; Hurst, 20; Aubrecht et al., 2019). As an example, we are keen on exploring how chemists apply elements of systems thinking within their work on sustainability-related projects (Vuorio, Aksela & Pernaa, 2024).

The aim of this presentation is to explain how to promote system thinking in practice through research-based chemistry education. We will introduce three examples: (i) system thinking in pre-service teacher education, through a course, (ii) system thinking in in-service teacher training, through laboratory clinics and (iii) system thinking for all, through open online course "Chemistry Nowadays and in Future."

Figure 1. LUMAlab, ChemistryLab Gadolin is an innovative learning environment for educating teachers for system thinking in practise. ChemistryLab Gadolin | Science education and Academic Outreach | University of Helsinki

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S5.3 – Sustainable Chemistry and Circularity Thinking in the Context of Sustainable Food Systems: Approaches to Empower Education Communities

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The concept of sustainable chemistry (SC) (Zuin Zeidler, 2023) addresses the reduction and simplification of total substance, material, product – including the so-called waste or loss – and energy flows, from the local to global level. Circularity for materials implies that the origin of products, their composition, ways to collect, extract, transform, reduce, reuse or recycle them, associated risks and benefits, costs and gains, drivers, potentialities, functions and services are perceived as a system, allowing one to start with measures at the source as under discussion for other sectors, such as the Food sector (Zuin Zeidler, 2024). Thus, in the context of circularity thinking, the knowledge required to apply systems thinking is fundamental to understand the challenges and potentialities promoting the construction of sustainable food systems collectively, in an integrated manner (Zuin Zeidler & Kümmerer, 2021; Zuin Zeidler & Eilks, 2019). This work is an invitation to put chemistry and specially chemistry education in a broader perspective to discuss circularity of materials and relevant processes aiming at empowering communities (UNEP, 2019), considering some key elements towards more sustainable food production and consumption models.

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S5.4 – Critical Raw Materials and Environmental Education: Promoting Ecojustice in the Face of Latin American Extractivism

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This study explores the intersection of extractivism and socio-environmental conflicts in Latin America, focusing on the critical role of science and environmental education. Particularly, I discuss the challenges posed by extracting critical raw materials (CRMs) in Global South. Historical and ongoing exploitation of natural resources – intensified by neoliberal policies and global capitalist dynamics – has led to significant regional socio-environmental conflicts (Svampa, 2019). These conflicts necessitated being considered as part of education shifting towards critical scientific and environmental literacies that are attuned to local contexts, ecological conflicts, and the promotion of ecojustice. Through a case study in Chile, this research examines neo-extractivism and the state's role in the extraction of CRMs, highlighting environmental impacts and socio-cultural implications for local and indigenous communities. By integrating outdoor science education based on conscientisation (Freire, 1970), this study proposes an approach to science and environmental education that leverages environmental conflicts as opportunities to analyse power dynamics and advocate for collective and activist responses. In doing so, I highlight the degradation of biodiversity, displacement, and alteration of cultural practices and traditional knowledge. The paper outlines the crucial nature of CRMs for advanced technologies but, at the same time, environmental repercussions of their extraction, including deforestation, soil erosion, and water pollution. Moreover, I recall the importance of including non-hegemonic and multicultural voices in scientific and environmental discourses, particularly those of local communities affected by extractivism, to foster a more inclusive, equitable, and comprehensive understanding of human-nature relationships. Methods are based on a collaborative research approach, referencing the Atlas of Environmental Justice's documentation of 587 conflicts in Latin America, with many related to CRM mining activities (Temper et al., 2015). In conclusion, this study recalled the need for counter-hegemonic discourses in science and environmental education, critiquing the traditional apolitical and disconnected nature of Western and Euro-centric scientific and ecological literacies approaches. The discussion extends to analysing economic cycles and historical environmental conflicts and promoting pro-ecojustice assemblages as collective endeavours. This inclusive narrative aims to enhance and promote equitable science teaching methodologies to navigate the complex challenges of CRMs extractivism and environmental degradation.

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S5.5 – Chemistry and Sustainability: Navigating Truth in a Post-Factual Era

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The way we think and act is greatly influenced by media messages. Not only articles in traditional print media, but also tweets, Instagram posts or reels on TikTok can motivate us to act responsibly, but also counteract this by allowing ourselves to be guided by simple, emotionally colored messages (Belova & Krause, 2023). The content can contain chemistry-related information which in many cases isn't based on scientifically proven sources. Due to the fact that nowadays anyone can disseminate information via social media and thus eliminate the gatekeeping mechanisms of traditional media, new skills are required to recognize reliable information and distinguish it from misinformation (Höttecke & Allchin, 2020). Aspects relating to sustainability in general and (sustainable) chemistry are being discussed intensively on social media, for example climate change, pesticide use or plastic pollution - to name just a few. Under the hashtag #sustainability, there are over 17 million posts on Instagram alone and the hashtag #greenchemistry leads to almost 50 thousand posts. It is often difficult to assess the reliability of such complex and sometimes controversial information; the concept of sustainability is often reduced exclusively to the ecological dimension and thus greatly simplified while chemistry is often depicted as a science producing dangerous and harmful "chemicals" that need to be avoided (Rollini et al., 2022). In addition, sustainability-related content is often shared by so-called "greenfluencers" who, on the one hand, advertise instead of informing by recommending supposedly environmentally friendly and often "chemistry-free" products and, on the other hand, call for even more consumption. Enabling students to deal with such information in a reflective manner should be the goal of all school subjects – including chemistry education - if only because today's learners are the "agents of change" in terms of achieving a more sustainable world. The presentation gives an overview of the communication mechanisms in social media with a focus on educational concepts in the sense of critical scientific media literacy. Based on this, concrete ideas for the implementation of learning via (social) media with a focus on aspects of sustainability and the SDGs in the chemistry classroom will be outlined.

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Symposium 6: Professional development of chemistry teachers for sustainability

Organizer and Chair: Avi Hofstein

Speakers: Ingo Eilks, Muhamad Hugerat, Miia Rannikmae, Avi Hofstein

Discussant: Rachel Mamlok Naaman

S6.1 – Professional Development of Chemistry Teachers for Sustainability

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Avi Hofstein: Introduction

Sustainability has gained vast importance in recent years, and scientists, in current case chemists, play a key role in the efforts to attain it. Chemistry teachers focusing on sustainability must educate the future citizens, through effective learning which calls for daily student-teacher social interaction as well as ongoing exposure to everyday life events. Most online social media tools have been developed with the aim of maintaining, managing, and enhancing social interactions between people, and have great potential to raise science teachers' awareness about important sustainable issues. The central importance of chemistry for our contemporary society and its sustainable development justifies every citizen's need for some basic understanding of chemistry to be a responsible citizen and active participant in society. Clearly, sustainability is one of the effective ways to make the learning of chemistry more relevant and thus connect it with the students' current life and the society in which they live and survive.

Ingo Eilks, from Germany, will report on a project conducted currently in six countries PRESS (Promoting Relevant Education in Science for Sustainability). PRESS invests in the capacity of Higher Education Institutions to better educate teachers for educa¬tion for sustainable develo¬p¬ment (ESD). The aim of the project is to prepare and implement courses for teacher educa¬tion in science with a focus on promo¬ting ESD. Courses are developed and imple¬mented to allow partners to strengthen the teachers' CK and PCK regarding sustainability.

Muhamad Hugerat from Israel, will report on Arabic chemistry teachers' awareness regarding important and relevant issues focusing sustainability. He will report on a study in which teachers were involved in a workshop. He will provide information on a study designed to assess the teachers' behaviour and their awareness regarding the importance of sustainability-related issues. The study was conducted in two phases: In the 1st phase the level knowledge of sustainability was assessed and in the 2nd phase

the source of their knowledge mainly social media was investigated. Finally, he will describe a workshop conducted to enhance teachers' CK and PCK.

Miia Rannikmäe from Estonia will report on a project conducted in three EU countries aimed at enhancing chemistry teacher readiness to promote sustainable science for life. In the capacity of the project, several modules were developed namely: Science for life, responsibility, and Self-management.

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W1 – How to Publish in Chemistry Teacher International

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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 be a platform for teachers of all levels, focusing on researchers in chemistry education. The objectives of the journal are:

- Bridging the gap between research and education
- Creating a platform for all IUPAC activities in the field of education
- Building an international journal not linked to a specific area or nation

The journal is indexed in leading international databases including the Web of Science – Emerging Sources Citation Index Expanded (ESCI, JIF: 1.5) and SCOPUS (CiteScore: 2.0).

This workshop aims to bring together Editorial Board Members and potential authors face to face to interact. The workshop will cover the following topics:

- Meeting with the Editorial Board Members
- Introduction of aims and scope of CTI, types of manuscripts accepted and policy for the future.
- Basic information about the journal (indexing and citations, statistics for content and coverage etc.)
- Submission and review processes as well as open-access policy and APC payment including APC waive policy of DeGruyter
- Special issue for ICCE
- Question & Answers session

W2 – AI - How we can use it to teach and learn

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Artificial Intelligence (AI) is rapidly transforming the educational landscape, offering unprecedented opportunities to enhance both teaching and learning. This workshop provides an in-depth exploration of how AI, particularly generative AI (Gen AI), can be harnessed to innovate educational practices and improve outcomes. We will begin with a thorough examination of AI fundamentals, tracing its concept and current capabilities. Emphasis will be placed on the role of generative AI in creating, analyzing, and adapting educational content, highlighting its potential to personalize learning experiences and its consequences on education.

One of the central themes of this workshop is the impact of ChatGPT, a prominent example of generative AI, on education. We will explore how ChatGPT can be utilized for various educational purposes. This tool has shown promise in providing immediate feedback, supporting diverse learning needs, and facilitating engagement through conversational interaction. The discussion will also address the practical challenges and ethical considerations associated with its use, such as data privacy and the need for accurate content generation.

A critical component of effectively using generative AI in education is prompt engineering. This skill involves crafting precise and contextually appropriate prompts to guide AI in generating useful and relevant responses. We will delve into best practices for prompt engineering, offering strategies to ensure that AI interactions are productive and aligned with educational objectives. Participants will learn how to formulate prompts that elicit high-quality outputs and address common issues related to prompt ambiguity and response accuracy.

In addition to theoretical insights, the workshop will offer practical guidance on integrating AI tools into educational settings. We will showcase several tools that have demonstrated significant utility in educational contexts, including ChatPdf for interactive document handling, School AI for enhancing administrative and pedagogical functions, and MagicSchool for creating engaging and adaptive learning experiences. These tools exemplify how AI can support a range of educational activities, from content creation and management to personalized learning and assessment.

The workshop will conclude with actionable guidelines for educators on effectively incorporating ChatGPT and similar AI technologies into their teaching practices. Key recommendations will include strategies for integrating AI into curricula, ensuring ethical and responsible use, and fostering a balanced approach to AI-assisted learning. Emphasis will be placed on aligning AI use with educational goals, promoting student autonomy, and addressing potential challenges.

By participating in this workshop, educators and administrators will gain a understanding of how AI can be leveraged to enhance educational practices. Attendees will leave with practical insights and best practices for utilizing AI technologies to create a more dynamic, personalized, and effective learning environment.

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W3 – 3D PRINTING AND LASER CUTTING MODELS TO LEARN CHEMISTRY AT SECONDARY SCHOOL

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Keywords: secondary school resources, atoms, molecules and ions, 3D printing, laser cutting.

Using 3D printing models in high school chemistry classes offers several educational benefits. For example they allow students to visualize atomic structures and molecular geometries in a tangible way or also for understanding the electron distribution in atoms and make meaningful the periodic table shape. Abstract concepts such as electronic configurations become more accessible when students can see and touch models that represent these ideas (Lane, 2020).

In recent times, laser cutting has been gaining space in secondary schools because it presents some advantages over 3D printing models. Such of these advantages or related to speed, precision and material versatility. Laser cutting is generally faster for producing flat, 2D components that, if needed, can be assembled into 3D models (Bater, 2019).

Besides, context-based chemistry education, particularly in the context of environmental sustainability, has proven to be an effective approach in high school settings. This educational strategy places chemical concepts within real-world contexts, making them more relevant and engaging for students, improving understanding and retention and developing critical thinking skills (Sjöström et al, 2015).

Taking into account those considerations and with the aim to engage students in enhance deep, meaningful and competent learning our participation as partners in "HOMELAB" (Homelab, 2021) lead us to develop secondary school activities with a competency approach for learning key ideas, in chemistry in contexts of environmental sustainability, that use 3D printing and/or laser cutting models.

In this workshop we will present and perform two activities of this project "*Let's imagine and represent the electrons of atoms using the periodic table. Using 3D printing and laser cutting models*" and "*Molecules and ions made with 3D printing models. Which of them are air or water pollutants?*". Participants will be able to carry out the activities and use and manipulate the 3D and laser cutting models and access the files for later printing. We will also present the previous results of their implementation in the classrooms.

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W4 – Computer Lab Assignments with Tools for Visualizing Chemical Phenomena

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Keywords: visualization, computer lab assignments, chemistry education

Chemistry education relies on visualization of phenomena invisible to the naked eye. Computer-based visualization tools allow students to engage with models of chemical phenomena, and in many cases to simulate molecular processes. They provide opportunities to learn by scientific investigation, and to develop skills that are relevant to modern research methodologies such as computer-aided drug design (Traube & Blonder, 2023). This domain of research has an increasingly important role in sustainable development (Mammino, 2023). However, students require support such as by written assignments to use these tools constructively. Research has generated heuristics for the design of such materials (Rehn et al., 2013), but they must be adopted by teachers to benefit students in chemistry classrooms.

Our design-based research focuses on implementation of computer labs in high schools using simulations together with printed assignments. It emanates out of a research context (Leif Eriksson´s group) where computer-based methods are used to search for novel and potent candidate drugs (Jha et al., 2023). Our latest comparison study (manuscript in progress) on simulations of molecule polarity and intermolecular attractions with n=63 high school students found learning gains equal to a control group. Students expressed that the activity increased both their engagement and curiosity, but suggested to use more integrated instructions, questions and tables to help them think scientifically. These findings and a follow-up classroom experiment on chemical equilibrium (under analysis) will contribute to the development of new methods for learning chemistry using visualization tools.

The proposed workshop will present visualization tools available for free online, together with written assignments. Teachers will work with these in laptop computers and are asked to reflect on how the assignments might support learning of chemical concepts, and their potential to increase student engagement. The discussion will include whether there are skills exclusive to the use of these tools that are relevant for modernized chemistry curricula. This workshop will thus provide examples of new learning methods and discuss the use of computer lab assignments in high school chemistry.

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W5 – Sustainable Chemistry in the School Laboratory

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In this hands-on workshop, teachers and educators will have the opportunity to try three different practical activities that you can use in your classroom related to sustainability and linked to the high school chemistry curriculum.

1. Aluminium-air batteries: a very simple experiment using mostly items found in a typical kitchen: aluminium foil, paper towel, charcoal, salt and water. Relevant curriculum topics are oxidation and reduction and diffusion. The relationship to sustainability is demonstrating the energy embodied in solid aluminium, which can be called “solid electricity”. Students will develop an understanding of the energy savings through recycling aluminium and make connections to contemporary research on metal-air batteries.

2. Biodegradable, food-safe water capsules: alginate is used to make small calcium alginate hydrogel beads. This relates to curriculum topics polymerisation, ionic interactions, density, pH and solubility. The environmental impact of plastics and food packaging can be discussed with students.

3. Electrolysis: This practical involves splitting water into its component elements, hydrogen and oxygen. Relevant curriculum topics include oxidation and reduction, electrochemistry, combustion, energy transformation, and gas laws. The relationship to sustainability is because hydrogen gas is part of the green energy transition narrative, given hydrogen will be part of a fossil fuel free future energy system. It can be generated through renewable electricity, for example on sunny days using solar energy or on windy days with wind turbines. Hydrogen can then be used as a storable energy source for periods without sun or wind.

These activities have been used previously in sustainable chemistry and systems thinking oriented school outreach and professional learning programs. The presenters will also briefly describe the results of their implementation in different education settings.

Acknowledgments: The authors wish to acknowledge those who have developed and shared with us versions of these practical activities, including (1) Diana Kennen (Rochdale K-12, USA) and Matthew McDowell (Georgia Institute of Technology, USA); (2) Adele Mastroyannis (Flinders University, Australia) and Tessa Faulks (Monash University, Australia); and (3) Zuriata Zakaria (Universiti Teknologi Malaysia, Malaysia).

W6 – Computational Thinking and Modeling in Science Education

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Keywords: Computational Thinking, Modeling, Higher Education

With the concept of 21st-century skills, organizations such as the EU, OECD, and P21 are defining important competencies for teaching, learning, and working in the 21st-century (Voogt & Roblin, 2010). In reference to the sub-category problem solving, we can draw parallels between computational thinking (CT), as originally formulated by Wing in 2006, and 21st-century skills. It is, therefore, clear that the promotion of CT is elementary for education in the coming decades.

In addition, the German ministries of education are demanding the integration of CT (although the concept is not mentioned literally) into existing curricula (Kultusministerkonferenz, 2021). To integrate CT into science lessons, a link can be established between CT and modeling. This link is based on problem-solving skills as they are central to both concepts (Liu et al., 2017; Li et al., 2020a, 2020b).

Based on this insight, we have developed a seminar concept for university. In this course, students acquire theoretical basics as well as fundamentally important skills in dealing with Scratch, microcontrollers, and Python to solve scientific modeling problems (Kärcher et al., 2024). The course aims for students to develop teaching concepts to promote CT and modeling in science classes. In addition to the seminar concept, selected student work and evaluation results will be presented.

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W7 – Química para os mais novos: THE CHALLENGE

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Keywords: experimental chemistry, science education, reversibility of chemical reactions, accessible activities, scientific thinking.

"Química para os mais novos" is a section of scientific experiments published in QUÍMICA, the Portuguese Chemical Society bulletin, since 2011. The primary objective of this rubric is to stimulate a passion for experimental science among young learners, even in the absence of ideal laboratory conditions.

In this workshop, we propose the execution of activities that foster scientific thinking and emphasize the concept of the reversibility of chemical reactions. Participants will be presented with a game-based challenge, wherein they must utilize the provided materials and their knowledge of chemistry to successfully complete the task. By engaging in these activities, attendees will gain practical experience while also reinforcing their understanding of key chemical principles.

The workshop aims to inspire chemistry teachers by showcasing innovative and accessible approaches to teaching experimental chemistry. By encouraging the use of everyday materials and emphasizing the relevance of scientific thinking, we hope to instill a sense of curiosity and excitement in students, fostering their interest in chemistry from an early age.

W8 – The Cold Pack: Laboratory work with elements of formative assessment for lower secondary school

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It is well-known that laboratory education often results in a cognitive overload for students (Johnstone & Wham, 1982). Over the past few decades, many studies have been presented on how students' intellectual engagement in laboratory work can be stimulated to meet this problem, but classroom practice is still largely the same (Seery, Jones, Kew & Mein, 2019). Formative assessment is about giving students feedback so that they can improve during the activity (Sadler, 1989). Various forms of formative assessment during laboratory education have been reported, but teachers still find it difficult to implement so there is a need for further studies about assessment of laboratory work other than laboratory reports (Gericke, Högström & Wallin, 2023).

To support formative assessment in lower secondary school, the Swedish National Agency for Education has recently published six resources for laboratory work in science (Swedish National Agency for Education, 2024). In the teacher's guide, a rubric is presented with various aspects of inquiry, designed to make the students' learning in the laboratory visible. It includes suggestions for how teachers can provide formative feedback during ongoing activities, e.g., guiding questions the teachers can ask and examples of student answers that can be discussed in class. In-service teachers participated in the development of the instructions, that were also tried out with students.

One of these laboratory resources, the Cold Pack, will be introduced and tried-out in this workshop. This laboratory work was designed for students to practice scientific work methods, including risk assessment, linked to product development. The teacher's guide includes a presentation with basic concepts about salts and thermochemistry, that could be used as an introduction.

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W9 – An Arts-integrating Approach to Bring Neuroeducation to the Chemistry Classroom

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Keywords: Neuroeducation, Art integration, Creative Thinking

Learning chemistry is a challenging task for the brain since it requires using highly specific language and symbols to explain observable phenomena at the microscopic and process levels. Students should be able to visualize material systems and create scientifically acceptable mental models from which to retrieve information and use it in reasoning to solve problems. This involves thinking about abstract concepts in a multi-level manner through visuo-spatial thinking, integrating between semantic expressions and visual representations (Cook 2006; Wu and Shah 2004; Vekiri 2002). Thus, the visual thinking abilities and representational competences of chemistry students are crucial when learning chemistry.

With these challenges in mind, a neuropedagogy-based, arts-integrating approach to teaching and learning chemistry was developed (Marchak et al 2021a). This approach explicitly addresses visual literacy to support visualization and understanding in chemistry. Art appreciation and visual literacy techniques were adapted considering relevant neuro-pedagogical principles, and a conceptual framework emerged (Marchak et al. 2021b) that allowed the methodological development of activities specifically designed to address either learning of abstract chemistry concepts or rehearsing research skills. Activities developed by this approach lead students through the processes of observation and analysis of complex images. Sometimes, these skills are gained through engaging with abstract artwork and then applied to imagery bearing chemical meaning such as symbolic representations of chemical content. Other times, students interact with non-abstract art and exercise visual thinking skills through an inquiry process like what they experience in laboratory activities.

In this workshop, participants will participate in two activities developed using this approach: one focused on visualization of abstract content and the other on rehearsal of research skills. We will also discuss the supporting neuropedagogical, arts-integrating, and chemistry principles that were considered during the development of the activities.

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W10 – Technology Enhanced Problem-based Learning in the Chemistry Classroom

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Keywords: Technology Enhanced Learning, Interactive Visualizations / Simulations, Problem-based Learning

The process of scientific inquiry itself is conceptualized as a complex, knowledge-based problem-solving process in the context of science education literature (Kauertz et al., 2010; Hammann, Phan & Bayrhuber, 2008). Consequently, problem-based teaching approaches in chemistry offer the opportunity to utilize experiments and models as subject-specific methods for addressing scientific problems (Pahl & Berchtold, 2019). Problem-based learning approaches can thus foster the acquisition of scientific inquiry skills, which contribute to the development of scientific literacy (Wellnitz et al., 2017). As part of a problem-solving process, digital interactive visualizations or simulations can be employed to explore cause-effect relationships within a system (e.g., the impact of an engine on a car's exhaust gas emissions). Compared to simple animations of processes, interactive visualizations have the potential to engage learners more deeply with the learning-material and consequently result in a particularly effective exploration of cause-effect relationships (Nerdel, 2002). Digital interactive visualizations offer numerous advantages for implementation regardless of spatial constraints and available resources (Wiemann et al., 2010). Consequently, there is a growing body of visualizations designed for integration within the chemistry classroom (e.g., PhET, Concord Consortium). However, given that this is an emerging technology, there remains a lack of visualizations addressing many topics relevant to chemistry education.

Aim: The aim of the project was, therefore, the development of interactive visualizations for the use in a problem-based learning scenario in the chemistry classroom for the topics of light and color and education for sustainable development.

Method – Conceptual Design and Development: The educational effectiveness of interactive visualizations/simulations and how they are processed by learners' working memory strongly depend on their design. Overly complex visualizations can overwhelm working memory and hinder learning (Chandler & Sweller, 1991). To mitigate this, Mayer (2005) proposed twelve design principles for multimedia learning materials. The principles of coherence, signaling, and temporal contiguity, aimed at minimizing cognitive load, guided the development of these interactive visualizations. As part of the development of a teacher training program on technology-enhanced teaching in the

chemistry classroom, the interactive visualizations were designed for the teacher training platform Toolbox Lehrerbildung.

The visualizations were developed using JavaScript-based dynamic geometry software, CindyJS, allowing for their use across all internet browsers. Hence, flexible use in school and university teaching is possible worldwide. Due to space limitations, an exemplary presentation of one of the thematic visualizations is not provided here. The visualizations on light and color can be accessed through the following link: http://go.tum.de/180028. The interactive visualizations on education for sustainable development have not been published yet and will be presented for the first time to a larger audience at this conference.

Discussion: However, when using interactive visualizations, it is important to ensure a didactically appropriate approach to their implementation in the learning process. This means, for example, that they should be used in combination with a supplementary instructional text. In other words, the visualization should be integrated into a teaching scenario in a didactically thought-out and meaningful manner. To achieve a positive effect, their use should, in any case, be accompanied by corresponding instructional guidance in a task-specific format (Schnotz & Bannert, 2003).

Conclusion – Importance: International and national programs and initiatives are increasingly recognizing the benefits of seamlessly integrating technology into educational settings, acknowledging the advantages of the effective integration of ICT in schools and classrooms and recognizing its potentially transformative impact on teaching methodologies and its role in student empowerment (UNESCO, 2018). The presented interactive visualizations provide a novel and innovative way to incorporate an interactive digital component into the growing array of digital tools for chemistry teaching and learning. Thanks to their specialized technical design, the presented tools are readily adaptable and customizable for chemical education at both school and university levels. They will be accessible as Open Educational Resources (OERs), along with additional resources such as worksheets and recommended chemistry lesson plans, providing further guidance for educators and learners. The accessibility of these resources as OERs provides the possibility to implement the visualizations in lessons or self-regulated learning materials tailored to individual needs, not only in Germany but internationally. In this way, the visualizations help to mitigate structural disadvantages and limited equipment in schools worldwide, to some extent.

In this ICT demonstration, the interactive visualizations are presented. Participants are invited to explore the tools firsthand and discuss the options for using the simulations to support the learning process. An exchange of implications and experiences in dealing with interactive simulations is planned, drawing from diverse global perspectives.

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W11 – "Chemistry, Climate, & the Numbers in Between": Skills-Centred Climate Chemistry Education

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Keywords: Climate change, Critical thinking, Cognitive skills

Nowadays, with the acceleration of technological developments, the vast amount of new information that is available on the internet, and even the possibility of chatting with artificial intelligence (AI) tools creates constantly changing challenges to future world citizens who are tasked with analyzing and evaluating the frequently updated data (Hernandez-de-Menendez et al., 2020).

One of the primary objectives of an education system is to prepare students for their adult lives by imparting them with the requisite knowledge, qualifications, and skills that will enable them to confront these future challenges effectively (OECD, 2019). In light of this goal, we developed the program "Chemistry, Climate, & the Numbers in Between". This program involves the chemistry of climate change, links between human actions and global warming, and the chemistry involved in possible technological solutions to the climate change challenge. This program aims to foster critical thinking skills and lead graduates to apply a critical approach and a well-informed perspective toward the world (Rap et al., 2023). The topic that we used to impart these skills is global climate change, and the scientific discipline we chose was chemistry, which provides students with the scientific knowledge needed to understand the phenomena we are discussing.

In our workshop, we will expose the participants to the program's contents while emphasizing the skills explicitly provided in the different units of the programs. The participants will also engage in selective activities from the program.

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ECRICE 2024

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Plenary Lecture

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PL1 – Teaching for a Sustainable Future

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This is the final lecture of an exciting conference where many chemists have been exchanging their ideas about teaching and chemical education. Our aim is to outline how we have tried to revitalise our teaching of green and sustainable chemistry over the past 5 years. Our goal is to help our students to think differently about the chemistry that they do. We also try to enable them to relate chemistry to the United Nations Sustainable Development Goals (SDGs).

In particular, we will explain how we help students to consider how chemicals are actually used as well as how they are made. In this context, we will highlight the concept of "Chemical Leasing", championed by UNIDO (the United Nations Industrial Development Organization) [1]. We will introduce our own concept of "Moore's Law for Chemistry" [2]. We also point out how teaching students during the pandemic helped us to rethink how we taught the course.

We have learned a quite a bit about what works and what does not. We found that our course was generally well received but the students had concerns on what would be examined. They were happy to bring SDGs into their exam answers and, most importantly, they saw connections with the SDGs that they had not been specifically taught. The student feedback has been pleasingly positive, for example:

"Definitely the most interesting lectures I have. I find it really interesting to learn about factors affecting the environment that I hadn't considered as well as the new technology solving them"

"Toxicology was very interesting. Would like the course to go into more detail."

"I think is a great module that really makes me think. It's my favourite one so far! Inspires me to do chemistry in the future"

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K1 – Diversity and Inclusion for Sustainable Chemistry Education

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Thinking about the goals of sustainable development (SGDs) often is the connection drawn to the nature, surrounding and our environment. Taking a deeper look into the SDGs, we can also see that “Gender Equality” is one of the named goals. Further, thinking about the “Good Health and Well-Being” or “No Poverty” and “Zero Hunger”, this is only possible to reach by the good and quality education of all citizens.

To do so, the requirements given need to be considered. All students – independent on which level of education – are different. Their differ in not only gender, but their socio-economic status, cultural background, mental and physical abilities, linguistic skills - just to name a few. We need to be aware and take into consideration the differences which our students, future teachers as well as our teachers bring with them when we offer courses and learning materials.

Starting from the concept of the diversity seen as a “resource for individual and mutual learning and development” (Sliwka, 2010, p.190). Starting from here, Sliwka (2010) describes inclusion as a concept where “differences are seen as an asset and opportunity”.

In my talk, an overview about projects which are focusing on different level in educational system will be presented. It will be shown that teaching and learning in the framework of inclusive science education requires participation of different “players”- starting from teachers in different educational disciplines, educators in non-formal education as well as parents.

Finally, in a discussion about possibilities for a future teaching at the university level considering differences of university students will be drawn.

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K2 – Chemistry and Cultural Heritage Integration in a Sustainable World

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Chemistry plays a vital role in the analysis of the composition and structure of artefacts and historical materials, understanding the degradation mechanisms and the impact of the environment on materials, and the conservation and restoration of cultural heritage in line with the principles of green chemistry. On the other hand, art and archaeology enable the contextualization of chemical concepts from both general and inorganic chemistry and organic chemistry (e.g. Vyhnal, 2022; Alcantara-Garcia & Ploeger, 2018) at all levels of education (Potočnik & Devetak, 2023), which helps students relate chemistry to other scientific disciplines and develop their transferable skills, improves their achievements, and increases the motivation for learning chemistry. The interdisciplinary approach to the topics of cultural heritage encourages students to apply their knowledge of chemistry and skills in hands-on experiments and arts and crafts activities, advanced laboratory experiments, cross-curricular projects, case studies, research projects, and community projects related to cultural heritage preservation, thus developing the respect for different kinds of world cultural heritage and the sense of responsibility for the preservation of cultural artefacts and sites. In addition to this, the scientific literacy of the young is improved through understanding the scientific principles which are applied in heritage preservation. Last but not least, the scientific achievements themselves become a part of cultural heritage. A case in point is the story about artemisinin, the Nobel Prize in Physiology and Medicine, awarded to Tu Youyou from China in 2015, and one old folder containing the recorded spectra and original notes which indicate that this compound was first isolated by Yugoslav chemists in the 1970s, under the guidance of Milutin Stefanović and Dragoslav Jeremić. The story was told within an in-service programme for the professional development of chemistry teachers in order to strengthen their competences in the application of cultural heritage in chemistry classes.

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K3 – Chemistry and Cultural Heritage Integration in a Sustainable World

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Teaching laboratories in higher education are the powerhouse of science training, where students spend hours honing their skills to become scientists. In chemistry education, much debate has been focused on competence development, curriculum design, and assessment of student learning. This keynote focuses on the epistemic core of doing chemistry in the laboratory. It rests on a foundation of experimental work as epistemic practice (Agustian, 2022), in which students engage in proposing, communicating, and evaluating knowledge (Kelly & Licona, 2018). Within this conceptual framing, various aspects related to students' learning processes were investigated, using a multitude of methods and analytical frameworks, including hermeneutic phenomenology and multimodal discourse analysis. By looking into a multidimensional view of student learning (Illeris, 2018), constructs such as epistemic affect and epistemic conation were substantiated. A part of the research program also seeks to find the nexus between embodied and epistemic cognition in the context of laboratory-related epistemic practices. Results revealed how laboratory work elicits a wide range of human emotions, mostly epistemic. In this context, epistemic feelings such as pride and humility are tied to nascent identity development as a chemist. Problematizing the highly individualized notion of grit, the study proposes a taxonomy of epistemic conation as a more socially embedded, epistemologically informed way of looking into students' motivation, goal orientation, perseverance, and learning strategies. The findings also evince how the embodied nature of doing chemistry in the laboratory, such as spatial navigation, sensorimotor integration, and embodied production of scientific phenomena are intertwined with how students engage with concepts and epistemic uncertainties. The epistemic focus of this research program strengthens an argument for laboratory instruction and curriculum development that are more aligned with the inner workings of science, in pursuit of higher quality learning experiences.

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K4 – Catalyzing Change: Teaching Chemistry for Sustainable Development

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As the world handles with escalating environmental challenges, the need for Green Chemistry Education has become more pressing than ever. This education is crucial not only for advancing the field of chemistry but also for promoting sustainable development on a global scale (Etzkorn & Ferguson, 2023; Wissinger *et al*., 2021). Institutional bodies such as the International Union of Pure and Applied Chemistry (IUPAC), the European Chemical Society (EuChemS), and the European Chemical Industry Council (CEFIC) play pivotal roles in directing and supporting these educational efforts. This seminar will explore the critical role that Green Chemistry Education plays in fostering environmentally responsible scientific practices. It will review educational initiatives across North America, Europe and Asia highlighting how these programs, supported by key institutions, instill sustainability principles in future generations of chemists. Additionally, the seminar will showcase NOVA FCT's comprehensive approach to integrating Green Chemistry into its educational framework (Pinto *et al.,* 2020), including high school programs, undergraduate and graduate courses, and doctoral studies. By highlighting these efforts, the seminar will underscore the imperative of educating chemists who are equipped to contribute to a sustainable future. The session will conclude with a discussion on the impact of these educational strategies and potential paths forward for expanding Green Chemistry Education worldwide.

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OP1 – The influence of authentic advanced lab experiences on students' NOS understanding

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Keywords: Nature of Science, Nano-scale Science and Technology, Scanning Electron Microscope

Understanding the nature of science (NOS), or more accurately the nature of scientific knowledge (NOSK), has been considered for the last decades as one of the goals of science education (NGSS Lead States, 2013) and it constitutes a critical component of scientific literacy (Lederman & Lederman, 2020). In recent years, there have been increased research efforts aiming to improve NOS understanding among teachers and students. However, there is still a severe shortage of controlled interventions that empirically study how NOS understanding can be improved as well as a debate about the best way to teach NOS (Abd-El-Khalick & Lederman, 2023). This study aims to contribute to the global pursuit for innovative ways to enhance students' NOS understanding, by adding an evidence-based empirical intervention study to the NOS research. McComas et al. (2020) highlighted the importance of context and a connection to the authentic work of scientists in NOS instruction. Teaching science through contemporary research topics such as Nano-scale Science and Technology gives students insights into the nature of scientific research (Blonder, 2021). Recent studies have shown that using a Scanning Electron Microscope (SEM) as a tool to explore the nanoworld provides students with an authentic learning experience (Yonai & Blonder, 2022). In this study, we investigated the contribution of a contemporary science lab activity using a SEM as a context for enhancing students' NOS understanding. We developed two outreach SEM laboratory activities: one activity is related to nanotechnology, and the other is related to school chemistry. We engaged high-school students in these authentic lab experiences and exposed them to the nature of science and scientific work. The research goal was to study how participating in a SEM laboratory activity influenced students' NOS understanding, and to explore the effect of the chemical content of the activity (advanced science vs. basic chemistry) on students' NOS understanding. Data were collected using student pre-post NOS understanding questionnaires, based on the SUSSI previously validated questionnaires (Chen et al., 2013; Liang et al., 2008). The NOS questionnaire included Likert scale items, followed by open questions, addressing the following NOS aspects: observations and inferences, the empirical and tentative nature of science, the theory-laden nature of scientific knowledge, and imagination and creativity in scientific investigations. During 2024, 250 high-school chemistry students participated in these activities. We are still in the data collection and analysis stages, and plan to conduct the following analyses: the reliability of the NOS categories will be calculated using the α-Cronbach Reliability Coefficient and a pre-post statistical analysis that examines the impact of the different activities on students NOS

understanding. In addition, the open-ended questions will be analyzed to enable an in-depth understanding of students' views of NOS. At the ECRICE meeting, we will present the results of these analyses and discuss their implications for the chemistry education community.

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OP2 – Fostering Critical Thinking in Science Education: Definitions, Assessments, and Implications for Sustainable Decision-Making

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Keywords: Critical Thinking, Socioscientific Issues, Science Teacher Education

Critical thinking is identified by the European Union as a key competence for lifelong learning (Council of the European Union, 2018) but has so far been vaguely and ambiguously defined (Rafolt et al., 2019). It is especially important in the evaluation of socioscientific issues (SSI) (Kolstø et al., 2006), as their controversial nature defies a clear solution (Zeidler, 2014).

Although, according to Facione (1990), critical thinking should primarily take place at the rational level, it is the affective level that significantly shapes our decisions (Gilovich et al., 2002). This leads to the fact, that often the cognitive level is not addressed sufficiently, which results in cognitive biases (Gilovich et al., 2002; Kahneman et al., 1982; Thompson et al., 2013)..

In the project presented here a practical definition of critical thinking is developed and a set of instruments to assess this complex construct is tested. Strategies and aspects in the evaluation of different SSIs by chemistry students were collected in an interview study and evaluated using qualitative content analysis based on Kuckartz (2016) and triangulated with other instruments (between-method). In addition, a new method, the Systemic Reflective Statement, was developed to explicitly address critical thinking and was evaluated in a pre-post-test design.

The results suggest that this explicit approach significantly increased multi-perspectivity in the evaluation of SSI and created an awareness of the influence of the affective level, resulting in increased self-reflection, attention to facts (knowledge) and questioning of information (epistemology).

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OP3 – A pedagogical strategy centred on water analysis in the community for a sustainable world: incorporating different elements of teamwork

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It is well recognized that students graduating from Chemistry courses can often lack some of the essential team-based skills for working in industry (Michaelsen et al, 2023). Therefore, the rational in this study was to design a team-based module, where the students could not only develop their analytical skills and learn about water quality and sustainability, but also develop their team-working skills. The activities were designed to give the students confidence, the ability to contribute to solving problems, effective communication, and various team-based skills.

After the teams were assembled (4 teams with 5 members), the students were introduced to an interactive virtual lab component aiming to encourage them to actively prepare for the team tasks. Each team worked in the laboratory to develop two analytical methods for water analysis using sustainable approaches, while tasks outside the laboratory involved preparation of documents, and data analyses. Once the analytical tasks were completed, the teams worked on producing a Standard Operating Procedure (SOP) for their two water analysis tests. The SOPs were then exchanged between the teams so that each team evaluated a SOP designed by another team. This facilitated peer-to-peer feedback between the teams.

Water samples were collected from the local community with co-ordinates identifying their locations. The teams analyzed the samples providing a map of water pollutants across a small region in Dublin. The students prepared a water report, and the levels of contaminants were compared with recent Environmental Protection Agency (EPA) reports on water quality for the East of Ireland. Finally, the students gave team presentations on their findings. With this range of activities, the students gained confidence in problem solving and team working skills, while learning about the importance for water quality for sustainability.

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OP4 – To stay or not to stay in reality: Insights from Cognitive Load Measurements via Electroencephalography and Heart Rate Variability

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Keywords: cognitive load, teaching methods, information and communication technologies (ICT)

New modern information and communication technologies have introduced innovative ways of teaching chemistry, e.g., through augmented reality, virtual reality, or interactive computer apps. However, before these methods can be advised for implementation on a larger scale in schools, it is crucial to evaluate their effectiveness. This could be done through measurements of cognitive load, often defined as mental effort connected to problem-solving and transfer of information between working memory and long-term memory. There are several ways to measure cognitive load. Classically it is done by subjective methods, like self-reported questionnaires, interviews, and tests. On the other hand, more objective results may be obtained by measurements of the physiological responses of the organism such as eye tracking, heart rate variability, or electroencephalography (Antonenko et al., 2010; Duffy et al., 2019; Skulmowski & Rey, 2017). At the conference, we aim to showcase preliminary findings from our research that compare various chemistry teaching methods – involving the usage of molecular models in virtual and augmented reality, on the computer screen, and traditional physical models. The research involves various groups of students learning with mentioned technologies, to solve problems involving changing chemical representations. The efficiency of methods will be compared via subjective and objective cognitive load measurements including self-reported questionnaires, tests, electroencephalography, and heart rate variability. The results of this study can significantly contribute to optimizing the teaching/learning processes, lesson planning, test development, and the integration of new technologies in education.

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OP5 – Laboratory Work for 1st year undergraduates – are we making the most of the opportunities?

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Keywords: laboratory work, assessment, learning in laboratory

Most, if not all, undergraduate courses in chemistry have a significant portion of time devoted to practical work. Why? There is almost universal acceptance that laboratory work is an essential part of chemistry and is necessary for students to develop the practices that allow them to be successful in their further careers in the chemistry world. It is identified as important to support theory, develop conceptual understanding, provide opportunities for critical thinking and problem solving, as well as developing skills in the use of specific apparatus and equipment as well as increasing student engagement and motivation (Hofstein & Mamlok-Naaman, 2007). Undergraduate laboratory work is also costly to implement, is time consuming, there are safety issues to consider, and many staff are involved both technical and academic. Therefore, it is important that the activities that are conducted during the laboratories are designed and assessed in accordance with the aims of the laboratory (Bretz, S. L., 2019; Agustian, et al., 2022).

In Ireland, currently the curriculum for 2nd level chemistry is being redeveloped with a major change in its assessment moving from a 100% final written examination to two assessments (written worth 60% and an additional component worth 40%). This new component places an increased emphasis on practical investigative work that has already been implemented in the 1ry curriculum and in the first 3 years of the 2nd level curriculum (NCCA, 2024). This change will influence the skill sets of the students entering University and thus will need to be considered in the design of undergraduate chemistry programmes.

This presentation reports on a case study of the laboratory work that is currently conducted in Irish universities, with the aim of determining the current practices and approaches adopted. Individual interviews were conducted with the academic in each institution with responsibility for the implementation of the 1st year laboratories for those students majoring in Chemistry. Key results from this study have highlighted major differences between the approaches taken across the Universities. This talk concludes highlighting opportunities to change and tweak the laboratory activities, approaches, and assessments to increase the student learning in the laboratory and to build on the competencies from 2nd level.

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OP6 – Measuring Success in Chemistry Practical Work: A Comprehensive Review

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Keywords: experimental activities in chemistry education; assessment tools; literature review

More than 40 years ago, Hofstein and Lunetta (1982) challenged the prevailing canon on the necessity of experimental activities for chemistry education. Their scepticism was shared by many authors, including Abrahams and Millar (2008), who highlighted the discrepancy between the expected and realized curriculum when it comes to practical work.

This contribution is part of the STExperiMents project (Preparation and evaluation of experiments suitable for effective pre-service teacher training in STEM disciplines). Its goal is to present partial results of a literature review focused on tools used to evaluate the effectiveness of practical activities in chemistry. Articles were searched in the Web of Science and Scopus databases using a combination of *Keywords* related to the field of interest, i.e., science or chemistry, and referring to the education sector, i.e., instruction, education, learning and teaching, and words specifying the research tool, i.e., assessment or evaluation tool, rubric, sheet, inventory, etc. The results were subsequently filtered to include only articles, early bird articles and conference proceedings in English. The datasets were combined, with duplicates removed. Selection of papers for more detailed evaluation was based on their titles and abstracts.

The results indicate a relatively limited number of tools, highlighting the need for well-described objectives of practical activities (see Osborne, 2015) and tools to verify their achievement.

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OP7 – Upper secondary students and teachers' experience with a teaching unit on organic synthesis with emphasis on green chemistry

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Keywords: green chemistry, teaching unit, students experience of relevance

Green chemistry was introduced as a new topic in the Norwegian chemistry curriculum for upper secondary school, that became effective from 2021 (The Norwegian Directorate for Education and Training, 2021). To address this topic in our teacher training program, we developed a one-day teaching unit that is given by pre-service teachers to upper secondary chemistry students each year at the University of Oslo. In the first part of the teaching unit, groups of upper secondary chemistry students synthesized benzoic acid from benzaldehyde using different oxidizing agents. In the second part of the teaching unit, the students used principles of green chemistry (Anastas & Warner, 1998) to evaluate and discuss which route of synthesis that is most sustainable from an environmental and green chemistry perspective.

In this study we wanted to find out how students and their schoolteachers experienced the teaching unit. Data was collected through a questionnaire (n=48) and semi-structured interviews (n=4) with the students, and semi-structured interviews (n=3) with the teachers. The results show that the students found the organic synthesis challenging, but motivating, and suggest a correlation between students' self-efficacy and experience of mastery when performing the synthesis. The organic synthesis itself was not considered very relevant by the students, neither in the individual, societal, or vocational dimension, as described by Stuckey, Hofstein, Mamlok-Namaan & Eilks (2013). The focus on green chemistry on the other hand, contributed to the students' perception of societal relevance by establishing a connection between chemistry and sustainability issues. Preliminary results from the interviews with the teachers suggest that they think that the introduction of green chemistry and green chemistry principles to the Norwegian chemistry curriculum adds something positive to the chemistry education, and that the way green chemistry is used in the teaching unit is fruitful and trains the students in arguing on matters where there is not one correct answer. The teachers are somewhat divided in their views on the quality of the argumentation and whether the students possess enough chemistry knowledge to do this type of evaluations and discussions in depth.

The findings suggest that the way green chemistry is used in this teaching unit can increase students' perceived experience of the relevance of their chemistry education by making connections to safety of workers, environmental issues, and sustainability.

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OP8 – Exploring the Role of Non-textual Components in Chemistry Learning

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This abstract presents a segment of a study exploring the influence of components commonly incorporated in chemistry educational materials on chemistry teacher students' comprehension of these materials. Chemistry texts typically include non-textual components such as tables, graphs, diagrams, images, and various models, necessitating emphasis on these elements as well (Eilam & Gilbert, 2014).

A considerable body of research has been conducted in the field of working with learning materials. Some studies focus on how students approach problem-solving tasks (Tóthová & Rusek, 2022), their understanding of science texts (Ariasi & Mason, 2011), or specifically on students' ability to work with graphs (Harsh et al., 2019). The direction of this research enables the deepening of already established information while also uncovering new insights into the effect of various components under the specific conditions of chemistry, which, compared to other natural sciences, is distinguished by a high degree of abstract representations.

The paper will introduce results from a pilot study designed to monitor students' level of engagement with learning materials containing specific components. Tasks, reviewed by an expert panel, underwent a pilot phase with a larger sample of students (N = 30) through three-tiered tasks, and with a smaller sample (N = 6) using eye-tracking technology. This study's findings identify problem areas that may represent obstacles in the learning process with science materials. These insights will contribute to a better understanding of students' needs and allow for a more targeted approach in teaching science subjects.

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OP9 – Immersive Technology for Teaching Undergraduate Analytical Chemistry in the Laboratory

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Keywords: Virtual Reality, Analytical Spectrometry, Laboratory Skills

This paper will discuss the introduction of immersive technology, specifically virtual reality as a pedagogic tool for teaching practical analytical chemistry at an Irish University [1]. This activity is part of a large nationally funded initiative across 5 Universities developing best practice for a blended approach to practical science where virtual training supports and reinforces the in-lab experience; enquiry-based learning, teamwork and development of work-place transversal skills are key pillars of this enterprise-informed approach.

The presentation will discuss the design, delivery, implementation and student evaluation of immersive interactive training experiences that we have developed in VR. These softwares were designed for training undergraduate students (3rd year chemistry) on chromatography and spectrometry techniques, specifically ion chromatography (IC) and atomic absorption Spectrometry (AAS). We are seeing that these interactive simulations allow learners to interact with and navigate virtual twin instrumentation, practice laboratory techniques, perform experiments, and hone their analytical skills and critical thinking in a virtual setting.

This presentation will share the experience in developing and implementing such hands-on training through these applications (now available on Meta's AppLab), in a risk-free environment that enhances student engagement, confidence, and retention of knowledge.

Figure: Screen grab of virtual AAS instrumentation from the Immersive Chemistry Lab hosted on Meta's AppLab.

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OP10 – Promoting Sustainability in Chemistry through Systems Thinking for Student Teachers

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Keywords: Systems Thinking, Teacher Training

Global challenges such as climate change, resource scarcity, and water pollution extend beyond environmental impacts with significant consequences for both the society and the economy. Hence, these challenges can be viewed as complex systems where a holistic perspective is crucial for a comprehensive understanding. The implication for chemistry education is that the traditional reductionist approach needs to be complemented by a holistic one in order to contribute to an education for sustainable development. The systems thinking approach offers a viable option as it facilitates the linking of chemistry concepts with the dynamic societal, economic and ecological systems in our world (Constable et al., 2019). However, systems thinking must be explicitly taught (Meadows, 2011), which requires, among other things, a shift in teacher training. Therefore, our research focuses on facilitating systems thinking in chemistry education for pre-service teachers. The aim is to enable them to connect chemistry concepts with broader systems, particularly in the context of sustainability. This study analyses the reasoning processes of students while dealing with a complex system containing (non-)chemical subsystems. During semi-structured think-aloud interviews 25 pre-service teachers solved various tasks. These tasks were related to the lithium production system in the context of innovative battery technologies. The students engaged with a visualisation of the system in question, presented in the form of a system-oriented concept map extension (SOCME). Inspired by the works of Mahaffy et al. (2019), this visualisation was created by the first author based on an extensive literature review. The interviews were transcribed verbatim and a qualitative content analysis was conducted in accordance with established methodologies (Mayring, 2022) using MAXQDA. The data collected was analysed in two main approaches. Initially, the approach was to examine the pathways that pre-service teachers followed as they reasoned within the system. Subsequently, a process-oriented perspective was adopted in order to investigate how pre-service teachers connected different components of the system in their reasoning processes, focusing on cause-and-effect relationships. First results indicate that pre-service teachers need further prompting to make adequate causal connections between different components of a system, especially when linking conceptual chemical knowledge to subsystems such as the economy or the ecology. In the presentation the study and its content will be introduced, as well as future implications for chemistry education.

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OP11 – Material Stewardship: Framing Education about Chemistry's Mission in Sustainability

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Keywords: material stewardship, chemistry education, systems thinking

It is argued that material stewardship should be adopted as a high-priority mission for chemistry (Matlin et al, 2024). This provides a comprehensive framework within which to situate chemistry's central role as a sustainability science. It interconnects the roles of sustainability frameworks (e.g., Sustainable Development Goals, Planetary Boundaries, Human Security) and tools (e.g., circular economy, life cycle analysis, systems thinking) with chemistry movements and orientations (e.g., circular, environmental, green, one-world and sustainable chemistry and resilience thinking) to achieve sustainability for people and for the physical and biological systems of the planet. The mission needs to be adopted by all involved in chemistry education, research and practice. In this paper we explore the scope of material stewardship and the implications for chemistry education of adopting material stewardship as a central mission, presenting some of the tools that can facilitate teaching and learning. These include the Sustainability and Systems Thinking In Chemistry Education website (SaSTICE, 2024) which provides many educational resources, the SOCKit tool to support use of systems thinking and exploration of systems boundaries (KCVS, 2024a) and the Planetary Boundaries interactive electronic learning tool (KCVS, 2024a) to explore chemistry correlates of Earth systems (KCVS, 2024b).

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OP12 – Exploring Sustainable Chemistry Discourse in Serbian Chemistry Textbooks

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Keywords: chemistry textbooks, green chemistry, sustainability

In light of international frameworks such as Agenda 2030, sustainable development has become integrated into the curricula of several subjects in the Republic of Serbia, including chemistry, biology, physics, and geography. Additionally, new elective subjects have emerged with a narrow focus on aspects of sustainable development (Vukić, 2020). When designing curricula or adapting them to include sustainability topics, it is crucial to consider the specific characteristics of the local environment. However, governments often resort to "copying and pasting" curricula from other countries or regions, thereby neglecting national sustainable development goals and local context.
As textbooks wield significant influence in shaping children's minds, it is imperative that they nurture students' sense of empowerment and equip them with the skills to tackle environmental challenges. This preparation empowers students to effect change within their communities and in their daily lives. Hence, the aim of this study was to assess chemistry textbooks designed for secondary schools in the Republic of Serbia, presently circulating in the market and endorsed by the relevant ministry, with a specific focus on exploring their coverage of green and sustainable chemistry concepts. Our research employed standard textbook analysis methods, including content and comparative analyses. In this presentation, we will discuss our findings on the representation of sustainability topics, portrayal of the local context, and their placement within various lesson components in the analyzed textbooks.

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OP13 – Virtual Laboratories: A Blended and Sustainable Pedagogic Approach to Teaching and Learning of Practical Chemistry

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The centrality of laboratory work within chemistry programmes (Bretz 2019) already challenged in some quarters has come in for closer scrutiny, and from a wider range of angles in the post-Covid period.(Simmons & Mistry, 2023) In this climate we, a group of five Irish Higher Education Institutes have been working together on a widescale study to try to understand the best pedagogic approach to teaching practical chemistry for the education of today's student for tomorrow's employment.

In terms of sustainability and green chemistry approaches technology-led offerings for teaching laboratory skills including simulations and video content have obvious attractions. The availability of appropriate digital tools suggest some component of technical training could be provided in a way that avoids certain environmental costs associated with a traditional wet-lab – there is no need for processes for purchase, storage and disposal of chemicals, energy usage is minimised, infrastructural and equipment needs are reduced. Undoubtedly, digital tools have much educational potential, and so the how, the where, and the when, of their adoption in the chemistry laboratory curriculum becomes the challenge.

A key objective of our interinstitutional study was to provide an evidence-based answer to the question of how virtual laboratory resources are best integrated into the lab learning programme. In this presentation you will hear about how we structured the learning of practical chemistry with Year-One undergraduate science students at Maynooth University. In particular, we will discuss how the in-lab experience was bolstered by pre-lab training with lab simulations and in-house video content, and the impact of post-lab technical reinforcement in a virtual laboratory environment. We will share feedback on how our students valued this three-pronged, digitally supported approach to their education.

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OP14 – STEM-Lab electrochemistry activity through a contextualized approach

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Keywords: pre-service teachers; STEM; Predict-Observe-Explain

In the process of learning Chemistry, students often perceive the subject matter as abstract and detached from their daily experiences, thus finding it challenging to comprehend (Morais, 2022). Despite this perception, it is undeniable that Chemistry is a relevant scientific area to address contemporary societal issues. Considering this, laboratory activities that integrate technology into pedagogical frameworks can foster active participation and critical thinking among students. Within the scope of initial teacher education, we integrate Science, Technology, Engineering, and Mathematics (STEM) to tackle contemporary energy challenges. By replicating the process of energy production, preferably sustainable, through concentration cells on a laboratory scale, we propose a laboratory activity, that is coupled with a data measurement system associated with sustainable materials and a low-cost electronic circuit using the Arduino system. The activity was presented to the pre-service chemistry teachers as a closed box, with a content they had to discover. Inside there was a concentration cell with identical metal electrodes in both half-cells and electrolytes featuring different ion concentrations of the utilized metal. Outside the box was an Arduino circuit designed to measure electrical conductivity and potential difference data utilizing off the shelf sensors. During the execution of the activity, participants carried out predictions, observations, experimental measurements, and explanations regarding the experiment, enabling the mobilization of knowledge about electrochemistry, following a Predict-Observe-Explain strategy. In the end, they were encouraged to reflect on the possibilities of contextualizing the activity and integrating the proposal into the Science, Technology, Society, and Environment (STSE) approach via a post-session questionnaire. Twenty pre-service chemistry teachers, enrolled in a teacher training course, participated in the activity. The content analysis of their responses, show that the participants realized the potential to the activity be employed in contexts related to climate change, sustainability, energetic matrices, new materials for energy production, among others, topics directly associated with a STSE approach. Besides, it facilitated a reflective process concerning the practical implementation, addressing potentialities and challenges associated with electrochemical concepts, pedagogical, and the technological integration of the activity. Finally, participants also pointed out the educational value of the activity which allowed for the discernment of knowledge advancement in electrochemistry.

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OP15 – From Knowledge to Hope: Assessing High School Students' Knowledge of Climate Change, Mitigation, and Adaptation in the Context of Constructive Hope

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Keywords: climate change, adaptation, mitigation, knowledge, Constructive Hope, high school

The climate change crisis is one of humanity's most difficult challenges. Mitigation and adaptation are key strategies to address this issue. "Mitigation" involves actions to reduce the causes of climate change, such as greenhouse gas emissions, while "adaptation" refers to actions to cope with the effects of climate change already occurring or expected (Ratinen, 2021). Understanding climate change can lead to feelings of hopelessness and pessimism, which are counterproductive for addressing the issue. Therefore, education should focus on maintaining hope and promoting problem-focused coping strategies. Knowledge of climate change, mitigation, and adaptation strategies enables individuals to choose meaningful actions and avoid denial or misinformation about climate change (Ojala & Bengtsson, 2019). Studies indicate that while students are generally aware of greenhouse gases and their impact, they often confuse different environmental issues, like climate change and ozone depletion. Their understanding of complex climate processes and adaptation strategies is limited, potentially hindering their ability to respond effectively to climate challenges. The study's main goal was to map the knowledge needed to deal with climate change and to explore the relationship between students' knowledge of climate change and the relevant mitigation and adaptation strategies and their constructive hope around the climate change issue. A descriptive-correlative quantitative study, using a structured Likert-type questionnaire with no intervention plan was conducted with 140 Arab 11th-grade students from the northern part of Israel, studying chemistry and biology. The results indicated that students demonstrated a substantial understanding of climate change, including mitigation and adaptation strategies. Furthermore, the analysis revealed no statistically significant differences between male and female students concerning their knowledge of climate change and associated strategies, or in their levels of constructive hope regarding these issues. Additionally, the study found a statistically significant positive correlation between the students' knowledge about climate change and their constructive hope about addressing it. It is recommended that all education levels integrate climate change education, including mitigation and adaptation strategies, with an emphasis on practical steps students can take. Positive messaging around

constructive hope may be more effective in motivating students than pessimistic scenarios.

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OP16 – The Evaluation of History of Chemistry Chapter in textbooks in Turkey

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In this study, I examined the 9th grade textbooks of high school in Turkey in terms of history of chemistry. At first chapter of 9th grade, I evaluated the parts of ‘‘from alchemy to chemistry’’, and then ‘‘the discipline of chemistry and the working area of chemists’’ and ‘‘the symbolic language of chemistry’’. At first part of ‘’from alchemy to chemistry’’, there is a subheading that is the process of chemistry becoming a science. In this part, the contribution of civilizations to development of chemistry and the scientists who contribute to chemistry are examined. There are some missing parts in terms of scientists and *References* in this part. For instance, Islamic scientists are not in this textbook except Cabir Bin Hayyan and Ebubekir Razi. In another aspect, the symbolic language of chemistry is unknown in these textbooks. The book written by Maurice Crossland (Historical Studies in the Language of Chemistry-kimya dili üzerine tarihsel incelemeler) covers all parts of symbolism in chemistry in the world. The links of books are below:

https://ogmmateryal.eba.gov.tr/panel/panel/EKitapUniteOnizle.aspx?Id=169&sayfa=46

https://ogmmateryal.eba.gov.tr/etkilesimli-kitap/kimya?s=6&d=44&u=0&k=0

OP17 – The Arsenator – Using Coca-Cola to Analyse Arsenic in Rice

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Chemical education supports both the learning of chemical principles and real-world or daily-life implications of chemical processes. Arsenic, a toxic metalloid present in the environment through both natural and anthropogenic sources, exists naturally in more than 100 different organo-arsenic species and the more toxic inorganic species, arsenite (AsIII) and arsenate (AsV). Worldwide, it is not uncommon to find concentrations of arsenic exceeding World Health Organization (WHO) limit of 10 µg L^{-1} in groundwater (mainly inorganic arsenic (iAs) compounds). Unlike the majority of grain and cereal plants, rice possesses the capability to absorb and accumulate arsenic in its grains during growth, which can impact human health. The maximum contaminant level (MCL) of inorganic arsenic in rice and rice products is monitored by an EU regulation. Arsenic in rice can be easily analysed using the Arsenator field deployable method, which is based on the Gutzeit method and detects only the toxic inorganic arsenic (Bratlatai, 2015). It has been shown to be able to monitor environmental issues and food quality, such as the assessment of inorganic arsenic levels in rice (Dressler, 2023). For cost-effectiveness, easy as well as safer use, the Arsenator has been adjusted to use Coca-Cola as an extractant due to its ubiquity in the modern world (Wehmeier, 2023). This allows for semi-quantitative, in-situ, analysis of inorganic arsenic in rice after only one hour.

Utilizing the Arsenator as a hands-on tool in environmental chemistry, we've developed a student-focused lesson plan centered around the theme 'Arsenic in Rice.' This topic serves as a gateway to exploring key concepts in environmental chemistry, such as redox reactions and the analysis of chemical species (Passler, 2023). The approach offers students a wide range of perspectives to choose from, enhancing their learning experience and building up scientific literacy. They can explore the relevance of science in everyday life by examining contaminants in food, delve into real-world environmental issues like arsenic contamination in both the environment and our food supply, and understand the importance of Sustainability Development Goals (SDGs).

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OP18 – Important Moments among Chemistry Teachers in a Collaborative and Dynamic Learning Environment

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Keywords: formative assessment (FA), chemistry teachers, noticing

Engaging teachers and students in formative assessment (FA) activities is challenging. Teachers need guidance and support to conduct FA effectively (Murray et al., 2020). Through a physical chemistry-based escape-room (CER), designed for high school students, we examined teachers' FA knowledge. This pedagogical environment is an example of a collaborative and dynamic learning environment (CDLE), as it allowed teachers to focus not only on content knowledge but also on students' discourse and 21st century skills, such as collaboration (Haimovich et al., 2022) and listening skills (Avargil, 2022). This study investigated chemistry teachers' professional noticing to explore their FA knowledge and approaches of noticing and interpreting their students' learning situations in a CDLE. The research questions are: (1) what did chemistry teachers emphasize to promote their students' thinking and skills in a CER? (2) what did chemistry teachers notice as important to assess? (3) what are the characteristics of chemistry teachers' interpretation? A mixed methods approach with concurrent nested designs was employed (Creswell, 2003). The study includes 36 chemistry teachers who participated in a professional development program (PD) called "CER as a pedagogical tool for assessment". Following the PD program, teachers visited the CER with their high-school students. Video-audio systems were used to observe students solving chemistry problems in the CER (Avargil et al., 2021). We collected data using a questionnaire, teachers' observation worksheet, and video-based interviews. We analyzed the qualitative data using direct content analysis. The questionnaire was analyzed using factor analysis. Interviews and questionnaire answers indicated that chemistry teachers emphasized students' 21st century skills, including leadership, cooperation, and problem solving-strategy, as well as students' enjoyment and students' challenges, such as technical difficulties and chemistry problems in a CER (RQ1). Based on the teacher's observations worksheets, three noticing dimensions were identified: chemical thinking, 21st century skills, and affective noticing (RQ2). We found that: problem solving-strategies, cooperation, and identifying topics in the chemistry curriculum that the student is using successfully or incorrectly, were the common characteristics of chemistry teachers' interpretation (RQ3). This study showed that teachers paid attention to students' enjoyment, communication, and leadership skills. These results extend the research findings of Haimovich and colleagues (2022), who argued that CER enables students to share information, make eye contact, and laugh spontaneously. In addition, we found that chemistry teachers paid attention to students' thinking and identified three dimensions of noticing. According to previous research, chemical thinking noticing was

a significant noticing dimension (Murray et al., 2020). This study contributes to the use of modern collaborative and dynamic learning environments in chemistry teaching, enriching the educational strategies available for improving students' learning. Also, this study could promote theoretical knowledge about FA and assessment knowledge through teachers' professional noticing and specifically in learning environments that promote collaboration and teamwork in problem solving.

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OP19 – Integrating Systems Thinking Approaches in Chemical Education for Sustainable Development: Exploring the Status Quo

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Keywords: Systems Thinking, Education for Sustainable Development, Scoping Review

Systems Thinking (ST) is considered highly relevant for sustainable development due to its holistic approach and ability to address the complex, interconnected challenges of sustainability, such as climate change, resource depletion, or economic inequality (e.g., Reynolds et al., 2018). To address these issues, a reorientation of chemical education through the integration of ST approaches has been called for in recent years (e.g., Mahaffy et al., 2019; Talanquer et al., 2020). Accordingly, the number of research and development projects is steadily increasing, forming a growing body of literature. To obtain an overview of this emerging field of research, a Scoping Review (Tricco et al., 2016) was conducted. For this purpose, the two prominent scientific databases ERIC and Scopus were searched, resulting in 40 and 162 entries, respectively. The sample was extended by snowball technique and then analyzed descriptively to grasp the basic information of the literature (e.g., type of paper, place and year of publication, addressed educational level). Additionally, a qualitative content analysis (Kuckartz, 2014) was applied regarding (1) the definition of ST and ST skills, (2) aspects of sustainable/green chemistry, (3) characteristics of instructional approach/material, (4) design of study/implementation, and (5) empirical findings/implementation experience.In my presentation, I will describe the search strategy and selection process in detail, characterize the selected studies, and summarize their key findings according to the aspects mentioned above. I will also highlight gaps in the evidence and discuss the results of the Scoping Review from the perspective of inclusive chemistry education.

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OP20 – The Adoption of Green Chemistry in Brazilian Higher Education

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Keywords: Green Chemistry; higher educational institutions; courses.

The chemical industries, although responsible for many essential products, have long neglected environmental issues. Green Chemistry (GC) emerged to deal with the environmental and human health impacts of chemicals. After the launch of the book "Green Chemistry: Theory and Practice", written by P. Anastas and J. Warner, which presents the twelve principles of this branch of chemistry, the area was boosted by several studies. The principles are used as a guide for the production of new products and processes, providing support from the selection of raw materials to ensuring the efficiency and safety of transformation (Anastas & Eghbali, 2010). However, its practical implementation is still incipient due to the little importance given to this field during education and professional training. In Brazil, the lack of appropriate legislation makes it difficult to include it in higher education curricula (Vaz, Girotto Junior & Pastre, 2024). Thus, this study aimed to analyze how Brazilian institutions are addressing GC for a later correlation with Ibero-American and European systems. In this work, we used documentary analysis to access and process the data, searched for a list of all Brazilian educational institutions with chemistry-related courses and conducted individual searches on each institution's websites looking for subjects related to GC. We collected information on the application of GC concepts in these courses. Finally, we reviewed and organized the collected information to avoid possible errors. In total, 370 educational institutions offering Chemistry courses were considered. Of these, only 40 educational organizations (10.8%) offered exclusive courses on GC, with some of them presenting multiple curricular components, totaling 54 proposals dedicated to the area. Furthermore, proposals were found in 59 educational organizations (15.9%) that addressed GC indirectly, with 79 curricular components. It was noticed that this topic is more present in optional and theoretical courses, mainly for graduate and teaching training courses, taught predominantly in public institutions located substantially in the Southeast region. Although there are interesting proposals, the number of educational institutions that promote GC in their curriculum is still considered low. The training of professionals in the chemical area has historically prioritized technical excellence. However, currently, it is essential to maintain this technical quality while prioritizing training to face the challenges of contemporary society. Including GC in undergraduate curricula can promote greater awareness and engagement. Thus, it is essential to incorporate it through activities that foster critical thinking. Believing that suddenly everyone will adopt GC as a teaching method and discussions of issues in different areas

is extremely ambitious. However, this change can only be possible if the spark for the beginning is given.

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OP21 – Environmental Education Challenges: Understanding Bio-Geo-Chemical Cycles Among Slovenian Pre-Service Teachers

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Keywords: environmental chemistry, bio-geo-chemical cycles of substances, pre-service primary school teachers

Bio-geo-chemical cycles of substances are fundamental to understanding the interactions and influences between living and non-living elements of ecosystems (Schulze et al., 2001). Environmental education plays an important role in educating young people about environmental topics such as bio-geo-chemical cycles (Johnson, 2020), that are also reflected in the Sustainable Development Goals (Sustainable Development Goals, n. d.). One of the multidisciplinary sciences that form the basis for understanding the molecular aspects of the ecosystem is environmental chemistry (De, 2003). Teachers play an important role in educating the younger generations on environmental literacy (Brundtland, 1987). However, Yilmaz Yendi (2019) found a lack of knowledge among pre-service teachers on the topic of bio-geo-chemical cycles. In addition, many misconceptions about this topic were identified. In Slovenian school system this topic is introduced to students, in the subject of natural sciences and technology, by the primary school teachers (Ministry of school, 2023). Therefore, it is important that teachers have sufficient knowledge about bio-geo-chemical cycles to adequately teach the younger generations about these processes (Brundtland, 1987).

The aim of this study is to determine the knowledge of Slovenian pre-service primary school teachers about bio-geo-chemical cycles. It was also investigated whether there are statistically significant differences between first year pre-service teachers with different level of individual interest, self-esteem and different final grades in biology, chemistry and physics and their level of knowledge about bio-geo-chemical cycles. Furthermore, the misconceptions of pre-service primary school teachers were investigated. To answer these questions, two paper-pencil instruments were used: 1) a three-tier achievement test for detecting misconceptions about bio-geo-chemical cycles and 2) a paper questionnaire on individual interests and self-esteem. Students also provided information about their final grades in chemistry, physics, and biology in high school.

Results show that pre-service classroom teachers possess roughly adequate knowledge about bio-geo-chemical cycles. There are statistically significant differences between pre-service teachers with different levels of individual interest and self-esteem and their performance on bio-geo-chemical cycles achievement test. Pre-service teachers also have misconceptions about this topic, but the number of misconceptions is low. The

percentage of knowledge identified on the three-tier achievement test is also low among pre-service primary school teachers, indicating inadequate teacher training.

Together with the previous studies, this study shows that environmental education is far from reaching its full potential. Therefore, teacher education needs to be strengthened to maximize the results of environmental education and accelerate progress towards sustainable development as cited by Brundtland (1987).

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OP22 – A Case Study on Integrating Sustainability and Project-Based Learning in Chemistry Teacher Education

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Keywords: Chemistry teacher education, project-based learning,

This case study explores the potential of a novel chemistry teacher education course to support pre-service chemistry teachers' professional development and self-perception as educators. The course integrates sustainability and project-based learning (PBL), involving pre-service chemistry teachers and primary school teachers in co-creating and facilitating after-school science clubs for children aged 9-11. PBL has been recommended for sustainability and science education as a student-driven, teacher-facilitated pedagogical approach that organizes learning around clearly defined projects and engages students in collaboration and constructive investigations of authentic problems (Birdman et al., 2021; Haatainen & Aksela, 2021). The course addresses the need for teacher education to effectively integrate collaborative PBL, as gaps in teachers' understanding and practices can affect learning outcomes (Haatainen & Aksela, 2021; Krajcik et al., 2023; Mentzer et al., 2017). Data collected through learning journals, PBL plans, and a post-activity survey were analyzed using qualitative content analysis. Results suggest that integrating sustainable PBL in teacher education through engaging environments like after-school science clubs can significantly support future chemistry teachers' professional development. It helps them understand their strengths as teachers and prepares them to implement more learner-centered teaching approaches like PBL. While further study is needed, these findings contribute to the growing body of research on feasible PBL integrations into teacher education. They highlight the value of practical teaching experiences in authentic environment and collaboration within teacher education courses in fostering effective future teachers in sustainable chemistry education.

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OP23 – Embedding Systems Thinking into Sustainable Chemistry Course for Pre-Service Teachers

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Keywords: systems thinking, chemistry education, sustainability education

This study aims to develop a sustainable chemistry course for pre-service teachers, incorporating Systems Thinking (ST) as a key learning objective. ST is widely recognised as a crucial competence in sustainability and is increasingly considered an essential element of chemistry education, especially in the context of sustainability (Bielik et al., 2023; Mahaffy et al., 2018; Orgill et al., 2019). While significant research on ST in chemistry education has been conducted in recent years, there remains a notable lack of research concerning the education of pre-service chemistry teachers (Bielik et al., 2023). This research forms part of a developmental study within a PhD project, aimed at developing an educational sequence for the Sustainable Chemistry course in chemistry teacher education. The research is guided by three research questions (RQs): 1) How do the elements appear in students' concept maps and written assignments? 2) How does the exercise support students' learning of systems thinking from students' perspectives? 3) Which aspects of sustainable chemistry does the ST exercise support in learning from students' perspectives?

The first implementation occurred in autumn 2023 and final data will be collected from the subsequent implementation in fall 2024. Data will be collected through course assignments and a group interview. The assignments, serving as data sources, comprise: 1) systems thinking concept maps, 2) written assignments, and 3) learning diaries. Assignments will be analysed by an assessment rubric to answer RQ1. RQ2 and RQ3 will be answered by qualitative content analysis based on learning diaries and group interview.

Preliminary findings suggest that the concept map exercise is an effective learning tool for ST, as all students reported that the concept map was the most effective exercise for learning ST in the course. However, a noticeable variation in the quality of the concept maps produced was observed.

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OP24 – Teachers' role in developing students' agency for SDGs

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Keywords: Sustainability development goals (SDGs), Students' agency, Case stady

Student agency refers to the ability to set a goal, reflect, and act responsibly to make an appropriate change. There are international calls to elevate student agency for the Sustainable Development Goals (SDGs) (e.g., OECD, 2019). Teachers play a key role in designing learning activities that could help students develop agency (Calvert, 2016). These specific teaching-learning activities provide a multifaceted collection of theoretical and practical approaches that could foster student agency and empower students to actively participate in achieving the SDGs. The SDGs were defined by the UN in 2015 as a group of 17 global goals, aimed at ensuring sustainable, prosperous, egalitarian life on earth for all citizens of the world, and they are considered essential for humanity's survival on earth (UN, 2015). The "speak to me in numbers" is an intervention program that was designed to address selected SDGs. The program is based on an innovative "data-driven" pedagogy that guides the students to access relevant data, process and analyze them, reach insights and conclusions, and then propose solutions based on the data analysis (Rap et al., 2022). At the end of each unit in the program, the students were asked to conduct an activism project that would help address and reduce the problem of CO2 emissions. This stage may serve as a fertile ground for developing agency. The research population included 15 science teachers teaching 9th and 10th grades, along with their 125 students. To determine what roles teachers play in developing student agency, we applied a qualitative research approach of case studies. Semi-structured interviews were conducted with all teachers and 10 of their students. Through these interviews we aimed to identify different ways in which teachers supported (or not) the development of their students' agency and to learn about the resources the students used to develop their activism about sustainability issues. Classroom observations were conducted over 3 lessons to learn about the teachers' methods and the role they played in developing the students' agency as well as the ways in which students enacted their agency to prepare and present their activism project. For triangulation, we also analyzed students' presentations of their activism project. We adopted a case study methodology to portray the teachers' different approaches. We found that the teacher plays a central role in mediating the development of their students' agency. The teacher can either develop an "educational sustainable agency" that nurtures the students' sustainable agency or they can develop a "co-agency" with their students. We also found that when the teachers did not utilize any of their agencies, consequently their students did not develop a meaningful agency for sustainable

development. We will discuss the results and the implications for teachers' professional development in the lecture.

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OP25 – Impact of Team-Based Learning on Student Engagement and Learning Outcomes in Physical Chemistry

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Keywords: team-based learning, student engagement, learning outcomes

Team-Based Learning (TBL) has emerged as a prominent instructional method in higher education, emphasizing active student engagement and collaborative learning (Considine et al., 2021). In this context, this study was conducted within a Physical Chemistry course designed for 1st-year gene technology students. The primary focus of this research was to investigate how various learning materials provided by the instructor influenced students' independent learning and academic performance, as well as to explore the impact of team dynamics on the effectiveness of solving application tasks in physical chemistry. Data for analysis were collected during both mid-semester and end-of-semester periods in 2023 and 2024.

To understand students' learning experiences in the TBL learning environment, we designed a comprehensive questionnaire based on previous studies (Craig et al., 2020; Jarjoura et al., 2014; O'Neill et al., 2020). The questionnaire consisted of 11 items with a 5-point Likert-type scale, ranging from "strongly disagree" to "strongly agree," and four open-ended questions where students could comment and justify their answers. The Likert-scale items aimed to measure various aspects of the TBL experience, including engagement, understanding, and teamwork dynamics. The open-ended questions provided qualitative insights into students' personal experiences and perceptions. Data were collected during the mid-semester and end-of-semester periods in 2023 and 2024, allowing for a comparison of student experiences and perceptions over time.

Freeman's study (Freeman 2012) and supporting research indicate that student resistance to TBL is a common issue during initial implementation. This resistance is often due to a preference for traditional lectures, the increased responsibility placed on students, and a general reluctance to change. Addressing these concerns through clear communication, gradual implementation, and highlighting the benefits of TBL can help mitigate resistance and foster a more positive learning experience. Additionally, the quality and diversity of learning materials, as well as the role of the instructor, play crucial roles in the adaptation of TBL methodology.

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OP26 – The Norms of Chemistry and How Students Figure Them

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Keywords: chemistry identity, upper secondary school, nature of chemistry

This study investigates how Danish upper secondary school students, with elective chemistry, figure the norms and practices of chemistry. This gives a way to better understand what kind of students can build a positive chemistry identity. Because of concerns about uptake in chemistry-related education, there is an interest in chemistry education research (CER) to understand students' considerations and aspirations about chemistry (Archer et al., 2022). This study is significant as it provides empirical insights into students' conceptions of the norms, nature, relevance, and celebrated practices in chemistry and how these support or hinder students' chemistry identity work. By using a novel approach in CER, figured world (Holland et al., 1998), to theorise how students figure chemistry and celebrate practices (Günter et al., 2023), this gives insights into what kind of students can build chemistry identity (Hosbein & Barbera, 2020). Classroom observations at 3 diverse upper secondary and focus group interviews with 45 students compromise the data. Analysis shows that students figure chemistry in two distinct ways: the lab and the theoretical classroom. The lab world characterises a creative, cooperative, process- and methods-focused way of doing chemistry. Lab is seen as the essence of chemistry which is made relevant with applied and sociochemical aspects (Sjöström & Talanquer, 2014), and practical knowledge is celebrated above mathematical knowledge. The classroom world is characterised by the high-stakes performance of chemical language, chemish (Markic & Childs, 2016). Even though students label the lab world as essential and desirable, their characterisation of a good chemistry student majorly describes what is celebrated in the classroom world. Such a strong celebration of a narrow and purist way of performing chemistry hinders students, especially female students and those without science-educated relatives, from identifying with chemistry. The performance in the lab is however not neutral either, as those students who perform the greatest variety of tasks seem to be those who have science-educated relatives. This calls for change in what performance is formally celebrated in chemistry, like in exams, and an increased investigation of roles in lab work.

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OP27 – First Hungarian Results of the IUPAC Teacher Survey on Green and Sustainable Chemistry Practical Activities

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Keywords: practical activities, green chemistry, sustainability

Sustainability and green chemistry are current and widely researched subject nowadays. Google Scholar have found in February of 2024 more than 1000 review papers for "Green Chemistry" and 477 review papers for "Sustainable Chemistry" published in this year. Therefore, these themes should appear in education of chemistry, too. Practical activities are also very important in chemistry teaching. Rogers & Fraser (2023) found that one practical work in every two weeks increased significantly the secondary schoolers' attitude towards sciences. Therefore, the goal of this research was to collect ideas from the Hungarian secondary school teachers about what practical activities they use for teaching green and sustainable chemistry concepts.

The other research question was what could help and what may make difficult to the teachers to use more practical activities. We use the online questionnaire of the project to collect data. We are still in the data collection phase, but we have already found some interesting ideas, i.e. use traditionally popular experiment from a new viewpoint. The first statistical analyzes of the data already available suggests i.e. that those teachers, who think that experiments help the students to develop their social competences, uses more practical activities.

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OP28 – Enhancing Diversity and Inclusion in Science Teacher Education: Insights from a Diagnostic Study.

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Keywords: Chemistry Education, Pre-service Teachers Beliefs, Mixed-Methods Study

This research is conducted under the auspices of the Erasmus Plus Teacher Academy acaSTEMy project (Project homepage) which aims to foster an international science teacher network. Through acaSTEMy, science teachers will be equipped with the necessary tools to prepare students for their future careers by addressing global challenges and promoting sustainability, including topics such as the 'Green Deal,' 'Health Education,' and 'Diversity and Inclusion.' These issues are not treated as separate entities but are fundamental components of a comprehensive approach to teaching chemistry. The project endeavors to enhance both pre- and in-service education through seminars focusing on these global issues.

With a particular focus on diversity and inclusion, this study aims to diagnose the current beliefs and perspectives of future chemistry teachers and subsequently utilize these insights to design a seminar session that addresses the specific needs of science teacher education.

Diversity in classrooms encompasses various facets including (dis)abilities, ethnicity, socio-economic background, and language diversity. Inclusiveness in teaching entails the ability to effectively engage and educate students from diverse backgrounds (Grace & Gravestock, 2008). To gauge the current understanding and identify areas of improvement, a diagnostic study on pre-service chemistry teachers` beliefs about diversity and inclusion was conducted. In a meaning of a mixed-method study, this work comprised both quantitative (Likert-questionnaire) and qualitative (open end) questionnaire.

The qualitative questionnaire revealed that most of the pre-service teachers already recognize various facets of diversity and understand inclusion as the process of fostering participation and equality. Despite a minority of students reflecting on the absence of perceived need for inclusion in both their past school experiences and anticipated future classrooms, as they were unaware of whom it would benefit, the majority of them recognized the inevitability of inclusion in their future classrooms. Nonetheless, they highlighted a notable deficit in knowledge regarding effective methods and skills to address diversity. These results were triangulated by the quantitative questionnaire. Moreover, while over 70 % of the participants claimed to recognize diversity within their classrooms, only a smaller proportion of them felt confident in identifying the resulting needs. The qualitative questionnaire further highlighted the challenges pre-service

teachers face, particularly regarding teaching chemistry to students with lower linguistic skills in the language of introduction.

These findings underscore the pressing need for science teacher education programs to cultivate a heightened awareness of diversity among future educators, alongside equipping them with strategies to effectively navigate diverse classroom environments. Thus, in our presentation, a snapshot of pre-service science teachers' beliefs and perspectives on diversity and inclusion will be presented and a seminar design discussed, which is implicated from the data. By addressing these issues head-on, we aim to contribute towards creating more inclusive and effective science education environments for all students.

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OP29 – Promoting classroom emotional climate for meaningful science learning: Findings from an ADDIE approach

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Student emotion is seen as one of the most crucial predictors with respect to student achievement in science learning (Chiang & Liu, 2014; Membiela et al., 2018a, 2018b), their aspiration to choose science-related career in future (Itzek-Greulich & Vollmer, 2017; Palmer et al., 2017), and their application of science learning in their everyday life decisions(Ma, 2021; Ritchie, 2014; Staus & Falk, 2017). However, several studies report a decline in student positive emotion in learning science, particularly physics and chemistry, as they advance from one grade to another (Potvin & Hasni, 2014; Sheldrake et al., 2019).

In mitigating against such decline, from one point of view, (Hofstein & Mamlok-Naaman, 2011; Oon & Subramaniam, 2011) suggest that physics and chemistry concepts become more complex, boring and abstract as the students advance to next level, which can be seen as contributing to student lack of interest. In line with that, (Höft et al., 2019; Lyons, 2006) suggest that the lack of motivation to learn physics and chemistry is strongly related to the lack of relevance of their learning with respect to their everyday lives. Hence, in addressing such concern, there is a need to promote physics and chemistry learning as comprehensible, interesting, relevant, and enjoyable (Holbrook & Rannikmae, 2017; Pelch & McConnell, 2017; Teppo et al., 2021), altogether expressed as meaningful learning (Jonassen & Strobel, 2006a; Onowugbeda et al., 2022).

From another point of view, in mitigating against decline in student positive emotion, recent research emphasises the significance of a promoting positive classroom emotional climate (Feyzi Behnagh, 2020; Long, 2016a; Membiela et al., 2018c; Rinchen et al., 2016). Recent studies suggest that students are more likely to engage in higher-level thinking and problem-solving activities, leading to a more profound understanding of scientific concepts, when they feel emotionally supported, and connected to their learning environment (Dávila-Acedo et al., 2021; Matthews, 2004; Sanchez-Martin et al., 2018).

In a positive classroom emotional climate, students are more likely to experience a sense of autonomy and competence, which are essential components of intrinsic motivation (Gillen et al., 2011; Hanuliaková & Barnová, 2015; Williams et al., 2013). This intrinsic motivation is linked to higher levels of engagement and a willingness to persevere through challenging science topics (Bates, 1979; Gottfried, 2016; G. Taylor et al., 2014). Furthermore, a positive emotional climate in the classroom enhances students' sense of belonging and reduces stress and anxiety, thereby creating an environment conducive to meaningful science learning (Allen et al., 2013; Long, 2016b;

Rahayu et al., 2017). When students feel included and valued, they are more likely to connect their learning to real-world applications and develop a deeper appreciation for the relevance of science in their lives (Banner, 2016; Bianchini, 2017). Ultimately, a positive emotional climate in the classroom fosters a supportive and collaborative learning environment, enabling students to engage in meaningful scientific inquiry and critical thinking.

Research further suggests that promoting meaningful learning within a positive classroom emotional climate require student involvement in in multiple stages (Ahmadi, 2021; Higgins et al., 2019; Mäkelä et al., 2018). Firstly, students are the primary beneficiaries of the school system; hence student voice offers a great deal of resource in the designing process of meaningful learning (Danaher, 1994; Fullan, 2015; Kozol, 2012; Levin, 1994). Secondly, student involvement in the development process of teaching-learning approach, material, and assessment offers a platform to utilise student emotional capital and lived experiences, which further allows them a sense of ownership, autonomy and sense of belonging (Aksela, 2019; Landoni et al., 2018; Örnekoğlu-Selçuk et al., 2023; Salisbury et al., 2020). And finally, student involvement in evaluation of meaningful learning and classroom emotional climate ensures social justice at a school level (Cook-Sather, 2018; Mansfield, 2014; C. Taylor & Robinson, 2009).

Therefore, the author of this study has conducted an action research over a one-year timeline, in which 4 aspects were taken into consideration – student voice, co-design with students, classroom emotional climate, and meaningful learning. In this article, a synopsis of the research is reported so as to initiate further research discussion in this context.

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OP30 – Computational Methods of Varying Complexity in High School Chemistry

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Keywords: chemistry education, computational chemistry, simulations

The use of computational methods in high school chemistry has long been a topic of academic inquiry (Jones, 2013). In research, computational chemistry is used for example to study biological molecules in the search of potent drug compounds (Genheden et al., 2017; Jha et al., 2023). Recent initiatives to implement computational chemistry to learn about physical properties of atoms and molecules in high schools have shown promising results (Hrubeš et al., 2024). However, such endeavours have also illuminated difficulties of disseminating these new methods into school practices (Traube & Blonder, 2023). The need of professional development may contribute to establishing new teacher competences, but introduces challenges to independent implementation of these methods by teachers. User-friendly computational methods and materials could be a complement for teachers to use directly in classrooms, or, as a way to also reach students of lower academic performance.

We performed two classroom studies (manuscripts in progress) to evaluate the design and classroom implementation of simulation assignments concerning physical chemistry (polarity, intermolecular attractions and equilibrium). Learning gains in the first study were similar for simulation activities and conventional teaching. In interviews to explain these findings, students indicated that the learning methods can be combined to better accommodate students´ different ways of learning. Materials for the assignments in both studies were of a moderate difficulty. They were designed in collaboration with chemistry teachers following workshops on computational methods for chemistry learning in classrooms. The design process provides a template for inviting teachers to simultaneously achieve professional development, while designing activities adapted to their respective student populations.

This presentation will outline emerging computational methods for working with chemistry in high school classrooms. Experiences of teaching and designing molecular modeling computer labs in university courses, together with outcomes of our studies and outreach activities will be taken as points of departure. Means for working with these topics while catering to different student needs will be discussed along with strategies for implementing computational chemistry in high schools.

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OP31 – Green and sustainable practical activities in Serbian secondary schools: The analysis of open-ended IUPAC teacher survey questions

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Keywords: green chemistry, practical activities, IUPAC teacher survey.

The integration of green chemistry and sustainable development topics in the chemistry education of students in many countries has become crucial. With this aim, many approaches have been implemented, and one of them is green chemistry practical activities in education process (Timmer et al., 2018).

Therefore, the purpose of this study was to find out what types of practical activities Serbian secondary school chemistry teachers utilize regarding green and sustainable chemistry. For this study, data was collected within multi-country IUPAC survey: International Teacher Survey on Green and Sustainable Chemistry (GSC) Practical Activities. The online survey was open for the Serbian chemistry teachers from November 2023 to May 2024, and the data from 223 secondary chemistry teachers was collected. The survey was translated to Serbian language and required 15 - 20 minutes to complete.

The Teacher Survey contains several blocks of questions, including teachers' demographics, closed answer questions, short answer – open response questions, and several additional questions unique to the specific country. Here, the results of open-ended and additional questions from the Teacher Survey will be presented. The survey contained four open-ended questions about the types of practical activities that chemistry teachers use in their classes and two additional multiple-choice questions unique for the Serbian teachers. The results will be grouped into several categories regarding the sub-topics of practical activities that teachers have used. The first results showed that chemistry teachers utilize practical activities regarding the water quality, water hardness, cleaning drinking water, recycling paper, and composting.

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OP32 – Universal Design for Learning - Building a University Culture of Inclusion

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Keywords: Universal Design for Learning, Cross-Faculty Initiative, Inclusive Laboratory Education

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. The UDL Framework, originated with CAST, Inc., The Center for Applied Specialized Technology1, but has subsequently been developed to address multiple intersectional barriers to learning. Despite the existence of the UDL framework and associated resources, implementing UDL in practice can be daunting for educators, particularly when working with large classes.

This presentation describes our experiences with an UDL Teaching and Learning Fellowship initiative entitled 'UDL - Building a culture of inclusion in Maynooth University'. The presentation will outline key learnings in terms of creating and building an all-campus culture of inclusion through the lens of UDL and through engaging with academic departments and professional and support offices to ensure a university culture of inclusion is the norm. Working in collaboration with the Maynooth University Access Office and the Centre for Teaching and Learning, four dedicated UDL Teaching and Learning Fellows, with backgrounds in diverse disciplines (Chemistry, Business, Education and English), have developed a transdisciplinary Resource Hub and an all-university awareness campaign. The presentation will outline the rationale for a cross faculty collaborative fellowship approach to creating and sustaining an awareness and culture of UDL for inclusion on campus. While the core principles of UDL remain consistent across disciplines, the specific strategies and methods for implementation vary to meet the needs of every students and to reflect discipline sensitive pedagogical approaches. We will describe the impact, evidenced from student feedback, that the UDL framework has on the teaching of laboratory chemistry at our university.

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OP33 – Science Lessons from the eternal Ice: Glaciers as a Gateway to an education for sustainable development

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Glaciers are a prominent example of climate change, but students have little knowledge about glaciers and alpine regions, which is also characterized by some misconceptions. (Felzmann, 2017). Students' ecological awareness is positively influenced upon direct engagement with firsthand experiences of climate change-affected landscapes (Young, 2020), but for most students it is impossible or at least quite difficult to get on glaciers and have these experiences. With our project, GlacierXperience (www.glaciereducation.com), we aim to integrate the topic of glaciers into science education by implementation of glacier excursions with student groups on-site, as well as through model experiments, inputs, and virtual glacier experiences within a digital 360°-learning environment with a VR-Option. The development of these experiments, utilizing the method of educational reconstruction (Duit et al., 2012), considers current research questions and results. Student inquiries, such as the nature of the black layer enveloping the ice, serve as examples to guide this process. For example, the project includes model experiments that investigate the melting of permafrost soil and glacier ice, which ins some regions can precipitate the acidification and the accumulation of heavy metals in rivers and lakes (Jones et al., 2019). The talk gives an insight into the development of the learning environment and the implementation of a glacier laboratory for students at the Schladming Glacier (Dachstein, Austria).

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OP34 – Pedagogical Content Knowledge and the implementation of a Multistrategic Didactic Unit on the theme of Green and Sustainable Chemistry: first approximations

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Keywords: Pedagogical Content Knowledge. Lesson planning. Green and Sustainable Chemistry.

Pedagogical Content Knowledge (PCK), a theoretical construct that models teacher professional knowledge, has been widely investigated since the late 1980s (Shulman, 1987). In this regard, a reference used in Chemistry lesson planning is the formative path called Multistrategic Didactic Unit (MDU), with which Alves et al. (2023) evaluated the mobilization of topic-specific PCK. In our work, we sought to further explore the relationships between the Refined Consensus Model (RCM) of PCK (Carlson et al., 2019) and MDU frameworks. That said, our study aimed to investigate the development of a pre-service Chemistry teacher's PCK throughout the implementation of an MDU on the theme of Green and Sustainable Chemistry. The method consisted of a qualitative case study approach with three stages, namely: (1) the application of a peer-validated Likert-scale questionnaire (Q1) on the RCM components; (2) the development of the MDU by the teacher under investigation; and (3) the reapplication of Q1. To carry out data assessment, we combined document analysis and Discursive Textual Analysis (DTA) (Moraes & Galiazzi, 2016). Findings indicate that the MDU contributed to the mobilization of the RCM components of the teacher, suggesting that professional development was achieved.

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OP35 – To do or not to do practical activities: Turkish chemistry teachers' experiences and views on practical activities and green chemistry reported on IUPAC global survey

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Keywords: Green and sustainable chemistry, Practical activities, In-service chemistry teachers

Practical activities as conveying the macroscopic level representations, are a fundamental aspect of chemistry, besides symbolic and sub-microscopic representations (Johnstone, 1991). They have been found to be effective in developing science process skills (Giddings, Hofstein & Lunetta, 1991), creating meaningful learning (Hofstein & Lunetta, 2004), improving problem solving skills (Gunstone, 1991) and developing positive attitudes towards chemistry (Shibley & Zimmaro, 2002). However, it is still questionable how well they are implemented in high school chemistry classes in Türkiye. This is due to potential limitations such as a lack of physical space, materials, and resources and inadequate teacher training. As the world increasingly adopts a green and sustainable approach in chemistry, it is important to investigate chemistry teachers' views and experiences with the green chemistry. As part of a chemistry education project funded by IUPAC, a global survey was developed to assess teachers' implementation of practical activities relevant to green and sustainable chemistry in different countries. The Turkish adaptation of the survey and implemented to the 120 high school chemistry teachers working at different geographical regions and types of schools in Türkiye. Additionally, five focus group interviews were conducted by the voluntary teachers to better understand the teachers' experiences and views. The analysis revealed the different perspectives, methods and views of chemistry teachers in implementing practical activities, both in general and specifically related to green and sustainable chemistry.

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OP36 – Sima Lozanić's secondary school chemistry textbooks as artifacts: changes in the Periodic table in late 19th and early 20th century editions

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Textbooks are integral parts of cultural and specific disciplines heritage because they represent the time and context in which they were written, reflecting trends and principles in particular areas of education. They also convey the academic knowledge and beliefs of their authors, influenced by various social, cultural, economic, and political factors. Reviewing and analyzing chemistry textbooks from their beginnings to the present provides insights into the development of ideas in chemistry and how chemical knowledge has been presented to generations of students.

The teaching of chemistry as an independent subject in Serbian secondary schools dates back to 1874. Significant improvements in chemistry teaching occurred in the mid-1880s, thanks to Sima Lozanić (1847-1935), a chemist, professor, president of the Academy of Sciences, first rector of the University of Belgrade, minister, ambassador, and diplomat. He wrote the textbook Chemistry for Secondary Schools, which had six editions published in 1895, 1897, 1903, 1910, 1921, and 1925.

Sima Lozanić did not include the Periodic table of the elements in the first edition of his secondary-school textbook, even though it was featured in his previously published university inorganic chemistry textbooks (1880, 1884). However, the second and all subsequent editions of Chemistry for Secondary Schools contained the Periodic table in different forms. Our research focused on the various representations of the Periodic table in Lozanić's secondary school textbooks and identified similarities and differences among them in light of newly discovered elements at the time. The Periodic table in the second edition had a tabular form, while schematic representations appeared in later editions. Each new edition featured more element symbols and additional information, such as atomic weights (1910, 1921) and atomic numbers (1925).

This comparative analysis of the Periodic table in textbooks by the same author over three decades provides valuable insights into the incorporation of scientific knowledge (Mendeleev’s Periodic table) into teaching practice. It also could be used in chemistry teaching as an illustration of the tentative nature of scientific knowledge in light of newly discovered evidence.

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OP37 – Engaging students in the exploration of Antibiotic Coordination Frameworks (ACFs) using sustainable methods

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Keywords: Laboratory Experiment, Antibiotic Coordination Framework (ACF), Medicinal Chemistry

For decades, antibiotics have been crucial in therapeutic applications, but antibiotic resistance now poses a significant global health threat. This work introduces an innovative laboratory practice for the inorganic medicinal chemistry course for Pharmacy and Biochemistry undergraduates, spanning three two-hour classes. In the first class, students synthesized an Antibiotic Coordination Framework (ACF) using nalidixic acid and zinc, achieving an 82% yield with high purity. Data collection involved characterizing the Zn-nalidixic acid ACF (Zn-ACF) in the second-class using Fourier-transform infrared spectroscopy (FTIR) and powder X-ray diffraction (PXRD). The final class tested the antimicrobial activity of Zn-ACF against Escherichia coli via the well diffusion method, analyzing the zone of inhibition to determine efficacy. Results showed Zn-ACF had significantly higher antimicrobial activity compared to nalidixic acid alone, demonstrating that minor chemical structure changes can result in substantial biological differences. Students presented their findings in poster format, enhancing their scientific communication skills. Conclusions indicated that this interdisciplinary experiment effectively integrated Medicinal Chemistry, Microbiology, Analytical Techniques, Public Health, and Pharmacology, promoting Service-Learning practices and providing a model for other courses and institutions.

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OP38 – Nanotechnology Education as a Gateway for Promoting Sustainability

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Education plays a critical role in promoting sustainability by equipping individuals with the knowledge, skills, and values necessary to address environmental challenges and work towards a sustainable future. In this regard, education of pre-service teachers is essential for integrating sustainability into education. They prepare educators to implement sustainable practices in their teaching (Van der Klink, 2023).

The current study deals with integrating nanotechnology aspects as a potential role in enhancing sustainability. For this purpose, this study aimed to teaching sustainable aspects based on nature mimicking and testing its effect on learning motivation, learning environment among science pre-service teachers. The study focuses in developing and implementing lab experiments aimed to produce superhydrophobic surfaces based on carbon nanostructures inspired by “lotus leaves” effect which hold great potential for developing sustainable superhydrophobic surfaces with enhanced durability, anti-fouling, and self-cleaning capabilities for various applications (Wang et al., 2022).

Employing a quantitative, quasi-experimental research design, it focused on second-year science pre-service teachers at the Arab Academic College in Haifa, involving a sample of 90 students. The research instruments comprised two questionnaires assessing learning motivation, learning environment, and a test to evaluate educational achievements.

The study's outcomes substantiated all three hypotheses, revealing that post-intervention, the experimental group exhibited significantly elevated levels of learning motivation, enhanced learning environment, and improved achievements compared to the control group.

The study concludes that the intervention, centering on the development and implementation of a nanotechnology-based laboratory experiment on superhydrophobic surfaces for sustainable effects, markedly benefits the experimental group's academic performance. The contrast in outcomes between the experimental and control groups underscores the intervention's pronounced efficacy. This finding reinforces the notion that pedagogical approaches, particularly those integrating contemporary scientific innovations with conventional educational frameworks, can substantially augment the academic outcomes of educators, thereby invigorating the educational milieu with innovative and efficacious methodologies.

The study underscores the paramount importance of adeptly training educators in the integration and application of technological educational tools. The objective transcends mere proficiency in tool usage; it emphasizes utilizing these tools to cultivate a

comprehensive, interactive learning environment. When astutely deployed, technological tools possess the capacity to metamorphose traditional educational settings into vibrant hubs of collaborative learning.

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OP39 – Practical (green) chemistry in Czech schools: A myth or reality?

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In the last decade, the topic of educational experimentation in school chemistry has gained attention, challenging the traditional view that chemistry is an experimental science reliant on experiments. Reflecting this perspective, some authors cautiously refer to such activities as practical tasks (Abrahams & Millar, 2008) to cover all activities of experimental nature and aiming to more accurately assess student engagement with experimental activities (Osborne, 2015).

In 2023, under the auspices of IUPAC, an initiative was launched to raise awareness of this issue in countries worldwide. The International Teacher Survey on Green and Sustainable Chemistry (GSC) Practical Activities has drawn the attention of researchers in over 50 countries. This contribution builds upon a previous survey (Rusek et al., 2020), intending to complement it with a generalizable sample schools and regions in the Czech Republic. The opportunity to compare results across participating countries is an undisputable benefit. By mid-March, over 900 respondents had completed the online questionnaire, with data collection continuing until the end of April. This paper will present an analysis of responses to questions about both the frequency and nature of experimental activities conducted. A special focus is placed on green chemistry, a topic not previously studied in the national context. The results aim to highlight an often overlooked aspect of chemistry education, providing concrete evidence of the need for support applicable to pre and in-service teacher training, and discussions with stakeholders who can promote the wider inclusion of meaningful green chemistry experiments in education.

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OP40 – Drawing Cartoon Strips as a Visualization Tool in Pre-service Chemistry Education

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Keywords: Pre-service Chemistry Education, Teaching Practices, Representations

There is a rich history of using various visualizations in chemistry education. Though, only infrequently students are directed to create visualizations. Drawing cartoon strips offers possibilities for pre-service chemistry teachers to acquaint themselves with representing chemistry contents using an activating model. In this model, students create visualization themselves. (Ainsworth et al., 2011; Williamson, 2015) In our study, chemistry education students draw cartoon strips when different titrations were applied. Altogether 21 students and three teaching assistants participated in the research. Research included questionnaires, interviews, and analysis of students' learning tasks. Aim was to investigate how students regard drawing cartoon strips, and how drawing helps students' learning. (Välisaari & Nuora, 2021)

Pre-service chemistry teachers considered visualization of titration using cartoon strips motivating and positive. Also, students were able to transfer their knowledge to new titration theories. Based on the results, we consider that the use of chemistry knowledge on multiple levels in visualizations leads to deeper learning. It was necessary, that students created their own representations. This guided students to build representations suitable for their own thinking. Thus, the used method proved as a motivating learning tool which was accepted by the pre-service chemistry teachers, both for their own learning and a tool for their own teaching.

According to the teaching assistants, teachers' support is needed when pre-service chemistry teachers create their cartoon strips. Representations of challenging contents may overload students' working memory and thus discussion with course instructor is necessary. Sometimes reading of students' drawings can be challenging and demands students' explanations. Arrangement where students first draw the cartoon strips and then instructor discusses with them, has proved to be a workable solution. Drawing of cartoon strips is also a tool to evaluate learners submicroscopic level understanding and to correct misconceptions. Further research is needed to find out how teachers can effectively use drawing of cartoon strips in upper secondary school teaching.

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OP41 – A Role-Playing Tabletop Game on Laboratory Techniques and Chemical Reactivity: Gamifying Organic Chemistry Education

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Keywords: Game-based learning, Organic chemistry education, Student engagement

Teaching laboratory classes are crucial in chemistry courses, aiming to enhance scientific understanding, convey the principles of the scientific method, and improve practical skills (Reid and Shah, 2007). However, past research shows that these goals are closely tied to student engagement (Bretz, 2001). Recent years have seen declining engagement levels, exacerbated by the COVID-19 pandemic (EdWeek Research Center, 2023), evidencing the need for new pedagogical approaches. One emerging strategy to address this is game-based learning (GBL), which makes learning more entertaining and motivating, thus fostering active participation. In chemistry education, GBL can stimulate critical thinking and engagement by presenting challenging concepts in an engaging format. Within this framework, we designed and implemented a new tabletop game with fantasy and role-playing elements in our organic chemistry laboratory. The game reimagines the classic 'Identification of an Unknown' challenge, where students collect information to identify an unknown organic compound. Information such as Infrared Spectra or Elemental Analysis is acquired with in-game currency, earned through solving organic chemistry problems and performing experimental tasks focused on common purification and separation techniques. The game also covers the chemical reactivity of functional groups using wet chemistry tests. The study aimed to develop students' analytical skills, enhance their process skills, and deepen their understanding of organic chemistry. Student reception was assessed via anonymous surveys, measuring engagement, motivation, and perceived learning outcomes. Evaluation marks also improved compared to previous years, suggesting that gamifying the organic chemistry laboratory enhances learning. This study indicates that GBL can be a valuable tool in promoting student engagement and learning in chemistry laboratories.

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OP42 – Unlocking Knowledge: Can Nanochemistry Escape Rooms Promote Learning?

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Keywords: Educational Escape Rooms, Nanotechnology, Secondary school

Escape Rooms (EsRms) have rapidly gained popularity as an enthralling activity, attracting participants from various backgrounds. These immersive games typically involve small groups collaborating to uncover hidden clues and to solve perplexing codes. Inspired by the success of EsRms, educators and researchers worldwide have adapted this concept for educational purposes. Educational Escape Rooms (EdEsRms) offer numerous benefits, ranging from fostering cognitive and emotional learning, to nurturing teamwork, critical thinking, communication, and innovation skills essential for the 21st century (Taraldsen et al., 2022; Veldkamp et al., 2020; Yayon et al., 2023).

In the realm of science education, EdEsRms, particularly in chemistry, have gained traction as innovative tools for teaching complex subjects. Chemical Escape Rooms (ChEsRms) cover topics like stoichiometry and the periodic table, providing hands-on experiences that reinforce the theoretical concepts. Feedback from participants indicates high levels of engagement and motivation, suggesting that EdEsRms effectively enhance learning outcomes (Abdul Rahim, 2022; Haimovich et al., 2022; Yayon et al., 2019, 2023). Recently, we developed a novel ChEsRm, themed around Nanotechnology, tasked with finding a nanoscale gold goblet. This ChEsRm blends physical and virtual puzzle-solving by integrating a chatbot interface for guidance. It introduces nanotechnology concepts without requiring prior knowledge in nanotechnology. It focuses on the following: (1) Size-dependent properties, (2) Innovations and applications of nanotechnology, and (3) Size and scale. Whereas the published ChEsRm were all designed as an engaging activity summarizing knowledge already taught, this ChEsRm was developed to teach the extracurricular topic of nanotechnology. This introductory nanotechnology ChEsRm was developed bearing in mind the potential challenges, such as frustration and cognitive strain, particularly when participants lack prerequisite knowledge (Veldkamp et al., 2023). The research goal was to examine the extent and nature of students' learning through their experience in the nanotechnology ChEsRm. The research population comprised 170 chemistry students from grades 9-12. We employed a mixed-methods approach (Creswell & Creswell, 2018) and collected data through questionnaires to determine the effects of ChEsRms on student learning outcomes. Our findings indicate that ChEsRms significantly promote learning, particularly among students with a background in chemistry, especially students in higher grades. This presentation will delve into the results and the methodology used,

including the unique questionnaires utilized to clarify the impact of ChEsRms on chemistry education.

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OP43 – Environmental literacy of Slovenian chemistry teachers in the context of hydrosphere pollution.

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Keywords: environmental literacy, chemistry teachers, hydrosphere pollution

As a society, we face environmental problems on a daily basis for which we are largely responsible, and water pollution is no exception. In fact, it is one of the most important, if not the most important, to address, as without water there is no life. Therefore, it is very important to educate environmentally conscious individuals with appropriately developed environmental literacy (Kaya and Elster, 2019; Yeh et al., 2021). Chemistry teachers play a major role in this, as they address their students directly when teaching environmental content (Burmeister et al., 2012). In order to teach properly, they need to develop a higher level of environmental literacy and individual awareness. The aim of the study is to find out how environmentally literate are Slovenian chemistry teachers in the context of hydrosphere pollution. The results of this research may contribute to changes in the education of future chemistry teachers. The study was a combination of qualitative and quantitative research approach. 53 lower and upper secondary school chemistry teachers participated in the study. The teachers completed an online questionnaire which was developed for the purpose of this study and was based on Hollweg's model (Hollweg et al., 2011) for assessing environmental literacy. The questionnaire consisted of three parts: Knowledge, Competencies and Dispositions (attitudes and behavior). It focused on five water pollution problems: agricultural pollution, ocean acidification, microplastics, e-waste pollution and persistent organic pollutants.
The results show that teachers are interested in these environmental problems. They believe that they are relevant and that it is therefore important to talk about them at school. They generally show positive dispositions regarding hydrosphere pollution (on average, teachers scored 77% on the dispositions questionnaire), but have limited knowledge of the issues presented. On average, teachers scored 58% of the points. Similarly scored (57% of the points) were their competencies for recognizing, analyzing, and providing solutions for the presented environmental problems. Results also show that teachers who have better knowledge are also more competent ($p < .001$). Based on this, a comparison was made between teachers who had attended in-service training on environmental issues and those who had not. Surprisingly, there were no statistically significant differences between the studied groups regarding their environmental literacy ($p = .706$). There were also no significant differences between the chemistry teachers at lower and upper secondary level ($p = .335$).

To conclude, teachers who participated in our study had, on average, limited environmental literacy regarding hydrosphere pollution. Although the presented topics on water pollution are not obligatory in the Slovenian chemistry curricula on the lower and upper secondary school level, the results suggest that they should be given more emphasis in future chemistry teacher education as well as at lower levels of education in order to increase the level of environmental literacy.

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OP44 – The Effect of In-Service Education on Chemistry Teachers' Understanding of Nature of Science

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Nature of Science (NOS) understanding is recognized as one of the important components of scientific literacy. Teachers have an important role in raising scientifically literate individuals. For this, it is suggested that teachers should be continuously supported in terms of their understanding of NOS and teaching approaches. In-service education is one of the ways to support teachers. This education can enable teachers to gain knowledge and skills related to NOS content knowledge and learning approaches. In this study, the effects of an in-service education to provide teachers with the knowledge and skills related to their understanding of NOS and the teaching strategies and methods they need were investigated. The in-service education lasted 20 hours with the participation of 27 chemistry teachers. Family Resemblance Approach Scale was used as pre-test and post-test to evaluate the effects of the training. Statistics tests were used in line with the data obtained from the scale. In this context, scale sub-dimensions were analyzed, and independent sample t-test and Mann-Whitney U test were applied. As a result of the findings, it was determined that in-service education had a significant effect on teachers' understanding in the scientific knowledge dimension of the scale.

OP45 – Challenges in drawing students to pursue Chemistry in Higher Education.

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Keywords: Chemistry, Students, Teachers

Science plays a vital role in a scientific literate and innovative society that prioritizes the well-being of both people and the environment while striving to ensure our planet's sustainability. Chemistry is essential for creating a sustainable world, as it plays a critical role in managing water and air quality, preserving the environment, advancing healthcare and pharmaceutical research, producing nanomaterials, developing energy solutions, innovating materials, and enhancing food production. However, it is now imperative to approach these endeavours through the lens of sustainability, while keeping in mind the 17 Sustainable Development Goals (SDGs).

In Portugal, chemistry is not a popular area of study among students (Ribau, 2024). A research study was conducted to understand the underlying reasons for it. The research questions were: "Who, how, and why do students choose their higher education courses?" A preliminary study was conducted in 2023. The initial phase focuses on analyzing official databases at the national level to discern the patterns of student enrollment in Chemistry subjects in 12th grade and Chemistry-related courses in higher education over the last decade. The subsequent phase involved developing and validating a questionnaire comprising open and closed questions, to understand the factors influencing students' decision-making when choosing their higher education courses, particularly in the field of Chemistry. A preliminary survey was conducted, at the NOVA School of Science and Technology at NOVA Lisbon University.

The analysis of official database documents has revealed a consistent number of students enrolling in Chemistry at the 12th-grade level over the past eight years. However, there has been a decline in the enrolment of students in Chemistry courses at higher education institutions over the past three years. The survey revealed, among other results, that the central factors influencing students' choice of the field were the Chemistry class and the Chemistry teacher. In conclusion, to develop green and sustainable chemistry is necessary to start by working and supporting the Chemistry teachers in this area.

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OP46 – Classroom implementation of an AI voice assistant for chemistry lab learning in secondary school

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Keywords: chemistry lab learning, voice assistant, technology implementation

In chemistry education, facilitating meaningful connections between technology implementation and classroom experiences is an important field of applied research. Our study approaches the learning of experimental skills via instructional prompting (Graulich et al., 2021) through a voice-operated AI assistant ("LabTwin") from the perspective of the Cognitive Load Theory (Sweller et al., 2019). That is, we deployed our digital assistant in a secondary school chemistry lab to investigate its effect on the quality of students' (N = 20) lab reports. LabTwin offers a responsive pre-structured protocol and real-time guidance for hands-on tasks. It guided students during an acid-base titration with different prompting strategies (step-by-step vs. open instructions) and we assessed the quality of the lab reports with respect to prior knowledge (self-constructed) and cognitive load (Klepsch et al., 2017). Additionally, we interviewed students and teachers to triangulate implementation challenges. Overall, students reported an improved focus on the hands-on process by minimizing distractions. In particular, the AI assistant reduced the need of constant referral to written instructions, thus, improving data accuracy and consistency in the reports for either prompting type. A cognitive load reduction while controlling for prior knowledge accompanied this qualitative finding. The reports indicated a lack of enhanced correlation between conceptual understanding and experimental engagement, challenging the supposition that liberated cognitive resources are directly allocated to knowledge acquisition. The teachers (N = 2) appreciated the systems' takeover of repetitive instructions. They used the freed-up time to give individualized feedback, complementing the impersonalized instructions of LabTwin. Nevertheless, they expressed apprehensions about lab activities in schools becoming mere cookbook activities through technology. In our talk, we will discuss how voice-operated tools could support future lab learning, present a larger follow-up study to scrutinize our findings in fall 2024, and sketch a prospective utilization to support students with special needs. Via a causal model (Weidlich et al., 2023), we will elucidate the relationships between the instructional prompts, the dimensions of cognitive load, and the resultant quality of students' lab reports. We propose this model as an exemplary application of a methodological framework that can generally guide implementation designs of technology in science education research.

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OP47 – A Web-Based Tool to Promote Self-Regulated Problem Solving in Chemistry Lessons

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Keywords: problem solving; metacognitive strategies; web-based tool

Todays' society is confronted with various sustainable issues, such as climate change or resource constraint. In order to tackle these problems and to actively participate in shaping a sustainable world, problem solving is considered a key competence, as it involves, for example, identifying challenges, analyzing complex situations and developing innovative solutions (Allen et al., 2014). It is therefore important to strengthen these skills in schools, especially in chemical education.

The aim of this project is therefore to develop and evaluate a content-independent tool that supports students in their self-directed problem-solving process. This tool is web-based and designed as a scaffold that provides flexible prompts on a general problem-solving strategy and it is adaptable to diverse problem types. Firstly, the tool intends to support metacognitive processes, and secondly to help learners building up a solid conceptual knowledge. The tool will be used over several weeks with approx. N = 250 participating students aged 15-18 from different school types. Among other things, the study focuses on the effects on students' problem-solving skills and their self-perceived metacognitive strategies (pre-, post-, follow-up).

Among N = 136 students, first results of the pre-test show a moderate level of students' problem-solving skills (adapted from OECD, 2004, 14 items, closed and open-ended questions containing problems from everyday life, n = 133, M = .58, SD = .20, α = .67) as well as a moderate level of students' self-assessment of their use of metacognitive strategies (adapted from Cooper & Sandi-Urena, 2009, 30 items, Likert-Scale, 1 = low, 5 = high, n = 122, M = 3.45, SD = .48, α = .85). These results underline previous findings on existing difficulties in problem-solving and metacognitive strategies (e.g. Graulich et al., 2021; OECD, 2004; Ohtani & Hisasaka, 2018) and also highlight the need to develop targeted interventions to promote students' problem-solving skills and, in particular, the component of metacognition. The study will provide a deeper understanding of the impact of the tool and its effect on students' problem-solving process, thus contributing to the ongoing discourse on 21st century education. Further results, e.g. on the effectiveness of the tool and students' evaluation of its attractiveness and usability, will be presented at the conference.

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OP48 – Investigating students' conceptions on molecular orbital theory via concept map analysis

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Keywords: molecular orbital theory, concept maps, student's conceptions

Mankind in the 21st century faces a number of challenges, such as renewable energy storage, disease treatment and development of new sustainable materials, which can only be solved by involving chemical disciplines, and thus well-trained chemists. (Wüthrich et al., 2024) However, in the last few years, a growing number of students have been dropping out of STEM degree programs in general and chemistry programs in particular because coping with the demanding subject content appears to represent a major difficulty. (Chen, 2015; Heublein, 2014; OECD, 2020)

An especially challenging, yet highly important subject in chemistry is molecular orbital (MO) theory. Students at universities with an "atoms-first" curriculum have to learn the basics of the underlying quantum chemical concepts right from the start of their studies (Chitiyo et al., 2018), but due to their abstract nature and mathematical requirements, learners must be specifically supported here. (Taber, 2005)

For this reason, we have developed, implemented and evaluated a digital-collaborative intervention unit for first-semester students of chemistry, chemical biology and chemistry teaching at our university in Germany. The students started their learning process with interactive videos about MO theory and then, building on the acquired knowledge created concept maps to deepen and link their conceptual understanding.

To investigate which of the relevant concepts were particularly difficult for the students, the maps were analysed with the help of a specifically developed coding manual.

We observed that students who worked in small groups were able to create higher quality concept maps. In addition, the students were well able to link basic concepts relating to MO diagrams as well as the interference between atomic orbitals. Ideas related to the formation of chemical bonds proved to be more difficult.

At the conference, we are going to present the interactive learning environment, the coding manual, and further results from which we draw conclusions for the design of atoms-first chemistry lectures as well as possible support measures for students at university level.

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OP49 – Students' and scientists' conceptions of the supply risk dimension of critical raw materials

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Keywords: Critical Raw Materials, Model of Educational Reconstruction, Students' Conceptions

In order to drive forward the clean energy transition, massive amounts of raw materials are required, most of which either do not occur or are not mined in Europe. Consequently, the EU is highly dependent on imports, often from geopolitical unstable regions (European Commission, 2020). Concerned about an increased risk of supply disruptions, the concept of critical raw materials is gaining attention (Schrijvers et al., 2020). The so-called critical raw materials are pivotal in discussions concerning their limited availability, as well as the social and environmental ramifications of the clean energy transition. Integrating this concept into science education can significantly enhance the focus on sustainability. As part of the educational research within the CRC Iron, upgraded!, focusing on science communication, we are utilizing the framework of Educational Reconstruction to investigate how critical raw materials can be effectively taught in the context of sustainable chemical technologies. This study aims to examine the conceptions of students and scientists regarding the supply risk dimension of critical raw materials, and develop instructional guidelines based on the comparison of their conceptions. Accordingly, scientists' conceptions were extracted by analysing 71 publications, these were selected based on a comprehensive literature review conducted by the International Round Table on Materials Criticality (Schrijvers et al., 2020). Meanwhile, data on students' conceptions were gathered through 15 guideline-supported interviews with upper secondary school students. Key statements from these interviews, along with the conclusions drawn in the scientific publications, were subjected to a qualitative content analysis with MAXQDA, following established methodologies (Mayring, 2022). Our findings suggest that the students perceive physical scarcity of raw materials as the main cause of supply disruptions, whereas scientists argue that such scarcity is unlikely to constrain the accessibility to any material in the foreseeable future (Coulomb et al., 2015). Instead, scientists primarily attribute the likelihood of supply disruptions to the concentration of supply and the resulting dependencies on the producing countries. Consequently, based on a comparison of these findings, we are discussing the didactic implications and proposing instructional guidelines for chemical education in the context of raw material criticality.
Keywords: Critical Raw Materials, Model of Educational Reconstruction, Students' Conceptions.

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OP50 – Digital and complexity-differentiated learning modules – a step towards adaptive learning?

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Keywords: differentiation grid, multitouch learning books, adaptive learning,

With growing diversity in the population, the need for more personalized learning in education arises. Digital media offers great potential to support students and individualize their learning experience (Holmes et.al., 2018). With this in mind, we developed an easy to create and adaptable learning method for digital and complexity-differentiated learning. These digital and complexity-differentiated learning modules (DCDLM) are based on a digital differentiation grid (Dietrich et.al., 2021). This differentiation grid and all needed learning materials are embedded in a Multitouch Learning Book (Huwer et.al., 2018) accessible via tablets, smartphones, or computers. Learners can thus choose their own learning path and explore theoretical aspects as well as experiments regarding the topic. Initial results of research into the DCDLM showed positive effects on learning, although it became apparent, that students when faced with the inherent complexity differentiation of the learning module, tended to choose easier tasks (ter Horst et.al., 2024). Research on the DCDLM was conducted with N=278 students last summer. The students were seperated into two groups, one with knowledge of the inherent complexity differentiation provided by the digital-differentiation grid (ddg) and one without knowing about the different complexities inherent in the learning module (dsl). The groups were than compared regarding the devlopment of their affective (learning emotions, expectancy value motivation) and cognitive (knowledege) variables. Results of this study will be presented in this contribution. While research on the DCDLM continues our focus lies on how to use DCDLMs to build an AI-supported, adaptive system.

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OP51 – Delicious: Promoting students assessment competencies through an inquiry-based learning student laboratory on food chemistry

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Keywords: non-formal learning, food-chemistry, transversal skills

This study describes the development and evaluation of a module in the LMUchemlab of the Ludwig Maximilian University of Munich, Germany. The student laboratory aims to provide inclusive science education through inquiry-based, context-based, and cooperative learning (Kieferle et al., 2024). The advantage of a student laboratory – in the meaning of a non-formal education – is the opportunity to create contextualized learning environments that promote curriculum-related skills. The use of scaffolding and inquiry-based learning also helps create inclusive learning spaces. This module focuses on food chemistry to align with the needs of the new Bavarian school curriculum. The module 'Nutrition of the Future' aims to cultivate students' assessment skills while providing an inclusive, engaging, and motivating laboratory environment. To include all these different aspects and expectations, experiments from analytical food chemistry are chosen and contextualized: In the fictive scenario, students are informed that their school cafeteria is considering a re-conceptualization, and a young startup has devised a new food concept. This startup asserts that its food concept excels due to its sustainability, taste, health, and equity aspects. Tasked to analyze the food and validate these claims, students are engaging in the following experiments: (i) iodometric titration of fatty acids, (ii) Bradford- protein assay, (iii) polarimetric determination of starch and (iv) potassium detection via Geiger-Müller counter.

This is the first stage of the development, following the approach of Participatory Action Research (Eilks & Ralle, 2002). The objective is to evaluate the initial material and collect feedback from students for further development. A questionnaire developed by Kieferle and Markic (2024) is adapted for this purpose. The study focuses on (i) students´ situational interest, (ii) their opinion on cooperation in team, (iii) auto- nomy and participation, (iv) inquiry-based learning and (v) assessment skills.
In the study, 154 students (65 female, 82 male, 1 diverse, 3 not stated, 3 missing) between the ages of 15 to 18 from seven classes (one grade 10, six grade 11from different grammar schools) participated in this study. The results are analyzed using SPSS 29. They reveal that students are interested in the topic of food chemistry but don't see its relevance for everyday life. They enjoyed working in teams to complete tasks. Students rate the items relating to auto- nomy and participation very high, but note that some experiments lack scaffolding, thus, the instructors needed to intervene. The evaluation of inquiry-based learning is mixed, possibly due to the lack of more specific scaffolding. Unfortunately, the goal of improving assessment competencies is not yet achieved,

resulting in a revision of this aspect. In the presentation, the results will be discussed in more detail. Finally, the implications for future work will be discussed.

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OP52 – Advancing Laboratory Education in Chemistry via Mapping Students' Expectations and Actual Experience

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For decades, the role of the school laboratory in natural science education, as a unique educational environment, has been the subject of scholarly debate, calling for a reevaluation of its role (Hofstein & Lunetta, 2004). Recent criticisms and transformations have particularly targeted traditional "cookbook" laboratory formats, which, while prevalent, are increasingly seen as insufficient for fostering meaningful learning (e.g. Boyd-Kimball & Miller, 2018). Recognizing the limitations of existing evaluation tools, which often fail to adequately measure students' perceptions of laboratory learning, the Meaningful Learning in the Laboratory Instrument (MLLI) was developed by Galloway and Bretz (2015). In this study, MLLI results were completed with interviews and video analyses of students' interactions during laboratory tasks. This multifaceted strategy enabled the construction of detailed learner personas (see Daston & Sibum, 2003), capturing the varied experiences and expectations of students within laboratory education. Our findings from a cohort of first-year undergraduate chemistry education students (N=43) underscore the critical need for diversified instructional approaches in laboratory education – these approaches must cater to a wide spectrum of experiences and educational needs among students. The findings of this study will lead to the development of a tailored scaffolding based on the identified personas. Implications of this study represent a crucial step toward harnessing the didactic potential of laboratory environments, suggesting a pathway for enhancing the efficacy and inclusivity of laboratory education in the sciences.

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OP53 – Developing an operational model to address attractiveness of Science Career Awareness. Strand number: 4 or 5 Miia Rannikmäe, Regina Soobard, Jack Holnrook

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The SciCar project seeks to closely link research with education and to build on research excellence to strengthen teaching strategies, strongly supporting a research-based approach at all levels in preparing and empowering new generations of science educators who are able to justify their approach to quality and relevant education. Thus, the project pays close attention to integrating of research outcomes with teaching strategies, seeking to improve the quality of science education in general, but also guiding early career researcher training within a recognised framework of international networking.

In achieving excellence through a dedicated centre, SciCar seeks to place high value on interrelating research-outputs with innovative educational approaches, complemented by best practice strategies. SciCar intentionally plans for the increasing of its impact and productivity through activities coinciding with research & scholarly, educational aspects. This is envisaged as a meaningful approach to promote and reward both excellence and new knowledge creation. SciCar thus endeavours to review and improve institutional and departmental strategies and policies with the intention to facilitate both intra- and inter-institutional learning plus research outcomes and knowledge transfer.

A joint focus on research & education inputs. SciCar facilitates the joint preparation of funding applications by the three consortium partners, providing technical and administrative support as well as ensuring opportunities for discussion and joint collaboration.

SciCar recognises the need for and strives to put emphasis on staff development, not only via peer review and follow-up, but by utilising opportunities for inter-institutional and international mobility (e.g. staff & researcher visits), presenting research results at conferences, workshops and seminars – all hosted by consortium partners, as well as participating in major international science education and STEM conferences. SciCar intends to pay special attention to providing feedback and guidance to early career researchers (including doctoral students) in STEM-related education fields.

SciCar creates an increased focus on joint research outcomes, placing particular emphasis on quality and modes of dissemination. The consortium seeks to pay careful attention through a designed set of measures to increase excellence in the production of research, publishing in lead journals thus increasing both the visibility and impact of the

research outcomes, produced by consortium members both by effective dissemination strategies and measures to make the research results known.

The SciCar project strives towards strong integration between institutional, national and European level policies, priorities and financial support where these focus on STEM disciplines, career enhancement and the advancement of crucial STEM-related education within the society.

SciCar places emphasis on sustainability at all stages. In this approach, all work-packages have inbuilt aspects focus on sustainability, where the sustainability strategy is seen as closer integration with other international networks. The SciCar work plan places great emphasis on securing funding so as to ensure the consortium is able to continue activities beyond the project lifetime.

The Model , described in table below for career awareness was developed including the following components considered important in the SciCar project.

Components for the Career Awareness Model	**Activity**	**Outcome**
Widen Responsible Research & Innovation (RRI)	Research driven STEM teacher staff education, science popularisation, out of school STEM related learning. Development of job shadow models related to science and technology	Decrease the gap between 'exact' research and education so as to improve synergies at university institute level and internationally. Staff exchanges and expert/researcher visits to promote knowledge transfer with industry and university.
Initiate joint research projects and activities including publications	Raising the capacity in science education research with publications.	Joint research seminars and international (joint) publications.
Promote young researchers and co-supervision	Involving PhD students in across institution, STEM education seminars, developing joint courses in science and STEM education to attract more students to undertake a PhD in science education.	New PhD positions, increased PhD student mobility, joint (summer) schools, soft skills & coaching training, young researcher start-up/entrepreneurship training, online training course.
Devise transdisciplinary (online) courses and teacher training modules	Course created between the Twinning partners, based on a critical analysis of EU-MA programmes in STEM education.	Open mobility for MA students at "job shadow" level, online training course, guideline/book of guidelines.

The model was evaluated by experts from 3 countries, The outcomes will be discussed.

OP54 – Integrating AI into Chemistry Education: Experiences and Concerns of Chemistry Preservice Teachers Using AI Tools During Their Teaching Practicum

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Keywords: artificial intelligence, chemistry education, preservice teachers, lesson plans

Artificial intelligence (AI) is a brand-new technology that has been integrated in education. AI tools are used for various reasons by large numbers of people, including university students (Chu, et al., 2022). As a part of their curriculum, in their 4th year, chemistry preservice teachers are required to teach chemistry lessons twice at a local high school. Preparing lesson plans might be challenging for preservice teachers, since they are inexperienced in teaching. When preparing lesson plans preservice teacher might refer to AI tools, if they struggle with the process of preparing a lesson plan. The purpose of this study is to explore the experiences and concerns of preservice chemistry teachers with the AI tools while they are getting prepared to teach a lesson during their teaching practice. In this qualitative study, thirteen 4th year preservice chemistry teachers were interviewed to understand how and why they used AI tools during their practice teaching. The data were subjected to content analysis to explore the emerging themes and categories. The results of the analysis revealed the types of AI tools they used, methods and purposes of using AI tools, how they benefited from AI when preparing lesson plans, as well as their overall experiences, concerns, and opinions.

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OP55 – Exploring the impact of an intervention on plastics and bioplastics on Israeli pre-service science teachers' green chemistry and sustainability awareness and their attitudes towards environmental education

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Keywords: environmental education, green chemistry, pre-service teacher, sustainability, bioplastic.

Various studies have explored the level of knowledge among both pre-and in-service teachers regarding green chemistry, sustainability, and environmental education (Basheer, et al., 2023; Burmeister et al., 2013). Most studies founded a low level of awareness on sustainability and green chemistry among current science teachers in Israel, despite generally positive attitudes towards environmental education.

Pre-service sciences' teachers show limited understanding of green chemistry and sustainability. they exhibited a shift towards more eco-centric environmental value orientations and a reduction in homocentric and egocentric tendencies after completing a green chemistry course. This observed change supports the cultivation of behaviors that can help both the teachers themselves and the students they instruct in adopting environmentally sustainable lifestyles (Karpudewan et al., 2012).

In this study, 198 pre-service science educators enrolled in primary and secondary school programs at a teacher education college in Israel were asked to respond to a questionnaire comprising 34 items. The purpose was to examine the awareness levels of pre-service science teachers regarding green chemistry, sustainability, and their perspectives on environmental education. A subset of these pre-service teachers, comprised of 29 prospective chemistry and biology teachers, participated in an intervention focused on the chemistry and applications of plastics and bioplastics. Subsequently, they completed a post-intervention survey. The results indicated a positive impact of the program on the participants, leading to enhanced comprehension of green chemistry and sustainability, along with a shift toward more favorable attitudes with respect to the environment and environmental education. Moreover, feedback from the perception survey indicated that the pre-service science teachers greatly appreciated the program, and particularly appreciated the discussions on societal and environmental impacts of chemicals, a topic of conversation that has previously been outside the scope of traditional chemistry.

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OP56 – Difficulties of first-semester students in redox- and electrochemistry

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Keywords: misconceptions; first-year students; electrochemistry

The possibilities of sustainable energy generation are in the focus of research worldwide. So-called renewable energies often rely on electrochemical principles such as electrochemical energy transfer. Prospective chemists and future chemistry teachers must therefore have a firm grasp of the concepts of redox- and electrochemistry. In many universities, the basics of this subject area are taught in the first semester of undergraduate chemistry courses. Meanwhile, it becomes apparent that students often have difficulties in this subject area, especially if the atoms-first approach is followed in the course (Chitiyo et al., 2018), as is the case at different universities and in an increasing number of textbooks (Chitiyo et al., 2018; Esterling & Bartels, 2013). On the one hand, many specific difficulties and misconceptions of students in the field of redox /electrochemistry have been reported in chemistry education literature (e.g., Goes et al., 2020; Nakiboglu et al., 2024; Schmidt et al., 2007). On the other hand, however, there is little research that looks at the difficulties faced by first-year students in this field (Tsaparlis, 2019).

Our aim is therefore to take a closer look at the key difficulties faced by first-year students and develop and evaluate tailored support measures based on this. Therefore, we developed exercises on the basis of difficulties and misconceptions of students in the field of redox /electrochemistry documented in the literature. Care was taken to ensure that these learning tasks firstly have a diagnostic character, secondly address both conceptual and procedural knowledge and thirdly require mathematization. The tasks were completed by students in the first semester, partly as homework and partly as part of a university seminar. The analysis of the students' written work on the tasks is carried out in two stages. First of all, interesting processing, recurring errors, and possible patterns are identified with the help of an overview analysis. A detailed analysis is then conducted at selected points in order to uncover possible underlying difficulties and misconceptions. Students' answers show a wide range from completely correct answers to mistakes in elementary basics. The identified difficulties and misconceptions faced by first-year students will be presented in detail at the conference.

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OP57 – Fast and Furious? Students' Quality Demands for Successful Science Communication on Social Media

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In recent years, social media has diversified the spectrum of science communication, driven by the new actors that have emerged and the new opportunities they offer. Particularly among young people, social media has become an important source of information (Belova et al., 2022). Thus, social media could be a new source of informal science education that may help young people to acquire scientific knowledge and skills. Many science communication handbooks suggest that content must be tailored to the target to reach them. However, there is a notable absence of detailed analysis concerning the p*References* of young people. This raises the question of what criteria young people use to evaluate science communication on social media.

To address this, 55 secondary school students were interviewed in 18 semi-structured, problem-centred group interviews. Main interests were students demands for science communication in social media. First, they were asked about their individual criteria for successful science communication to gain insight into students' perspective. Second, participants were presented with 16 cards containing quality criteria from journalism and media education (Arnold, 2009) to facilitate discussion and provide structured feedback.

A structuring qualitative content analysis revealed that for students short and concise content is important. They often prefer factual knowledge that has a connection to their everyday world, especially if it is useful for school. In addition, entertainment and design are important in informal learning contexts.

This study contributes to a more nuanced understanding of how students perceive and evaluate science communication on social media. The insights gained could lay the groundwork for further research aimed at enhancing the quality and effectiveness of science communication in social media. This might increase the potential of social media as an informal learning opportunity.

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OP58 – Generative Artificial Intelligence (GenAI) as the Artist of Chemistry Visuals: Chemistry Preservice Teachers' Reflections on Visuals Created by GenAI

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Keywords: Generative Artificial Intelligence, Visualizations, Preservice chemistry teachers

Today, with technological developments, the use of artificial intelligence has increased in the field of education as in every field. Loeckx (2016) suggests that artificial intelligence offers students the opportunity for a more effective learning experience by reducing the burden of both teachers and students. Inevitably, artificial intelligence has become an intelligent tool that can be used for various purposes at different stages of education such as creating lesson materials and asking for teaching ideas (Emenike & Emenike, 2023). To this end, it is important to investigate how preservice chemistry teachers experience Generative Artificial Intelligence (GenAI) systems, which are predicted to take more place in education in the future (Alasadi & Baiz, 2023). The necessity of including macroscopic, symbolic and particle levels (Johnstone, 1991) in learning chemical concepts requires the use of different representations in chemistry lessons (Treagust & Chittleborough, 2001). Although preservice chemistry teachers are expected to include visualizations that adopt these three levels in their lesson plans, finding appropriate visualizations can be challenging. Therefore, preservice chemistry teachers may refer to GenAI systems to get an idea or the visualization itself. The aim of this study is to examine the experiences of preservice chemistry teachers during their teaching practicum process where they were asked to use GenAI created visuals including three levels of representations. In this phenomenological study, 20 preservice chemistry teachers studying in the 4th grade of a state university were first given the Experience of Use of GenAI and Visual Generation Questionnaire developed by the researcher, consisting of two parts and 15 open-ended questions. Then, individual interviews were conducted with ten selected preservice teachers to better understand their experiences and views on this issue. Content analysis was carried out to analyze the experiences and views. The findings of the study revealed that all the preservice teachers had used artificial intelligence before except for generating a chemistry visualization. None of the preservice teachers was satisfied with the images created by the GenAI systems due to the scientific deficiencies, including inappropriate visual elements for the structure and content of the concept. Hence editing of visuals was found to be a requirement before

their use in lessons. It can be suggested that preservice chemistry teachers might need to learn how to train artificial intelligence in line with their own needs and GenAI systems should increase their capability of producing chemistry visualizations with scientific accuracy.

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OP59 – New results in improving experimental design skills

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Keywords: experimental design, inquiry-based education, attitude toward experiments

In a longitudinal project, our research group is teaching the main principles of experimental design, using a simplified version of the Experimental Design Diagram in the book by Cothron et al. (2000). At the start of the project (1st September 2021), 992 seventh-grade students were involved. In each school year of the four-year project, these students spend six lessons on hands-on activities using the worksheets we provide. At the start of the research, we divided the 7th grade students (aged 12-13) into three groups. Group 1 (control group) follows the step-by-step instructions. Group 2 follows the same instructions as Group 1, but after the experiment they also complete the experiment design scheme on their worksheets. Group 3 has to design the experiments according to the scheme. To increase motivation, we apply the systems thinking approach (Orgil et al., 2019) on each group's worksheets, helping students to relate chemistry to their everyday life and environmental issues. This could also improve students' attitudes towards the subject in the long term. The impact of the intervention on students' Experimental Design Skills (EDS), Disciplinary Content Knowledge (DCK), chemistry grades, attitudes to the subject and to experiments is measured using structured tests at the beginning of the project and at the end of each academic year. During the first two years, the intervention resulted in a medium effect size positive change in the EDS of Group 3 students compared to the control group (Group 1), as measured by the tests (Cohen's d: 0.26). By the end of the second year, there was only a small difference in the change in DCK between the experimental groups and the control group (Cohen's d value of Group 2: 0.10 and Group 3: 0.11). The only positive change in attitudes measured in the first two years is that Group 3 rejects the experimental design tasks less than Group 2. The first results have already been published (Szalay et al., 2023). The results of the first three years of the project will be shown in the presentation. Student worksheets and tests used in the first half of the project can be downloaded from the project website.

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OP60 – Analyzing Students' Conceptual Progression of Chemical Reactions: A Cross-age Study

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Keywords: Learning progression, chemical reactions, qualitative study

Previous studies suggested mapping the patterns of change in students' conceptions, which assists informed arrangements in curricula, instructional strategies, and assessment tools, (Stevens et al., 2010). Currently, the focus of science education research moved to explore understanding of crosscutting disciplinary concepts across a time span to promote students' conceptual knowledge and scientific literacy (Sevian & Talanquer, 2014). In particular, Sevian and Talanquer identified six crosscutting disciplinary chemistry concepts, namely, chemical identity, structure-property relationships, chemical causality, chemical mechanism, chemical control, and benefits-costs-risks. This study mainly focused on the concept of chemical causality, and the goal was to examine the patterns in students' conceptual progression of chemical causality across different grade levels and with respect to the type of chemical reactions.

A total of 77 students participated in the study: 20 Grade 12, 20 freshmen, 20 seniors, and 17 graduate students. Undergraduate (freshmen, senior) and graduate students were working toward their degree in chemistry in the chemistry department of a research university. Qualitative data were collected through semi-structured individual interviews. Interview protocol included four chemical reactions, namely, double displacement, single displacement, decomposition, and combination. Grounded theory was utilized as a research methodology, and data from interviews were analyzed by using constant comparative approach. Constant comparative analysis of the data revealed dimensions and conceptual modes for chemical causality. Such dimensions and conceptual modes were named by adapting the previously developed scheme (Weinrich & Talanquer, 2015; see Figure 1).

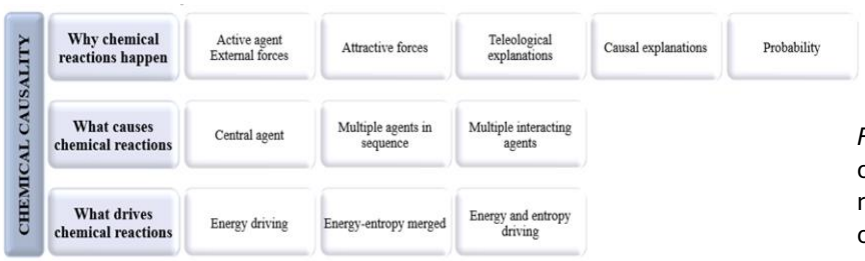

Figure 1. Dimensions and conceptual modes regarding chemical causality.

Based on findings, as the grade level increased, students showed dramatic progressions in their conceptual modes when expressing the chemical causality. The sophistication

of students' conceptual modes also changed with respect to the type of reaction (e.g., when explaining the single displacement reaction (a redox reaction), the majority of students focused on an active agent as a reason for why such a reaction happens.

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OP61 – Empowering Green Changemakers: The All Aboard Project's Journey Towards Sustainable Education

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Keywords: Education; Sustainability; Gamification in Education

Advancing towards a sustainable future hinges on embracing learning, yet many education and learning programmes still overlook the crucial aspects of sustainability. Building upon an understanding of the interactions between the environment, society and the economy, sustainable education cultivates people's ability to take informed actions that contribute to a sustainable future (Sterling, 2001).

The urgency of rapidly moving towards a more sustainable education, especially given the imperative of empowering the younger generation as active citizens, is clear. This presentation aims to highlight the objectives and outcomes of the All Aboard project, a two-year Erasmus+ KA2: Cooperation Partnerships in School Education initiative that began in October 2022 and will conclude in October 2024. The aim of this project is to promote sustainable education and empower children aged 8 to 12 to contribute to the green transition. The initiative, which is now being implemented in primary schools in Sweden, Portugal and Turkey, uses a student-centred pedagogical approach to actively empower children as 'green changemakers'. To improve teachers' ability to promote sustainable practices, All Aboard has planned the development of a Methodological Approach Framework (MAF).

The Toolbox consists of 15 sustainable strategies and activities that address mentoring competences related to sustainability, climate change, environmental challenges, sustainable habits and consumption, energy and water conservation, as well as strategies and activities that address the circular economy. Primary teachers can use these strategies and activities during their classes or activities with students to promote sustainability competences. This includes a catalogue of good practices in this field. The MAF also included workshop results developed with experts from various scientific fields to better shape the outline of a Capacity Building of Teachers Programme titled 'Supporting young children to lead change (CBoT)'. This programme has been implemented at both international and national levels in Agrupamento de Escolas de Loureiro in Portugal, Ahmet Baldöktü İlkokulu in Turkey, and Ebba Braheskolan in Sweden.

The All Aboard initiative focuses on student-centred project results, including the development of a Green Changemakers Gamebox and a Mini Mentor's Programme

Camp, designed to engage students and cultivate their leadership skills. The Programme also employs an innovative approach to assess its impact in schools.

Erasmus+ projects, such as All Aboard, can enhance and cultivate lifelong learning skills that align with the Sustainable Development Goals (SDGs) outlined in the United Nations 2030 Agenda. The project methodology enables schools to create opportunities for students to improve their creativity, critical thinking, communication, and cooperation skills. To address environmental concerns, we aim to promote a mentoring program among students. This initiative aims to improve cross-curricular knowledge, promote inclusivity, develop educational skills, enhance the overall learning experience for all participants, and empower them to become agents of positive change in mindsets in both their immediate communities and beyond. Collaborating with younger students can inspire changes in school practices and policies to promote a culture of sustainability (Caruana & Pace, 2018). This fragment discusses waste management and energy efficiency within school facilities, as well as outreach efforts directed to homes, families, and the local community, with the aim of contributing to the sustainability of our global ecosystem. Recognising schools as pillars of lifelong learning within the communities they serve, our efforts also position them as recognised examples at local, national, and international levels, inspiring others to adopt sustainable practices for a better planet.

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OP62 – Interactive online learning environment for self-regulated learning in chemistry

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Keywords: E-Learning, self-regulated learning, feedback

The dropout rate in chemistry study programs raised to tremendous 52 % over the last years (Heublein et al., 2022). Many students start their studies with minor understanding of chemistry contexts and contents. Due to the cumulative structure of knowledge (Klauer & Leutner, 2012), it is difficult to build further knowledge structures in chemistry without first closing the gaps that already exist. This may explain why deficits need to be overcome in the early phase of the studies, as otherwise dropout becomes more likely (Heublein et al., 2017). For this reason, we developed several digital learning lections for self-regulated learning and repetition of chemistry content taught in school.

Based on an empirically validated learning progression (Walpuski & Celik, 2024) covering the first three learning years in chemistry at lower secondary level ten learning units were developed to address important topics of chemistry. Since self-regulation of learning is a major problem for students at the beginning of their studies (Trentepohl et al., 2022), we tested two implementation conditions on a total of N = 139 chemistry students during winter term 2023/24. One group was free to use the developed material in addition to the lecture, the second group had to use it as part of non-graded assignments of the term.

Group two used the learning tutorials more intensively and achieved significantly better exam results. A regression model ($F(4,37) = 11.01$, $p < .001$, corr. $R^2 = .494$) with controlled prior knowledge furthermore shows that especially low performing students profit from obligatory work with the learning lections.

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OP63 – Enhancing Diversity and Inclusion in Science Teacher Education: Insights from a Diagnostic Study.

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Keywords: Chemistry Education, Pre-service Teachers Beliefs, Mixed-Methods Study

This research is conducted under the auspices of the Erasmus Plus Teacher Academy acaSTEMy project (Project homepage) which aims to foster an international science teacher network. Through acaSTEMy, science teachers will be equipped with the necessary tools to prepare students for their future careers by addressing global challenges and promoting sustainability, including topics such as the 'Green Deal,' 'Health Education,' and 'Diversity and Inclusion.' These issues are not treated as separate entities but are fundamental components of a comprehensive approach to teaching chemistry. The project endeavors to enhance both pre- and in-service education through seminars focusing on these global issues.

With a particular focus on diversity and inclusion, this study aims to diagnose the current beliefs and perspectives of future chemistry teachers and subsequently utilize these insights to design a seminar session that addresses the specific needs of science teacher education.

Diversity in classrooms encompasses various facets including (dis)abilities, ethnicity, socio-economic background, and language diversity. Inclusiveness in teaching entails the ability to effectively engage and educate students from diverse backgrounds (Grace & Gravestock, 2008). To gauge the current understanding and identify areas of improvement, a diagnostic study on pre-service chemistry teachers` beliefs about diversity and inclusion was conducted. In a meaning of a mixed-method study, this work comprised both quantitative (Likert-questionnaire) and qualitative (open end) questionnaire.

The qualitative questionnaire revealed that most of the pre-service teachers already recognize various facets of diversity and understand inclusion as the process of fostering participation and equality. Despite a minority of students reflecting on the absence of perceived need for inclusion in both their past school experiences and anticipated future classrooms, as they were unaware of whom it would benefit, the majority of them recognized the inevitability of inclusion in their future classrooms. Nonetheless, they highlighted a notable deficit in knowledge regarding effective methods and skills to address diversity. These results were triangulated by the quantitative questionnaire. Moreover, while over 70 % of the participants claimed to recognize diversity within their classrooms, only a smaller proportion of them felt confident in identifying the resulting needs. The qualitative questionnaire further highlighted the challenges pre-service

teachers face, particularly regarding teaching chemistry to students with lower linguistic skills in the language of introduction.

These findings underscore the pressing need for science teacher education programs to cultivate a heightened awareness of diversity among future educators, alongside equipping them with strategies to effectively navigate diverse classroom environments. Thus, in our presentation, a snapshot of pre-service science teachers' beliefs and perspectives on diversity and inclusion will be presented and a seminar design discussed, which is implicated from the data. By addressing these issues head-on, we aim to contribute towards creating more inclusive and effective science education environments for all students.

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P1 – Integrating green and sustainable chemistry into Austrian secondary education using the example of wood biorefinery

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Keywords: Green Chemistry, Teaching and Learning Sequence, Wood Biorefinery

The sustainable use of resources is a global challenge. Exploiting scarce resources like fossil fuels contrasts with increasing environmental pollution. Chemistry education addresses these challenges from the perspective of future generations: developing knowledge, skills, and competencies in the sense of scientific literacy (OECD, 2023) is a necessary condition to become a responsible citizen, a prospective scientist, or an informed decision-maker. To support students in this regard we developed a teaching-learning sequence (TLS) to introduce the concept of green and sustainable chemistry using the example of wood biorefinery for Austrian secondary students. In this poster, we present the concept of the TLS as well as findings of the accompanying mixed-methods study, focusing on students' (N=25) ideas about wood biorefinery and green chemistry. The students were prompted to complete given statements and write down associations about green chemistry in a pre-, post-, follow-up design. We applied a summative qualitative content analysis (Kuckartz, 2012) to capture the development of learners' ideas over time and found that there has been a gradual increase of associations regarding the 12 Principles of Green chemistry over time (Anastas & Warner, 1998), whereas mentions of buzzwords (e. g. 'sustainability', 'eco-friendly') without explanations decreased. Furthermore, measured situational interest (Reschke et al., 2020) remained on a constant high level. The abstract picture of green chemistry among students aligns well with the lack of information about green chemistry in general public (Lembens et al., 2022). Our study supports the assumption of growth in content knowledge; however, students' situational interest remains uninfluenced by the TLS. For this reason, further research will explore the mechanisms that influence students' situational interest on green chemistry topics and its value regarding sustainability decisions.

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P2 – Developing Critical Thinking Skills in High-School Students within the Context of Environmental Issues: A Comparative Study between Arabic and Jewish Societies

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The prevalence of false information in online and social media underscores the need to develop critical thinking skills in students in order to evaluate claims, interpret evidence, and make informed decisions. Critical thinking encompasses evaluating claims, questioning assumptions, assessing evidence, and avoiding logical fallacies, which are vital for fostering independent thinking and democratic participation (Ennis, 1987; Paul, 1984). Socio-scientific issues (SSIs), such as climate change, serve as effective pedagogical tools for cultivating these skills by requiring students to analyze and evaluate evidence within complex, real-world contexts (Sadler et al., 2016). This study examines the impact of the "Chemistry, Climate, and the Numbers in Between" program on the critical thinking and argumentation skills of Arab and Jewish high-school students in Israel by exploring cultural influences on education within these communities. The program integrates critical thinking with chemistry content on climate change and renewable energy, challenging students to evaluate information from diverse sources (Rap et al., 2023). Employing a mixed-methods approach, this study utilizes a pre-post questionnaire adapted from the CRITIC tool, which encourages critical reading through a series of questions (Bartz, 2002); it includes eight questions that examine different aspects of critical thinking. Each question will receive a score from 0-4 according to the level of critical thinking scores assessed using a dedicated rubric (Oliveras et al., 2013) and adapted for this study. This study assesses the critical thinking and argumentation skills of high-school chemistry students from Arab and Jewish societies in Israel by exploring the effect of cultural context on these skills. The intervention aims to enable students to evaluate claims, distinguish between facts and opinions, and construct arguments based on scientific evidence. A convenience sample included chemistry students in grades 9-12 (high school) from Arab and Jewish schools. The sample included 20 classes from 3 different schools from Arab (n=300 students) and Jewish (n=300 students) from 9 schools, whose teachers opted to participate in the research after undergoing appropriate training. Our research questions focus on how the program affects students' critical thinking and argumentation skills and whether there are differences between students from Arab and Jewish backgrounds. The preliminary results indicate that students showed improved critical thinking when engaging in familiar media like Facebook posts, but hesitated to critic when assessing scientific articles, suggesting a need for enhanced educational emphasis on evaluating academic content. This discrepancy underscores the importance of teaching methods that

encourage questioning and critical analysis, particularly in culturally traditional settings where authority is sometimes challenged. The findings aim to contribute to our understanding of how to promote critical thinking across diverse cultural contexts. This research underscores the pivotal role of critical thinking in empowering students to navigate complex, real-world issues and make informed decisions grounded in evidence.

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P3– Promoting decision-making competence through self-regulated learning strategies in chemistry education

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Keywords: decision-making, self-regulated learning, artificial intelligence

In the complex, digitalized world, the ability to adaptively learn and critically evaluate new knowledge is becoming increasingly important (Kirschner & Stoyanov, 2020). The competence of self-regulated learning (SRL) as a key competence for lifelong and successful learning enables learners to design individual learning paths and to optimize them in a self-reflective manner. Among other things, this makes it possible to prepare pupils for the changing labor market and influence academic performance, motivation and, in particular, metacognition indirectly, especially in a sustainable world. SRL as an interdisciplinary competence must therefore be integrated into the individual disciplines and continuously developed. It offers enormous potential for individual learning in chemistry education and can also help to make the acquisition of subject-specific skills more transparent and effective (Seibert et al., 2021). The presented study explores how a learning environment must be designed and which facets of SRL support the decision-making process. Correlation analysis was used to analyze the relationship between SRL and decision-making competence of learners to initiate a study within a socio-scientific issue (Zeidler et al., 2019). Experiments involving cigarettes and vapes in the Schülerlabor CLeVeLAB provide the basis for decision-making process along the „WAAGEr“ model (Langlet et al., 2022). An AI-regulated feedback system supports learners in their decision-making process through metacognitive structuring aids. The intervention study was conducted in a 2x2 pre-post-experimental design and analyzed within a multi-factorial ANOVA. The data were collected in a pre-post questionnaire on self-regulated learning and decision-making skills. Initial results will be presented and successful approaches to promote decision-making competence by implicitly strengthening SRL will be critically discussed.

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P4 – Conceptualizing science learning at grade 9 level with the respect to energy change

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Keywords: energy change, multiple choice questionnaire, response coding strategy

Energy change is a fundamental concept in everyday life and in science education (Fortus et al, 2015). Researchers (Driver et al., 2014; Herrmann-Abell & DeBoer, 2018) have indicated students' problems to understand energy change. Mainly multiple-choice questionnaires (MCQ) have been used as research tool for understanding students' energy change (Opitz et al., 2015; Park, 2019). These researchers' energy change MCQ formats have 4 options (4-OMCQ), including 1 best-response and 3 distractors. According to Haladyna and Rodriquez (2013), the most time-consuming aspect is constructing three plausible distractors for an item while developing 4-OMCQ, since the distractors may be based on previously piloted students' typical errors, or proposed by researchers, which may lead to including 2 distractors and one implausible distractor. To avoid implausible distractors appearing in MCQ items, a Greca and Moreira (2002) physical phenomenon model can be used, which sets the scientific phenomenon beforehand via a mathematical model.To investigate the impact of different MCQ distractors based on the following a research question: how does an item's distractor encoding strategies affect test results?

Based on Kõlamets et al. (2023) concept of energy change (CEC) analysis, a 4-OMCQ test was developed, focusing particularly on the energy transfer-transformation process. The CEC 4-OMCQ items were divided into 5 different constructs: a) chemistry (6 items), b) physics (6 items), c) biology (8 items), d) earth science (6 items), e) interdisciplinary investigatory skills (6 items). The CEC 4-OMCQ items were piloted with 9th grade students (n=158, in 3 schools) in May 2023 and the main study was conducted May 2024 (n=459, in 10 schools). Rasch analysis was undertaken using WINSTEPS (Linacre, 2016). Test item mean difficulties was centred at '0' (Herrmann-Abell & DeBoer, 2018) and the following minimum parameters by Linacre (2016) were set for test acceptability: person reliability > 0.8, items reliability > 0.9, person separation > 2, items separation > 3. item infit and outfit mean square between 0.7 < >1.3. Also, item point-measured correlation > 0.2 (Pedaste et al., 2023) were set as acceptable fit parameter.

Using correct and partially correct coding schema (correct = 4 points, scientific phenomenon and mathematical model incorrect = 3 points, mathematical model correct = 2 points, incorrect option = 1 point, no answers = 0 points) for analyzing CEC MCQ data 28 items were fit with statistical parameters. Item's reliability .99, items separation 9.45, students' reliability .83 students' separation 2.17. When only one

correct answer (1 point) and distractors (0 point) were used for analyzing CEC MCQ, only 27 items fit partially (items reliability .98, items separation 6.63) with our CEC MCQ parameters. Students' reliability .73 and students' separation 1.66 indicate a poor statistical fit. Effective distractors coding strategy can influence MCQ statistical parameters and can give for future investigation more subsequent information about students' understanding about the energy change.

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P5 – A New Proposal for Inquiry Activity Using a Low-Cost Remote Acid-Base Titration

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Keywords: Distance Learning, remote experiments, acid-base titration

Students' reports on remote experiments indicate that their engagement can be enhanced by incorporating synchronous aspects (Accettone, 2022). The fact that students ask questions about the experiment improves their understanding and allows the facilitating teacher to assess the teaching and learning process. Synchronous elements for remote experiments can be achieved using videos, with the control being carried out by the students themselves. From the perspective of experiment architecture, low-cost devices such as Arduino are commonly utilized (Kang et al, 2019). In this work, an acid-base titrator connected to the internet was developed for conducting remote investigative experiments. The experiment was broadcasted in a high school senior classroom, with the presence of a facilitating teacher. The activity required students to determine the indicator present in the solution. To carry out the activity, students added acid or base to sweep the pH range from 0 to 14 and noted the corresponding coloration to the pH through video analysis. The results obtained were very satisfactory, both in the identification of the indicator and in the acceptance and engagement of the students in the activity.

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P6 – Aspects of problems with chemical mathematics

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Keywords: Chemical Mathematics, Think-Aloud, Eye-Tracking

Mathematics is an integral part of chemistry at school and university. According to Johnstone (1991), the use of formulas, graphs, tables and verbal descriptions of mathematical connections is important for the application of chemical concepts. These representations originate from Janvier (1987) and are well elaborated in mathematics education. Even though students should be familiar with these types of mathematical representation, problems often arise when these types of representation need to be translated into each other in scientific context (e.g. Geyer & Kuske-Janßen, 2019; Potgieter et al., 2008). While a detailed study on these difficulties is already available for physics didactics (Geyer, 2020), there are no such results for chemistry didactics.

In order to close this research gap, the presented project examines three main topics. First, the difficulties in chemical-mathematical tasks (including the translation of mathematical representations) with a think-aloud study in which 12 high-school students participated. Second, the cognitive load during these tasks using an eye-tracking study with 16 university students. Thirdly, we shed light on motivational aspects of chemistry and mathematics using a questionnaire survey (N=193).

The core results of the three sub-studies and their combination, a resulting confirmatory study, will be presented at the conference.

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P7 – Effects of Transparent Digital Learning Environments

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Keywords: digital learning environment; learning objectives; transparency

The increased emission of carbon dioxide in our industrialized world is causing lasting changes to the global climate. One consequence is that the carbon dioxide cycle is becoming unbalanced, leading to ocean acidification. Promotion knowledge of chemical equilibrium is therefore of great importance in chemistry lessons in order to acquire, firstly, natural changes, secondly, industrial processes or, thirdly, a general understanding of chemical concepts (e.g. quantification of the donor-acceptor concept). However, students often struggle with this topic and there are numerous misconceptions (e.g. van Driel & Gräber, 2003).

The aim is therefore to develop a digital learning environment for secondary school students (aged around 16 to 17). This should not only provide students with subject-specific knowledge, but also support them with learning objectives and reflection measures, which should make their learning process transparent to the students. The use of learning objectives with a focus on the learning process shows an improvement in learning (e.g. Minbiole, 2016; Brame & Biel, 2015). The learning environment consists of three modules, whereby the third module serves as an additional module for the faster students. When implementing the learning environment, students are presented with learning objectives right at the start that give them an overview of why they are learning something, what they need to work on and how they can assess their learning performance (Winkelmes, 2023). The students work on a learning unit (e.g. videos, simulations, texts) an then complete out tasks. After completing the tasks, the students receive a reflection measure (examples of solutions and learning objectives), which are intended to help them question whether they have gained a deeper understanding. After a brief self-assessment of their learning process, students have the opportunity to follow three different paths: The first path allows them to revise the learning unit or task, the second path offers them the chance to deepen their specialist knowledge with a further task, while the third path takes them directly to the next module.

The learning environment will be used in three different intervention variants. The first group receives transparent learning objectives before the learning unit and for reflection. The second group also receives transparent learning objectives at the beginning, but for reflection gets examples of solutions. The third group only contains examples of solutions for reflection and the learning objectives are not mentioned. The developed

learning environment and an outlook on the study design, with which the effect of the learning environment is to be evaluated, will be presented on the poster.

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P8 – Systems Thinking in Chemistry Education – modelling & test development

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Keywords: systems thinking, competence modelling, education for sustainable development (ESD)

Education for sustainable development (ESD) deals with phenomena and processes from the perspective of sustainability and identifies systems thinking as one key competence in this regard (UNESCO, 2017). Systems thinking (ST) is a set of analytical skills for dealing with complex systems (Arnold & Wade, 2015). Chemistry education plays an important role in ESD since many phenomena, processes and systems related to sustainability involve chemical concepts. One example of this is the pollution of drinking water, in which chemical processes help to understand the formation of the pollution and the reprocessing of contaminated drinking water. Yet, research on ST related to chemistry focuses on undergraduate students and the few existing studies that are related to chemistry in school focus on the implementation of ST in the curriculum (Budak & Ceyhan, 2024). Against this background, the present PhD project aims to get more insight into the development of upper secondary school students' systems thinking skills in chemistry. To reach this goal, the project follows three steps. The first step includes a literature search for synthesizing characteristics of chemical systems and the development of a competence model of systems thinking in chemistry education. Based on the work by Rempfler and Uphues (2011), the competence model is divided into the dimensions of system organization and system behaviour and three competence levels are distinguished based on the complexity of the systems. For each competence level, a specific skill was defined for each dimension of the model, partly based on the work of York and Orgill (2020). The second stage, in which the present PhD project is currently situated, includes the development of test items (3 to 5 items per skill) that measure the skills defined by the competence model, focusing on water as an essential context. Afterwards, within the third step, the developed test items will be validated and then applied to the targeted sample, which includes students from chemistry classes around the age of 16 years.

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P9 – How Does Plastic Enter Our World? Co-Constructing and Evaluating Lesson Plans on Plastic Pollution for Lower Secondary STEM Education.

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Keywords: STEM education; plastic pollution; sustainability

Plastic pollution has become a pressing global issue, infiltrating various aspects of our environment. Microplastics were found, for example, in human placenta (Ragusa et al., 2021), which underlines the need for action with regard to plastics, as their impact on ecosystems and human health cannot be estimated clearly (Kumar et al., 2021). Addressing this concern requires comprehensive educational initiatives targeting young people. This poster presents the co-construction and evaluation of teaching materials aimed at fostering a deeper understanding of "How Plastic Enters Our World" among lower secondary school students in STEM education. The objective of this study is to develop a learning environment spanning the following main topics:

- drawing attention to the problem of plastic pollution,
- investigating properties of plastics,
- analysing soil and water samples to assess plastic pollution,
- investigating greenwashing to further learners' critical media literacy and
- discussing mitigation strategies and the importance of recycling, as well as the learners' individual responsibilities.

Initially, students are presented with the problem of plastic pollution in the environment to spark curiosity and concern. Subsequent lessons involve hands-on activities to investigate the properties of plastics and explore their accumulation in the environment. The curriculum culminates in a call to action, emphasising the principles of rethink, reduce, reuse, and recycle. The learning environment is evaluated through action research in that teachers and educational researchers from the STEM disciplines co-construct the materials and the teachers evaluate them in their classes. We collect data both by observing the learners and by monitoring their learning outcomes in the form of answers to the worksheets. In conclusion, this study investigates how complex environmental challenges such as plastic pollution can be addressed in a STEM classroom. By actively engaging students in the learning process and empowering them to take action, educators can cultivate a generation of informed and environmentally conscious citizens poised to effect immediate and drastic positive change.

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P10 – Interrupted Case Studies on Edible Films as a Way to Help Undergraduate Chemistry Students Craft Written Arguments

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Keywords: higher education, edible films, chemistry.

Unregulated disposal of synthetic polymer plastic films is causing significant environmental pollution on a global scale. To minimize this problem, there is a possibility of using edible films, which are thin films prepared from biological materials that act as a barrier to external elements protecting the packaged product from physical and biological damage, increasing its useful life. Recently, there has been considerable interest in developing edible films capable of preserving fruits, which have a reduced shelf life. This interest is mainly due to the demand for high-quality foods and environmental concerns about the disposal of non-renewable materials from food packaging. Equally crucial alongside efforts to avoid food waste and environmental pollution is the development of teaching strategies aimed at broadening students' knowledge of food conservation, at the same time that favor the development of critical thinking and the ability to argue about the topic. Given the above, this paper reports the application of an interrupted case study (Lima & Queiroz, 2024) entitled 'Guavas, edible films and minerals' carried out with undergraduate chemistry students. Implementing the case study as a teaching strategy, students are tasked with utilizing provided data to formulate a written scientific argument advocating the best solution for the case study. The purpose of this study was to determine the quality of the argumentative essays written by nine students. This evaluation of quality was based on Leitão's (2000) unit of triadic analysis, which proposes it as a minimum unit of analysis of the argumentation consisting of the argument, counterargument and response to the counterargument. The results show that all the argumentative texts comprised points of view and justifications supported by graphs representing changes in the weight of guavas over time and tables presenting information on various properties of the fruit after edible films, for example. The researchers concluded that the case study method enhanced the argumentation skills of the students (FAPESP: 2023/01936-1).

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P11 – Educational escape games with experimental and digital enrichment - an innovative format in science education

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Keywords: game based learning, Educational Escape Games, Digitisation, STEM

Escape games are innovative formats that are both motivating and have great potential to integrate subject-specific content and train future-oriented skills (21st century skills). In the Science4Exit project, experimental escape games with digital enrichment will be developed, tested and evaluated. The escape games are developed in the Chemistry Teaching and Learning Laboratory at the University of Education Weingarten and in the Science4Exitschool sub-project, which focuses on chemistry education in schools. The aim is to increase school students' motivation for scientific topics and interest in STEM subjects, and to consolidate the application of knowledge acquired at school. In addition, 21st century skills (creativity, collaboration, interest, engagement and self-regulation) are promoted by embedding them in a playful context. In escape games, experimental approaches and solutions are important to achieve the goal. Some of the escape games are digitally guided (e.g. Actionbound, H5P) or digitally enhanced with various technologies (AR, explanatory videos, etc.) as needed. On the one hand, the accompanying research in the Teaching and Learning Lab focuses on the students in terms of motivation, interest and self-efficacy as well as application-related knowledge. On the other hand, the student teachers will be observed videographically with regard to their professionalism as teachers.

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P12 – Learn and play: magnetic atomic structure boards for understanding atomic structure

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Keywords: hand-on learning, atomic structure, playful learning

In teaching and learning chemistry, it´s crucial for students to grasp the subject's context on three levels : the macroscopic and tangible (what we can see, touch, and/or smell, or other ways sense), the submicroscopic (key blocks in chemistry: atoms, molecules, ions, and structures), and the representational (symbols, formulas, equations, molarity, etc) (Trivic & Milanovic, 2018).Therefore, for the students learning and comprehending chemistry, it is crucial to truly understand the concept of atomic structure and how to use the information in the periodic table to characterizations different compounds. A study by Franco-Mariscal found that only 3% of grade-10 students and 23,6% of grade-12 students in Spain accurately calculated the number of protons, neutrons, and electrons in the neutral atom of iron. (Franco-Mariscal et. al., 2016) The result is quite concerning. To improve students' understanding of atomic structure (and thereby chemistry), recent studies have suggested using games to teach abstract fundamental relationships to middle and high school students, as games help to create a deeper understanding of the topic through meaningful learning (Kelkar, 2003).

In the workshop, we will use magnetic atomic structure boards to explore the particles within atoms and to create the planetary (Bohr) models of different atoms and ions. To reinforce cognitive knowledge, we will also use the models to write electron configuration in a specific software – Praktikal app. Praktikal is developing practical teaching-learning sequences to help teachers provide effective and engaging lessons. In the workshop we will use one of Practical's tools to demonstrate a more playful approach to teaching atomic structure. We get to test the hand-on learning methods and in addition, we will improve our digital skills (the representational component) and learn a playful way to teach and learn atomic structure.

Interviews with students (n = 32) who studied atomic structure using this method indicate that they enjoy the variety of learning approaches (instead of just representation). They also reported a better understanding of how ions are formed. As a teacher, I have noticed that students who have learned atomic structure with Praktikal tool have a better capability of writing electron configuration.

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P13 – Gamification in Organic Chemistry: An Inclusive and Engaging Card Game for All

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Keeping students interested and actively involved for deeper learning is one-of-the biggest challenges in the present day dynamic educational ecosystem. Game-based instructional design has been acknowledged in the organic chemistry literature as an innovative teaching aid. Modern educators have access to a variety of resources, including card games, board games, puzzles, and electronic games. [1-4] In this work, is discuss the effectiveness of using Gamification as a pedagogic tool in Organic Chemistry.

For that it was designed a new card game to help students understand electrophilic aromatic substitution (SEAr) reactions. The objective of this game is to offer students a learning tool to (1) predict the reaction products and (2) understand fundamental concepts of SEAr.

Figure 1 - Students engaged in playing the game on electrophilic aromatic substitution.

The cards are distributed in three categories: starting material, reagents and products. There were 20 students divided into two teams who played the game for half an hour.

The study was an uncontrolled experimental investigation conducted during Organic Chemistry II classes of the Integrated Master's in Pharmaceutical Sciences at Universidade Lusófona. It involved an intervention using a game and evaluated 20 participants with a 26-question quiz developed from literature [1-4]. For data analysis, a descriptive analysis of the results was performed.

Results indicate gamification enhances learning enjoyment and cognitive skills, bridging theoretical knowledge and practical understanding. Educational games transform learning into interactive, engaging activities.

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P14 – The Impact of Integrating Simulations in Teaching Electrical Conductivity in Electrolytic Solutions on Cognitive and Emotional Aspects among Eighth-Grade Students

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Keywords: electrical conductivity in electrolytic solutions, simulation, motivation, classroom atmosphere.

Studies show that there is difficulty in understanding complex and abstract scientific concepts. Due to these difficulties, computerized teaching that incorporates technological tools is required, which will help them integrate the complex information and develop their ability to deal with learning challenges. One of these abstract and challenging subjects is electrical conduction in electrolytic solutions. Integrating simulations into the teaching and learning process can affect achievement, motivation and a dynamic classroom atmosphere among students (Beal et al., 2017; Papadakis et al., 2023).

This research examines the impact of integrating simulations into the teaching of electrical conductivity in aqueous solutions and electrolysis on student achievements, motivation, and classroom atmosphere among eighth-grade students. The study involved 130 students from four eighth-grade classes in two middle schools in Israel, consisting of 64 males (49%) and 66 females (51%). They were divided into two groups: an experimental group of 68 students who learned through simulation-integrated instruction, and a control group of 62 students who received traditional instruction.

This intervention study assessed three variables (achievements, motivation, and classroom atmosphere) before and after the intervention (16 lessons) in both the experimental and control groups. All participants completed a motivation questionnaire, a classroom atmosphere questionnaire, and pre-and post-tests.

The findings indicated that the integration of simulations in teaching electrolytic conductivity improved student achievements, particularly benefiting those with lower initial achievements. Additionally, the use of simulations significantly enhanced motivation for studying chemistry and improved the classroom atmosphere in all its dimensions. The findings also showed no significant gender differences in the three variables. Lastly, a strong significant positive correlation was found between student achievements and their motivation to learn science, as well as between the classroom atmosphere and motivation.

This study provides important insights into the benefits of using digital and technological tools, such as simulations, in education. These tools make learning more meaningful, engaging and experiential for students and highlight the need for decision-makers to incorporate such tools into educational programs.

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P15 – Analytical projects with smartphone

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Keywords: IBL projects, smartphone, spectrophotometry

There is an extensive literature on the use of smartphone in the classroom in public education. Researchers highlight both the advantages and disadvantages of using a phone. The use of the phone as an information and media tool is evident, with numerous special apps to support the learning process. A major application area is gamification, which not only results in performance gains, but also demonstrably improves several important competences (Firmansyah, Hamdani and Kuswardhana, 2020) However, the topic of phones in education is controversial. Studies from Belgium (Amez, Vujić, Baert, 2021), Spain (Beneito and Vicente-Chirivella, 2020) and the UK (Beland and Murphy, 2016) show that banning mobile phones in schools improves academic performance, especially for low-achieving students.

The role of the smartphone is quite different in the case of science, where it is a very useful tool for recording and processing events (experiments), but it can also be used as a measuring tool. In chemistry, for example, it is the simplest tool for optical analysis. Its application in this field is well developed, and its role in understanding the methods involved is significant (Grasse, Torcasio, Smith, 2015).

Furthermore, once we have a well-established measuring tool, we can use it as a measuring tool in IBL projects. In our poster we present some IBL project ideas in the field of environmental analysis, food analysis and kinetic measurements, where the smart-phone replaces the UV-VIS photometer.

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P16 – Philosophy of Technology and Teaching: Thinking about Teacher Training

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Keywords: Philosophy of technology. Teacher training. Technological education. STS approach. Epistemology of technology.

This article explores the contributions of the Philosophy of Technology to teacher training and its implications for teaching, based on the premise that technology is not neutral and that its incorporation into the educational process requires careful analysis and an active stance on the part of educators. The Philosophy of Technology is presented as a field of study that seeks to understand the nature, meaning and implications of technology in society and human existence, offering a theoretical and conceptual framework for a deeper and more critical analysis of the implications of technology for the teaching and learning. The different dimensions of technology (such as artifact, knowledge, activity and human volition) are discussed, as well as the interrelationships between technology, economy and sustainability. The epistemology of technology and Activity Theory are approached as perspectives that allow understanding technology as a form of knowledge inherent to artifacts and historically-culturally incorporated into human activity. The differences between scientific and technological education are also analyzed, highlighting technology as its own field of knowledge, with its specificities and epistemology. Education, culture and identity are discussed as forms of narratives that shape the way technology is taught and learned. The article highlights the importance of teacher training for technological education, considering the historical and philosophical context of education and technological education itself in each country or region. Challenges are highlighted, such as the limited view of technology as a mere artifact, and promising perspectives, such as investment in teacher training and the improvement of educational policies. Proposals for teaching technology, based on the different views highlighted by Mitcham, are presented, emphasizing the importance of exploring technology as an artifact, knowledge, process and human attitude. The STS (Science, Technology and Society) approach and studies of the variables of the civilization equation are highlighted as fundamental perspectives for the training of teachers in technological education, fostering discussions of ethics, responsibility, sustainability and humanized training. It is concluded that the Philosophy of Technology, combined with the STS approach, the studies of civilizational variables and the understanding of education as a narrative, offers a solid conceptual basis for the training of teachers in technological education, contributing to the construction of a more humanized education, reflective and transformative, capable of facing the challenges of the 21st century.

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P17 – Sparking Interest in Chemistry: The Role of the Real Chemistry Lab Experience in Inspiring the Next Generation.

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Keywords: students' engagement, hands-on laboratories, secondary school

The field of chemistry, as well as many other fields, is facing a significant challenge: a declining number of students choosing to study this discipline. This trend, observed globally, is particularly concerning given the critical role that chemistry plays in addressing many of the world's most pressing problems, from climate change to public health. To reverse this trend, it is important to engage students at the secondary school level, sparking their interest and curiosity in chemistry. One effective approach could be to invite these students to university laboratories. These visits would provide students with a firsthand experience of the exciting and practical side of chemistry that is often not captured in textbook learning. Furthermore, it is important to acknowledge that many school laboratories are not adequately equipped to train students in practical skills, making these university lab visits even more crucial. By exposing students to the dynamic world of chemical research, we can demystify the subject, highlight the impact that chemistry has on our daily lives and shape positive and realistic perception of research scientists (Bernard & Dudek, 2017). This exposure, combined with active encouragement and guidance, could motivate more students to pursue chemistry at the university level, ensuring the continued vitality of this essential field. By fostering early engagement and providing real-world context, we can inspire the next generation of chemists, securing the future of this vital scientific discipline.

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P18 – High School Chemistry Teachers' Attitudes Towards Environmental Education Integration

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Keywords: Teachers' attitudes, Environmental education, Chemistry curriculum.

Educators occupy a pivotal role in advancing environmental education within schools, serving as pivotal agents in equipping students with the requisite knowledge and skills to foster environmentally responsible behaviors among forthcoming generations. Despite the critical importance of environmental education, it remains an optional component within the curricular frameworks of numerous nations, including Israel. This study delves into the perspectives of Chemistry teachers within the Arab sector of Israel regarding the integration of environmental education into the Chemistry curriculum. Specifically, the research aims to dissect and elucidate the components of environmental education as they are reflected in the attitudes and perceptions of these educators. Furthermore, this inquiry assesses the significance these educators ascribe to environmental education within the curriculum, explores the topics they prefer to include or exclude, and investigates the optimal placement of these topics within the Chemistry curriculum. This exploration is contextualized against various background variables of the teachers, such as gender, seniority, and the nature of their academic qualifications.

The methodological approach of this study is qualitative, employing semi-structured interviews as the primary research tool. A total of 25 experienced Chemistry teachers from the Arab sector, who instruct students up to the matriculation level of 5 study units, participated in the interviews. The data analysis was conducted through content analysis, utilizing a categorization method to distill and interpret the findings.

The results reveal a consensus among the teachers regarding the inadequate integration of environmental education within the Chemistry curriculum. They unanimously reported a lack of inclusion of fundamental environmental education principles that could benefit their students. Furthermore, there was a noted disparity among the teachers concerning the appropriate incorporation of environmental education topics within the Chemistry curriculum. Background variables of the teachers, such as their academic degrees, years of experience, and gender, significantly influenced their awareness, willingness, and considerations regarding the incorporation of environmental topics into their teaching practices.

In conclusion, the findings underscore the necessity for a substantial enhancement and modernization of the high school Chemistry curriculum to more comprehensively incorporate environmental education. This study highlights the need for educational policymakers within the Ministry of Education to more seriously consider the insights and attitudes of teachers when designing and updating curricula, ensuring that

environmental education occupies a more central and realistic position within educational planning and policy.

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P19 – Developing digital learning environments on green and sustainable chemistry in synergy with professional development courses

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Keywords: Green Chemistry, Digital Learning Environment, Professional Development Courses

Considering the challenges facing our society, the development of an individuals' argumentation and decision-making skills in the sense of Scientific Literacy (OECD, 2023) is becoming increasingly important. One avenue to foster an informed and sustainable approach to (chemical) products is through chemistry education (Mammino, 2015). In the context of Public Understanding of Science, however, science communication measures should be accessible to both students and the interested public. To this end, we develop digital learning environments (so-called ScienceSpots), which are freely accessible via QR codes in public space, introducing users to aspects of green and sustainable chemistry (Lembens et al., 2022). In addition, we design corresponding teaching materials and lesson plans for chemistry lessons in schools utilizing the information provided in the ScienceSpots. Both the ScienceSpots and the corresponding lesson plans are developed in co-construction with chemistry teacher students. To integrate both more strongly into educational settings, we offer professional development courses for in-service chemistry teachers. Participants are provided with guided access to the content of the ScienceSpots as well as the accompanying teaching materials so that they can easily use them for their own chemistry lessons.

In this poster, we present the newly developed ScienceSpots on green and sustainable chemistry, along with the accompanying teaching materials and lesson plans, and provide insights into the corresponding professional development courses. The scientific content focus on the 12 Principles of Green Chemistry (Anastas & Warner, 1998), biogenic plastics, wood biorefinery, as well as the production and usage of (green) hydrogen gas. Through this multidimensional approach, we hope to contribute to the broader objectives of Scientific Literacy as basis for informed citizenship in the realm of green chemistry.

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P20 – Pedagogical Content Knowledge of a Future Chemistry Teacher on Polymer Materials for Education for Sustainable Development

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A concerted effort to integrate Education for Sustainable Development (ESD) in chemistry teaching necessitates a positive teacher attitude towards sustainability, specific subject matter, and pedagogical knowledge (Forsler, Nilsson, Walan, 2024). In this context, the framework of Pedagogical Content Knowledge (PCK), emerges as a crucial element. This study investigates the PCK of Brazilian preservice chemistry teachers in the realm of ESD, specifically in teaching polymer materials. Our study participant, fictitiously named Paul, is engaged in a specific initial training program, demonstrating a keen interest in ESD. Data collection involved reports, lesson plans, and audiovisual recordings of meetings and interventions. A qualitative thematic analysis, guided by the five components of PCK according to Park and Oliver (2008), elucidated Paul's PCK. Orientation to Teaching Science component was analyzed from the four basic models of approaching sustainability issues in chemistry education (Burmeister, Rauch, Eilks, 2012). Results shows that Paul emphasized integrating SD dimensions into teaching, exemplified by an experiment where students produced biodegradable plastic from potato starch, complemented by lessons on polymer concepts and critical analysis of experimental results. Paul also designed a project culminating in a presentation to the school community. In terms of Orientation to Teaching Science, Paul's approach is more closely aligned with third Model: Using controversial sustainability issues for socio-scientific issues that drive chemistry education. Paul addresses the exponential increase in plastic production and its environmental impact, prompting students to consider potential solutions for a sustainable future. Regarding knowledge of instructional strategies, dialogues during weekly meetings underscored Paul's commitment to teaching methods that facilitate students' understanding and connection to SD principles. As for Knowledge of Students' Understanding, no direct observations were provided. In terms of knowledge of assessment, emphasis was placed on argumentation to assess students' engagement and critical thinking skills. Regarding Knowledge of Curriculum, Paul presented knowledge by proposing to adapt an activity to the curriculum emphasizing environmental issues. In conclusion, Paul's pedagogical approach not only underscores the potential for integrating SD principles into chemistry education but also presents evidence of addressing most of the PCK components. By fostering scientific understanding, ethical responsibility, and environmental stewardship among students, Paul's teaching methods exemplify a holistic approach to education that prepares students to be informed and responsible global citizens.

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P21 – Professional Development for Chemistry Teachers: Experimental Workshop in Promoting Sustainable Development

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Keywords: chemistry teachers professional development, non-formal learning environment, sustainable development

Effective chemistry teachers professional development (PD) in sustainable development education promotes teachers to foster students for building sustainable communities (Ateskan & Lane, 2018). Many teachers lack innovative PD opportunities that integrate systems thinking and sustainable development into chemistry education. It is a topic that is relatively new to many educators and needed at all school levels (Vesterinen & Ratinen, 2023). This case-study explores the effectiveness of an experimental workshop (EW) in providing PD for chemistry teachers, focusing on systems thinking in sustainable chemistry education. The EW was organized in a non-formal student laboratory in chemistry after school hours. Teachers tested experimental activities related to sustainable development and systems thinking.

A quantitative survey and semi-structured interviews were conducted. Six teachers completed an online survey based on the theory of relevance, using modified model dimensions (Stuckey et al., 2013). Four teachers participated in follow-up interviews to provide more in-depth results.

Results indicate the personal, societal and professional relevance of the EW. Teachers strongly agreed on its impact on their interest, learning, and future teaching practices (Sihvonen et al., 2023). They valued discussions, knowledge exchange, and acquiring new skills and insights. Interviews revealed that EW was highly beneficial and interesting with new subject matter. Teachers intend to integrate concepts into their teaching but cited time constraints. The results highlight the effectiveness of EWs in enhancing teachers' perspectives on chemistry education and its societal significance.

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P22 – Enhancing Teacher Ability to Promote Career Preparedness

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Generally, education is seen as having an economic aim, i.e., to prepare learners for their future careers, and to enhance their employability according to the labour market needs (Billett, 2022; Knight & Yorke, 2003; McCowan, 2015; Onyeike & Onyeagbako, 2014). However, largescale research has shown that school and higher education alone have not been meeting the needs of labour market (Billett, 2022; Woessmann, 2016). One of the key reasons behind the mismatch between education outcomes and labour market need is seen as - a rapid advancement of technology, for example the sudden insurgence of AI or automation of labour which creates disparity between educational vision of current job market and needs for future job market (Akkermans et al., 2020; Albanesi et al., 2023; Choy, 2019; Felten et al., 2019). Another reason, more relevant to education, is - education and career are becoming less linear, i.e., students' do not necessarily end up in a career for which they have a specialisation (Badescu, 2018; Caena & Punie, 2019; Choy, 2019; European Commission, 2020). Therefore, it has been suggested that much improvement within education sector is needed in facilitating students with necessary skills to navigate an increasingly complex and dynamic job market (Brunetti & Corsini, 2019).

The implication of such disparity between educational outcome and job-market can be seen in both job-crises, i.e., lack of competent employees for the labour market (Georgieff & Hyee, 2022; Pachegowda, 2023; Pizzinelli et al., 2023) and career crises, i.e., employees feeling dissatisfaction for having to pursue a career that no longer aligns with their values, interests, or aspirations (Dimian et al., 2017; Lalioti, 2019; Sparreboom & Tarvid, 2016; Wolbers, 2003). Therefore, policies and research advocate for a synergic and effective cooperation between educational institutions and employers to ensure that the skills taught are relevant to current and future job markets (Badescu, 2018; Caena & Punie, 2019; European Commission, 2020; OECD, 2024; UNICEF & European Training Foundation (ETF), 2024).

In creating a crossroad between education to employment, hereby enabling students a smooth transition from school to work, literature suggest undertaking work-based learning approach (Costley & Abukari, 2009; Hafid et al., 2019). Generally, work-based learning refers to various programs and initiatives that integrate classroom learning with practical work experience, aiming to enhance students' competences (knowledge,

skills, values and attitudes) related to their career of interest and need of the labour market (Baker et al., 2017; Bezerra et al., 2020; Murtazin et al., 2020). These programs include, and not limited to – lecture/seminar/work-shop by guest speakers, tour/site visit, job shadow, internship, apprenticeship, school-based enterprise (Alfeld et al., 2013). Literature suggests that these programs generally differ in purpose, for example – career exploration or career preparedness (Darche et al., 2009); process, for example – location, supervision, time, compensation, and participation (Stasz & Stern, 1998); and product, for example – curriculum- structured outcome, or open-ended outcome (Murtazin et al., 2020).

Teachers play a crucial role in promoting work-based learning, so as to helping students navigate the complexities of career planning and preparation (Mariah & Sari, 2019). By providing tailored work-based learning, teachers can shape high-achieving students' career development and help them align their education, skills, and aspirations with the evolving job market (Marijani et al., 2023). Research suggests that parents, teachers, and guidance counselors should recognize their critical influence in guiding students' career paths (Kim, 2010). Additionally, teachers can assist students in exploring their potential, fostering their self-awareness, and facilitating their career planning (Anggela & Astuti, 2020). This process helps students determine future career choices, make informed decisions, and achieve personal and professional development. By empowering students to take an active role in their career planning, teachers can enhance students' preparedness for the evolving job market and help them navigate the complex landscape of career opportunities.

The purpose of this research is to promote pre-service teachers' self-efficacy towards promoting career awareness and preparedness among students. In so doing, in addition to designing a structured course, two research questions are put forward:

1. What are pre-service teachers' self-efficacy towards promoting science-related career prior to undertaking a structured interactive course?

2. What are pre-service teachers' self-efficacy towards promoting science-related career after undertaking a structured interactive course?

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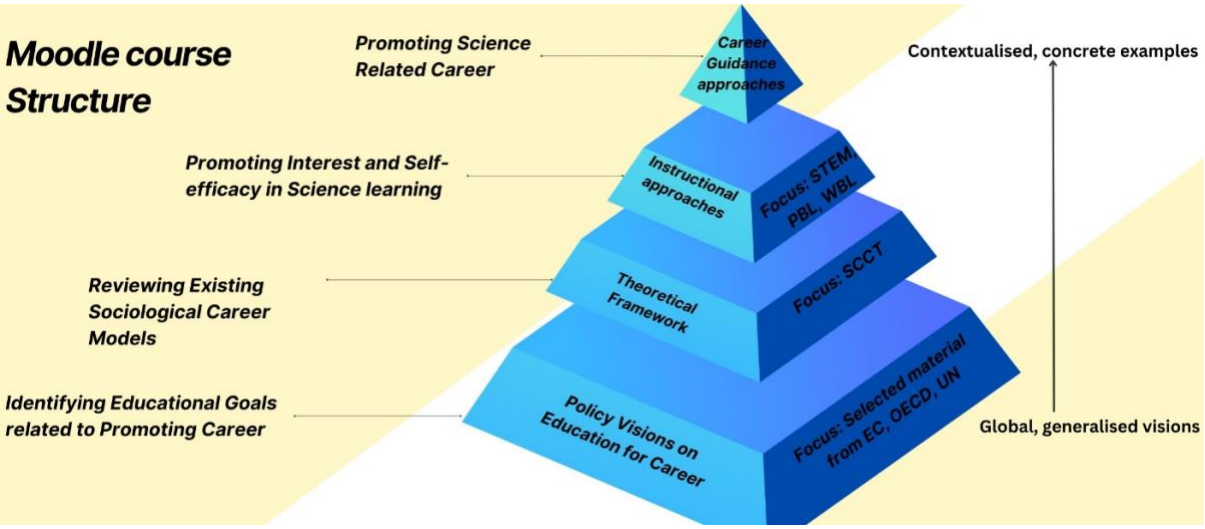

P23 – From labs to community – sharpen regional sustainability knowledge

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Keywords: regional, sustainable behavior, participation

The “Open Digitalization Alliance Palatinate (ODP)” project with seven innovation areas aims to intensify cooperation between region and universities strengthening topic-specific transfer into society. In this context, the department chemistry education from University of Kaiserslautern-Landau (RPTU) works on sustainability and resource efficiency. Our main approach is a participatory one to promote interaction between science, environment and society focusing on science communication. Relevant sustainability topics are identified in dialogues between researchers and public also considering the 17 Sustainable Development Goals (SDGs). The selected topics are implemented in adequate regional concepts, using a method consisting of three phases (input, experimental, inter-exchange). By involving the participants into local activities, the psychological distance, one of the main problems to not adopt a more sustainable behavior, should be reduced (Heitfeld & Reif, 2020; Kruse & Funke, 2022). Two events were designed to evaluate the usability of our three-phase method for citizens, which were asked for feedback regarding comprehensibility and benefits of the event. Launched by the World Water Day the first event mainly addressed SDG 6. The input focused onto the importance of water for humans and the environment, its chemical properties and components as well as the problem of global water shortage. Setting out from the global aspects we analyzed (inorganic & sensory parameters) local water samples from the surrounding area, which were partially classified by data from the federal state water portal . Also, the participants were invited to analyze and evaluate their own water samples followed by discussing the results with researchers. The second project topic was about PFAS (per- and polyfluorinated hydrocarbons), a group of persistent organic pollutants currently gaining high interest in media and society, addressing mainly SDG 3 and 12. First, PFAS´ chemistry, their usage, health hazards and regulation were presented followed by a plenary discussion (researchers from fields of toxicology and chemistry) with consumer- and society-relevant contents and explanations. An experimental phase in the end provided deeper knowledge on PFAS usage. The lab-related citizen lectures seem to be a successful concept due to their proximity and experiential nature for the participants which will be pursued in other topics. In the future, the three-phase method will be combined with a pre-post interview about sustainable behavior as well as role and perception of science.

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P24 – Surveys on Students' Perceptions of the Criticality of Metals – exemplified by Platinum and Iron in Sustainable Technologies

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Over the past decades, fuel cell technology has improved considerably. For mainstream applications, however, costs are still relatively high. In the case of the Proton Exchange Membrane Fuel Cell (PEMFC), the platinum catalyst is the price-determining factor. The precious metal is geopolitically critical (c.f. European Commission, 2020). Current research focusses on iron and its function as a non-precious metal catalyst for PEMFC cathodes (c.f. Kübler, 2021), because it offers a visionary option for substitution. This is the area of interest in our research. Hence, our team supports the CRC *Iron, upgraded!* (cf. https://www.chemie.tu-darmstadt.de/iron-upgraded/) with science communication and didactic analyses of students' perceptions. The focus is on various aspects of sustainability such as green chemistry, recycling, material optimisation and critical raw materials as well as their substitution. Our poster presents the results of two independent surveys carried out among students in middle and upper secondary school (in 2023: N = 295, in 2022: N = 255). The design was an online questionnaire with an open and closed question format. With the aim of examining how students categorise the criticality of the metals they are presented with and justify their decisions. Furthermore, semantic differentials were used to inquire about polar connotations of terms such as expensive/cost-effective, environmentally harmful/environmentally friendly, unimportant/impor-tant. These were put in relation to platinum and iron. Our main findings indicate that the students use preconcepts aligning with everyday ideas, for example, they associate metals used in jewellery as rare and expensive, resulting in characterising them as critical. In case of metals unknown to them, such as gallium, a regression towards the centre was observed, regarding their perception of criticality. Our results also show that students take a differentiated view of criticality, with a tendency to see the physical scarcity of raw materials as the main cause of supply disruptions. Additionally, our findings about the semantic differential strengthen our conclusion of students' perceptions relying on everyday ideas. As an outlook, didactic implications for teaching and science communication will be presented (cf. Prechtl, Ibraj & Legscha, 2023).

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