This conference, run under the auspices of the EuCheMS Division of Chemical Education and the RSC Higher Education Group, is targeting issues in teaching and learning and continuing Chemistry at college and university level. Papers may deal with the practical aspects of teaching chemistry or with research in chemistry education at third level (university or college), at both undergraduate and postgraduate levels. Papers on the pre-service education of chemistry teachers, as well CPD of in-service chemistry teachers or third level staff members in chemistry are welcome.

The conference theme "Promoting science career awareness and transversal skills through chemistry in higher education" is targeting the need for promoting transversal skills in teacahing chemistry at third level.

The Eurovariety conferences follow the tradition of the UK Variety in Chemistry Education (ViCE) conferences in encouraging chemists involved in teaching Chemistry at third level to share their experiences with and learn from colleagues from other institutions and other countries.

As well as invited plenary lectures there will be workshops, oral and poster presentations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme

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SciCar

10th European Variety in University Chemistry Education 2023

June 28–June 30

Promoting science career awareness and transversal skills through chemistry in higher education

10th Eurovariety in Chemistry Education 2023

June, 28 – June, 30 2023

Tartu, Estonia

Editors:
Jack Holbrook
Miia Rannikmäe
Moonika Teppo

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Theme: Promoting Science Career Awareness and Transversal Skills through Chemistry in Higher Education

This conference, run under the auspices of the EuCheMS Division of Chemical Education and the RSC Higher Education Group, is targeting issues in chemistry teaching and learning and continuing Chemistry at college and university level. Papers may deal with the practical aspects of teaching chemistry, or with research in chemistry education at the tertiary level (university or college), both undergraduate and postgraduate. In addition, papers on the pre-service education of chemistry teachers, as well CPD of in-service chemistry teachers, and/or tertiary level staff members in chemistry are welcome.

The conference theme "Promoting science career awareness and transversal skills through chemistry in higher education" is targeting the need for promoting transversal skills in teaching chemistry at the tertiary level.

The Eurovariety conferences follow the tradition of the UK Variety in Chemistry Education (ViCE) conferences in encouraging chemists involved in teaching Chemistry at the tertiary level to share their experiences with and learn from colleagues from other institutions and other countries.

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- Sirje Üprus, University of Tartu
- Heili Kasuk PhD, University of Tartu
- Lauri Kõlamets, University of Tartu

Dear Participants,

On behalf of the University of Tartu and its Faculty of Science and Technology, Institute of Chemistry may we welcome you to Tartu, the second largest and University town of Estonia, where we have the pleasure to host the 10th Eurovariety in Chemistry Education conference. This is the second time when we are hosting this conference and we try to transfer best practices from Eurovariety 2015 to 2023. Within this time, chemistry education as has the overall education sector has overcome COVID issues and impacts from the ongoing war in Ukarine.

Teaching in Universities is nowadays more challenging than ever – the proportion of youth entering universities is growing, the amount of information available in electronic form is literally overwhelming and the knowledge and motivation of students is not what it used to be. Unfortunately not too many students choose science-related faculties and Estonia is short of chemistry, as well physics, teachers. It is clear that the old teaching style, based on classical lectures, cannot be allowed to survive and new ways of providing higher education need to, and are, emerging. I hope this conference can help us all to advance our understanding of how to create a more fruitful and instructive environment for our current students and future colleagues.

On behalf of the University as the Estonian host, we wish that this conference provides new opportunities to realise the scientific potential of university graduates in the region, create new grounds for scientific collaboration and enhance personal contacts in the chemistry and chemistry education fields. The organisers are making strong efforts to provide you with an attractive scientific and social programme.

We wish you all a fruitful and pleasant Estonian experience from your participation in the 10th Eurovariety in Chemistry Education conference.

Thank you.

Professor Enn Lust, Director of the Institute of Chemistry
Professor Peeter Burk, host of 7th Eurovariety Chemistry Education conference in Estonia

Dear Participants,

It gives me great pleasure to welcome all participants to the 10th Eurovariety in Chemistry Education conference.

This conference is taking place at a very special time when the world of science education is heavily emphasising, besides solid knowledge and skills in science, the need for promoting 21st century, cross-disciplinary skills among the young generation. Moreover, this is seen as the target of life-long learning and therefore promoting those skills becomes a bridge between different levels of education, between the younger generation needs and also the demands for a knowledge-based society.

This conference reflects on research endeavours in the field of chemistry education, bringing together well known professors, university lectures and researchers in chemistry education around the world to highlight different directions in how best to overcome the gaps existing between students' needs and teaching, between the education for chemistry teacher and the changing societal expectations, and between the science research community and advancements in education research. A paradigm shift is needed to encourage more young people to take-up chemistry and science-related careers and for that it becomes important to promote science-related career awareness and employability skills at all levels of education.

The conference brings together delegates from 10 countries, giving presentations covering the major conference themes and providing inputs into a mutual understanding about best practices for tertiary level chemistry education across Europe, Australia, and Canada. This conference has been supported by the Horizon 2020 project "Addressing Attractiveness of Science Career Awareness (SciCar)" for which the major goals are to reduce the gap between reserachers in science disciplines and researchers in science education and to address the academic training of reserachers and lecturers so as to reflect context-based approaches, responsible research & innovation (RRI) aspects, digital learning as well as assessment, combining these aspects with career awareness.

The conference organisers have prepared the programme so as to allow all participants to admire the untouched landscape of Estonia and also lake Peipsi, which forms the border of the European Union.

On behalf of the Eurovariety organisers, I wish all a pleasant stay in Tartu and in Estonia, and hope you can take advantage of our long daylight hours, so special for the Estonian summer. I hope this Eurovariety conference gives to all new ideas, new friends and a willingness to come back again to 'our' Estonia.

Thank you.

Professor Miia Rannikmäe Conference chair

Programme

Wednesday, June 28

14.00–14.30 **Opening by:** Rachel Mamlock-Naamann, Enn Lust and Miia Rannikmäe

14.30–15.30 **Keynote Address** – Roy Shenhar (Israel) (Introduced by Ron Blonder)
Zoom In, Zoom Out: A Post-COVID Perspective on Chemistry Teaching from the Course Level to the Institutional Level.

15.30–16.00 Coffee break

16.00–17.30 **Paper Session**
ICT and Smart Technologies in Chemistry (Higher Education)
(Session chair, Shelley Rap)

1. **The Effect of Formative Engagement upon Summative Performance in Online Assessments.**
   Roy Lowry (UK)
2. **MOOCs: Empowering Lifelong Learners with Online Education!**
   Meelis Härmas (Estonia)
3. **An Alternative Assessment Course for Science Teachers Towards their MSc Degree.**
   Rachel Mamlok-Naaman (Israel)

Short Break • Soft drinks

17.45–18.45 **Keynote Address** Ivo Leito, Estonia (Introduced by Heili Kasuk)
Ten years of web-based teaching – what have we learned?

19.00–20 00 Welcome reception

Thursday, June 29

	Paper session **Preparation and Professional Development of University Chemistry Lecturers and Chemistry Teachers** (Session chair Luca Szalay)
9.00–9.45	**A Model for Developing Contemporary Content Knowledge (CCK) of Chemistry Teachers** Ron Blonder (Israel)
9.45–10.30	**STEM Continuous Professional Development at European Universities.** Nataša Brouwer, Stefania Grecea (Netherlands) Krištof Kranjc, Črtomir Podlipnik (Slovenia), Maria Noelia Faginas Lago, Oreste Tarallo, Vincenzo Russo (Italy) Aleksandra Lis, Iwona Maciejowska, Michał Woźniakiewicz, Bartosz Trzewik (Poland) Matti Niemelä (Finland) Sanjiv Prashar (Spain)
10.30–11.00	**HighFlier – Promoting Transdisciplinary Skills important in Science/Chemistry Education.** Miia Rannikmäe, Regina Soobard (Estonia)
11.00–11.30	*Coffee break*
11.30–13.00	**Paper Session** **Innovative Teaching and Pedagogies – Learning Materials for third level Chemistry Teaching** (Session chair Roy Lowry) **1. Measuring Photosynthesis and Respiration with Intact Cells: Integrating Chemistry into Biology in a First-Year Laboratory Environment.** Zahra M. Sharif, Denis Maxwell, Renee Webber, Felix Lee (Canada)

2. **From presumptive test to advanced instrumental analysis. The complex exercise on the forensic identification of white powder.**
   Michał Woźniakiewicz (Poland)
3. **Enhancing the laboratory experience in Year 1 university chemistry laboratory teaching: overview of a multi higher education institutional pedagogical research project on Virtual Laboratories and early reflections from a pilot study.**
   Brian Murphy, Edwin McCullagh, Carmel Kealey, Sean Reidy, Ann O'Malley, Mary Booth, Sinead Devery, Denise Rooney, Carmel Breslin, Frances Heaney, Marwa Aly, Ronan Bree, Bernard T. Drumm, Aoife Morrin, Eric Moore and Christopher Burke (Ireland)

13.00–14.00 *Lunch*

14.00–15.30 **Paper Session**
Promotion of Chemistry and Attracting Students to Study Chemistry at University (Session chair Jack Holbrook)

1. **In-service and Pre-service Teacher views on Chemistry Experimental Design worksheets.**
   Luca Szalay, István Füzesi (Hungary)
2. **Research Based Learning – the difficult Role of Supervisor: that is why we need Diploma theses.**
   Iwona Maciejowska, Michał Woźniakiewicz (Poland)
3. **I Learned more from TBL than from the Traditional Method of Teaching!**
   Heili Kasuk, Kaire Uiboleht, Siiri Velling, Peeter Burk (Estonia)

15.30–16.00 *Coffee break*

16.00–18.00 **Paper Session**

Chemistry and Interdisciplinary Science in Tertiary Education (Session chair Miia Rannikmäe)

1. **Bridging the gap between Research in Science Education and Student Learning.**
   Rachel Mamlok-Naamann, Ron Blonder (Israel)
   Jari Lavonen (Finland)
   Jack Holbrook, Regina Soobard, Miia Rannikmäe (Estonia)
2. **Health Literacy and Chemistry Education.**
   Inga Ploomipuu (Estonia)
3. **More than just a laboratory course in advanced organic chemistry – preparation for writing a BSc thesis in style**
   Bartosz Trzewik (Poland)
4. **Transdisciplinarity in Chemistry Education.**
   Jack Holbrook (Estonia)

18.00 Bus to the Conference Dinner

Friday, June 30

9.00–12.15 Paper Session
Chemistry Education for Promoting Climate Awareness: Teaching Environmental Chemistry for Responsible Citizenship and promoting SGDs
(Session chair Iwona Maciejowska)

1. **Climate Change Awareness – A key to Climate Change Mitigation and Adaptation**
   Piia Post (Estonia)

9.45–10.15 Coffee break

2. **An Exploratory Study of Factors Influencing Acceptance of Technology in Teaching Climate Change Issues.**
   Shelley Rap and Ron Blonder (Israel)
3. **How to learn more from environmental chemistry research papers?**
   Siiri Velling, Edith Viirlaid, Kaire Uiboleht (Estonia)
4. **Renewable Energy Day for Secondary School Students.**
   Karin Hellat, Riinu Härmas, Karl-Ander Kasuk, Ülle Kikas (Estonia)
5. **Analyzing the Relevance of Learning Outcomes associated with the Concept of Energy in Estonian (grade 7–9 science/chemistry curriculum).**
   Lauri Kõlamets, Heili Kasuk (Estonia)

12.15–12.45 Final comments

12.45–13.45 Lunch

BOOK OF ABSTRACTS

Contents

Zoom In, Zoom Out: A Post-COVID Perspective on Chemistry Teaching from the Course Level to the Institutional Level

Roy Shenhar

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In teaching Chemistry, making observations is essential for making progress. Observing students which we teach leads to interesting insights into how they learn. Unlike Chemistry, though, observing student cohorts over a few years reveals changes in learning fashions that reflect the evolution of human culture with time, which educators need to be aware of in order to adapt their teaching approach to guarantee efficient learning. This calls for a certain extent of experimentation (of teaching methods) and observation, trial and error, and correction. Like in Chemistry.

In my presentation, I will share a few insights I gained over 17 years of teaching General Chemistry, and how they led me to evolve my course with the changing times and needs. This gradual process, which started in the previous decade, received a boost during the COVID period, in which teaching was promoted – at least for a couple of years – to the forefront of academic activity.

My role as the head of the Teaching Technologies committee in the Teaching and Learning Center of the Hebrew University during the COVID period also endowed me with the opportunity to observe the evolution of teaching at an institutional and even national level. Now that remote teaching is no longer mandatory, where is academic teaching heading? The unique COVID period experience exposed many of us to new methodologies and techniques, but how can we turn this experience into a continuous trend that will promote teaching in the long run?

I will describe a tool we have developed to assist us in this quest.

Ten years of Web-based Teaching – What have we Learned?

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Web-based teaching has been receiving a lot of attention in higher education, including education in chemistry. After initial hype of Massive Open Online Courses (MOOCs) there has been a period of steady development in web-based teaching, both in terms of technical realization, as well didactics, followed by another surge of interest caused by the COVID pandemic.

This presentation outlines the experience of web-based teaching of analytical chemistry in different forms at the University of Tartu.[1–3] Experience with running MOOCs[1,2] (see https://sisu.ut.ee/measurement/uncertainty and https://sisu.ut.ee/lcms_method_validation), lecturing in hybrid mode, taking exams online, etc. is presented. Web-based teaching has been highly instrumental in running the international *Erasmus Mundus* master's programme *Excellence in Analytical Chemistry* (https://www.analyticalchemistry.eu/),[3] and proved indispensable during the COVID pandemic.

An important part of the presentation is related to MOOCs and their comparison with conventional teaching. Our experience suggests that MOOCs are no real competitors for the conventional university degree programs. Instead they can rather be seen as useful add-ons. At the same time in the context of practitioner training, online courses can offer significant advantages over the conventional 1–3 days intensive course format.[1,2] The on-line teaching materials of a MOOC can find many uses, e.g. as supporting materials for conventional university teaching.[2]

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The Effect of Formative Engagement upon Summative Performance in Online Assessments

Roy Lowry

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Staff frequently provide formative assessment in their courses to provide low stakes opportunities for students to practice, gain feedback and develop skills before taking summative assessments. However, student engagement with formative tasks is often highly variable. For the last six years, students on our science foundation programme (N=877 total) have had their lab. results and subsequent calculations consistently assessed by a series of online assessment systems designed in association with LearnSci. The four practical sessions assessed are arranged as two pairs, covering gravimetric analysis and titration respectively. Each pair consists of a formative and summative assessment. Within each pair, the techniques and overall question flow between the formative and summative assessment are comparable, but the chemical subjects and, therefore expected answers, are different. In both topic pairs, there is a relatively even split between students who engage with the formative assessment and those who do not. This structure has allowed a statistical analysis of the marks, recorded by the students, to be undertaken. Finding indicate that students who engage with formative assessment (which have instantaneous feedback, regardless of their score), obtain significantly higher in the corresponding summative marks than those who do not. The presentation describes the online assessments themselves, the results of the statistical analysis and puts forward further discussion of the implications.

MOOCs: Empowering Lifelong Learners with Online Education!

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Massive Open Online Courses (MOOCs) have emerged as a double edge sword for higher education, offering flexible and accessible learning opportunities to a wide audience often seen as a competitor to the academy. However, the MOOC format offers academy new opportunities– allowing the vastly higher efficiency in terms of knowledge transfer rate per time invested. At the Institute of Chemistry, we have developed and successfully applied the MOOC format for our Hydrogen- and renewable technology-based course.

The integration of MOOCs into traditional university education can enhance the learning experience by providing students with access to diverse educational resources, fostering interdisciplinary collaboration and promoting lifelong learning. By incorporating MOOCs into the curriculum, universities can provide students with opportunities to explore specialized areas of study or gain supplementary knowledge beyond the confines of their major.

However, the integration of MOOCs into university education also poses challenges that need to be addressed. These include ensuring the quality and credibility of MOOC content, aligning course objectives with university standards and addressing the digital divide to ensure equal access to online resources. Universities must develop robust strategies for course selection, faculty training and assessment methodologies to effectively integrate MOOCs into their curriculum.

In conclusion, the integration of MOOC courses into university education holds immense potential for enhancing the learning experience and expanding educational opportunities for students. By leveraging the advantages of MOOCs, universities can become more efficient and diversified. However, careful planning, faculty support, and quality assurance mechanisms are crucial to overcome the challenges associated with teaching MOOC courses at the university level. Based on our experience there is a great need and demand for MOOC style courses for emerging fields such as renewable energetics. One of the few ways to satisfy this growing demand is to embrace MOOCs and overcome the associated flaws.

An Alternative Assessment Course for Science Teachers Towards their MSc Degree

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Alternative assessment is identified with formative assessment. It has developed as from recent evidence on learning, and engages the student in the learning process. It is partly based on contemporary cognitive psychology that indicates the fact that meaningful learning is reflective, constructive and self-regulated. It also provides evidence to how and whether students structure and use information in context in solving problems.

Another aspect of alternative assessment refers is based on research papers, in which the authors claim that instructional techniques in science needs to be matched with the students' characteristics and needs, as well as with appropriate assessment tools, in order to maximize the effectiveness of the teaching and learning processes, as well as to increase students' motivation.

According to the National Research Council (1996): "Assessment policies and practices need to be aligned with the goals, student expectations, and curriculum frameworks. Within the science program, the alignment of assessment with curriculum and teaching is one of the most critical pieces of science education reform". (p. 211).

The presentation consists of activities' examples regarding the alternative assessment course. The course is conducted at the Weizmann Institute of Science in Israel, in the framework of a two years' program for science teachers who study towards their MSc (Master in Science) degree.

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A Model for Developing Contemporary Content Knowledge (CCK) in Chemistry Teachers (CCK)

Ron Blonder

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Current school chemistry content often does not represent the current state of chemistry development nor does it reflect an authentic process of chemistry knowledge utilization in modern research labs and in industry. Designing a course to develop teacher Contemporary Content Knowledge (CCK) requires several steps. First, identification of the essential concepts of the contemporary content. Here, NST, a fascinating and growing scientific field (NAP, 2016), was used as a test case to demonstrate this process. Second, development activities for students of different ages in different settings. Finally, I developed a course introducing NST CCK and authentic scientific processes to high-school chemistry teachers (Blonder, 2011; Feldman-Maggor *et al*., 2022).

However, we realized that developing teacher CCK in NST is not sufficient in itself. Teachers needed a scaffold so they could meaningfully link the CCK and authentic scientific processes to their school teaching practice. Consequently, we developed a model for teacher PD that introduced three additional stages into the teacher PD program. Over the stages of the model, the participating teachers, all experienced professionals, put into action their teaching expertise, and actively contributed to developing their knowledge. The model empowers teachers to learn contemporary science, critically analyze its feasibility for their students, engage their students in learning this new science, and assess student learning. Through the stages of the model, the teachers turn the general CCK knowledge into their personal CCK (p-CCK). In my presentation, I will discuss the stages of the model and compare it to the refine model of science teacher PCK (Carlson *et al*., 2019).

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STEM Continuous Professional Development at European Universities

Nataša Brouwer[1], Stefania Grecea[1], Krištof Kranjc[2], Maria Noelia Faginas Lago[3], Aleksandra Lis[4], Iwona Maciejowska[4], Matti Niemelä[5], Črtomir Podlipnik[2], Sanjiv Prashar[6], Vincenzo Russo[7], Michał Woźniakiewicz[4], Oreste Tarallo[7], Bartosz Trzewik[4]

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Fast development of science and technology knowledge is strongly connected to complex social quests. To cope with these developments and to assure sustainable quality of teaching and learning in higher education STEM (Science, Technology, Engineering and Mathematics) courses, a lifelong continuous professional development (CPD) of lecturers in their local context is needed. The three years long STEM-CPD@EUni project, led by the Faculty of Chemistry of the Jagiellonian University in Krakow, has been devoted to the above-mentioned topic (https://ectn.eu/work-groups/stem-cpd/). The project has been funded by the EU, under the KA2 – Cooperation for innovation and the exchange of good practices, KA203 – Strategic Partnerships for higher education action of the Erasmus+ programme of the European Union. The activities of this project have aimed at integrating technological, pedagogical, and content knowledge (TPACK) in teaching and developing technology-based approaches, enhancing student learning experiences.

During project, two summer schools were organised for lecturers who intend to implement STEM-oriented CPD activities in their faculty. Following the summer schools these lecturers became CPD Ambassadors, by sharing the knowledge in the higher education STEM-CPD community. The activities of CPD-Ambassadors were introduced to improve the quality of teaching at their faculties and beyond, adopting a *train-the-trainer* approach, embracing co-creation, peer-learning and knowledge sharing.

The third STEM CPD summer school will be held at the University of Aveiro from 15–19 October 2023 (see: https://ectn.eu/stem-cpd-summer-school/).

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HighFlier- Promoting Transdisciplinary Skills Important for Science/Chemistry Education

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The goal of the presenattion is to introduce a new vision for chemistry teachers within a STEM teacher career pathway, seen as novel and recognising the need to attract non-science oriented persons, who later become motivated to take up a chemistry teacher career. The vision further recognises the inclusion of attributes, highly acknowledged among the younger generation, such as those related to business, policymakers, leaders, managers, international ambassadors, as valued acquisition for science teachers.

The theoretical framework is based on – skills highlighted in Education 2030 model (OECD, 2018,), a three stage motivational STEM teaching model (Holbrook & Rannikmäe, 2017), plus self-determination theory (Ryan & Deci, 2000) and social constructivism (Bandura, 1977).

An optional modular course for future STEM educationalists was developed, comprised of four modules, each module targetting a specific group of competences and presented in a motivational real life situation so as to promote science-related career awareness (Soobard et.al, 2020).

Designing a practical course for this purpose is challenging, particularly in the emerging field in which there are insufficient STEM, especially chemistry, teachers in Estonia and worldwide. For this reason, this course targets undergraduate students in the fields of science and mathematics as these fields being seen as the source for future STEM teachers. In this study, the course follows four developed modules from the ERASMUS + project "*Highly Interactive Guidance Helpful For Leadership In Educationally Relevant Skills*" i.e. (1) relevant communication skills, (2) understanding nature of science,

(3) modern science teaching methodology and (4) self-management plus leadership skills for STEM teachers. The whole learning process is supported by the Moodle environment and includes scenario-based activities that enable collaboration and support creativity in order to understand the essence and specifics of teaching and to support the learner's own development.

Based on the outcomes from the first piloting of the course, it appears that students appreciated the course, as they gained an insight into what is expected from STEM/chemistry teachers in school and in any aother science related career areas

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Measuring Photosynthesis and Respiration with Intact Cells: Integrating Chemistry into Biology in a First-Year Laboratory Environment

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The Integrated Science program at Western is a four-year undergraduate program designed to provide up to 60 students with the broad science education necessary to address the interdisciplinarity that defines many of today's scientific challenges. The program combines unique Integrated Science courses with traditional discipline-specific courses within an area of concentration that students select, starting in their second year. For example, students can choose the *Integrated Science with Chemistry* option.

The flagship course in the program is a first-year course that is taken by students in the second semester. This course replaces four distinct science courses and integrates the major science disciplines (chemistry, biology, physics, mathematics, earth sciences, astronomy, and computer science) into a single course. The course has a rigorous laboratory component that enables students to explore the connections between the different scientific disciplines.

One of the experiments in the laboratory component of the course is the multi-period *Integrated Metabolism* experiment. In this experiment, students use intact algae cells (*Chlamydomonas reinhardtii*) in combination with a liquid-phase, O_2–electrode system and spectrophotometry to measure the fundamental processes of photosynthesis and respiration. These metabolic processes are measured in optimally grown cultures of *C. reinhardtii,* as well as after the cells have been subjected to various environmental stressors.

Through this series of lab. sessions, students learn the fundamentals of redox reactions, electrochemistry, spectrophotometry, photochemistry, and analytical calculations. A formal lab. report and an oral presentation conclude the experiment. The valuable technical and transversal skills that the students learn in this interdisciplinary experiment, while strengthening their understanding of chemistry and biology fundamentals, are presented.

From Presumptive Test to Advanced Instrumental Analysis. The Complex Exercise on the Forensic Identification of White Powder

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This presentation highlights the significance of comprehensive laboratory classes in forensic chemistry education for second cycle students. It explores the entire process of analysing forensic evidence, within a restricted timeframe. The research objective is to identify compounds and detect prohibited substances, while the learning aim is to introduce students into a forensic real-case scenario.

The laboratory exercise begins with students being introduced to the sample, which has been sent to the Laboratory for Forensic Chemistry for analysis. Initially, they perform presumptive tests (colour reactions) on the white powder to gain preliminary insights. Since – as in real life – the results are inconclusive, these tests are followed by analytical methods, starting with the use of a simple ATR-FTIR. However, the complexity arises as the sample is found to be a mixture, necessitating confirmation of the results obtained through additional techniques, which then need to be identified. Once this is achieved, students employ GC-MS and high-resolution mass spectrometry to ultimately identify the components of the sample. Through this exercise, students gain hands-on experience in utilizing both basic and advanced instrumental techniques. The entire forensic examination process is completed within a five-hour timeframe.

Laboratory classes in forensic chemistry facilitate the development of crucial skills in students. They learn to observe keenly, draw informed conclusions and write expert opinions to address the questions, posed by the prosecutor, effectively. Moreover, these classes provide a platform for students to enhance their analytical thinking, problem-solving, group working and scientific writing skills. They also gain a practical understanding of the complexities and challenges involved in forensic analysis. By engaging in real-world scenarios, students are better prepared for future careers in forensic science and in analytical chemistry, as the presented case drives students to use a variety of methods and instrumentation.

Enhancing the Laboratory Experience in Year 1 University Chemistry Laboratory Teaching: Overview of a Multi higher Education Institutional Pedagogical Research Project on Virtual Laboratories and Early Reflections from a Pilot Study

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A consortium of five higher education institutions in the Republic of Ireland, Maynooth University (MU) (Project Lead), Technological University of the Shannon (TUS), Dundalk Institute of Technology (DkIT), University College Cork (UCC) and Dublin City University (DCU) are currently collaborating on a highly innovative pedagogical project focused on the use of virtual laboratories as a teaching tool across the chemical and biochemical sciences. Funding for the project is provided by the Government of Ireland Higher Education Authority (HEA) under its Human Capital Initiative (HCI) Pillar 3 (P3). Pillar 3 Innovation and Agility supports innovative and agile projects from clusters of institutions with application and impact across the higher education system in Ireland. P3 projects align innovation and agility with national strategic objectives in Ireland, key system objectives for the higher education system and future skills needs for society and the economy.

This ambitious project, with enterprise partners and education technology providers is to involve up to 5,000 students across the five partner higher education institutes over its lifetime. The project aims to develop work-ready graduates, with enhanced experimental, project management, communication and team working skills, through design of an agile and responsive curriculum, where learners are afforded the opportunity to experience a real-work environment through virtual training and engagement, with enterprise partners and industrially relevant workplace problems. The project also aims to enhance engagement and student success in the learning of experimental techniques in the chemical laboratory and the understanding of key concepts in the chemical sciences, through a blended approach, complementing a real laboratory, face-to-face, experience with a virtual laboratory experience. To date, across the project, Virtual Laboratories have been rolled out to approximately 2,500 students in the partner universities and institutes, across over 25 programmes of study at both undergraduate and postgraduate level. The project has involved over 75 academic, technical and laboratory staff and 18 industry partners.

In this presentation, a holistic overview is given of the entire project. An overview is given of the Year 1 Chemistry laboratory programme delivered at TUS and how the laboratory experience has been significantly enhanced through Pre-Lab. and Post-Lab. activities, involving Labster Virtual Laboratories Simulations, LearnSci Chemistry Laboratory Simulations, Jove and RSC Videos and Moodle Quizzes. Initial findings, from a pilot group of Y1 BSc in Pharmaceutical Sciences students, is presented together with an outline of the next phase of the project.

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Virtual Labs HCI P3 Initiative

Virtual Labs HCI P3 Short Video

In-service and Pre-service Teacher Views on Chemistry Experimental Design Worksheets

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Experimental design skills are part of scientific literacy (OECD, 2019) and central to inquiry-based learning. Our research group has been trying to find ways to help their development (Szalay *et al*., 2021; Szalay *et al*., 2023).

992 seventh-grade students were involved in our present project from 25 Hungarian schools in September 2021. Their four-year compulsory chemistry education was influenced by 6 student sheets per school year that we provided. Group 1 (control) only performed step-by-step experiments. Group 2 followed the same recipes, but they also answered questions on an experimental design scheme (Cothron *et al*. 2000). Group 3 designed their own experiments using the same scheme. Systems thinking tasks were included on each type of worksheets to maintain motivation (Orgil *et al*., 2019).

32 in-service chemistry teachers working in our research group and 36 pre-service chemistry teacher students completed a questionnaire concerning the first year's student sheets. The worksheets were largely considered to be of sufficient theoretical difficulty, but the in-service teachers also stressed that they were appropriate for this age group and relevant to the year 7 curriculum.

From a practical point of view, the most frequently mentioned positive aspects were that the experiments were generally easy to carry out and the equipment and materials were not difficult to obtain. In-service teachers also highlighted the development of students' manual dexterity, the benefits of teamwork and the learning about laboratory equipment and procedures. For in-service teachers, building on prior knowledge and motivation were significant criteria. Only pre-service chemistry teachers mentioned the importance of safety. Some pre-service teachers felt that complicated wording and experimental design might reduce the value of some worksheets. While in-service teachers chose Group 3 worksheets most often as those they would like to use with their students, pre-service teachers more often preferred the Group 2 worksheets.

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Research-based learning – the difficult role of the supervisor: that is why we need diploma theses

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Students of chemistry in most European countries are required to prepare and then defend a research-based final thesis to be graduated with a professional degree. Such a process is similarly described in the Eurolecturer and EuroMaster ECTN label requirements (European Chemistry Thematic Network, http://www.ectn-lc.eu/index.html). However, doing research and then writing a thesis is challenging for students and their advisors and may be a source of frustration, burn-out and eventually a prolonged graduation process. At this point, we can ask ourselves a slightly perverse question, namely, is the effect is worth it?

In the presentation, we discuss the teaching and learning goals of diploma theses and the challenges met along the cooperation of supervisors with bachelor and master students, including, e.g. expectation shifts, decreasing motivation, out-of-schedule work, drop out just before completing the thesis, misunderstandings during the review-revise process. The ways to circumvent these confusions and difficulties, including writing a bilateral contract, using professional tools and techniques for project management such as GANTT, Ishikawa diagram or decision tree are also proposed.

We will share the conclusions of the workshops on RBL, conducted by us in the local environment, namely the Jagiellonian University in Krakow, and internationally – as part of the summer school for so called Continuous Professional Development Ambassadors, organized as part of the Erasmus plus Strategic Partnership STEM-CPD@EUni project in October 2022.

I learned more from TBL than from the traditional method of teaching?!

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TBL is a small group instructional method in which students are guided to apply conceptual knowledge through a recurring sequence of activities that involve individual work, teamwork, and immediate feedback (Kibble *et al.*, 2016).

This study implemented the TBL method in the three chemistry courses. A questionnaire was prepared to evaluate the effectiveness of team-based learning and students' perceptions of learning outcomes. The results of the learning and questionnaire were analyzed in three aspects:

- Whether and how pre-tasks and learning materials prepared for independent learning support learning?
- Whether and how TBL supported (deeper) learning process?
- Whether and how assessed learning outcomes and students' perceived learning outcomes differ?

Data was collected from three chemistry courses: General Chemistry (1st-year natural sciences and technology international group students), Physical Chemistry (1st-year gene technology students), and Environmental Chemistry (1st-year environmental technology students). To understand students' learning experiences of the learning process in the TBL learning environment, we designed a questionnaire considering previous studies (Craig *et al.*, 2020; Jarjoura *et al.*, 2014; O'Neill *et al.*, 2020). The questionnaire consisted of 7 items with a 4-point Likert scale and one open-ended question where students could comment and justify the answers. Also, the summative assessment results were analyzed and compared with previous years.

The preliminary findings indicated that according to the students' perception, the prepared learning materials supported the preparation for TBL classroom meetings. The students pointed out that the tasks supported individual learning, explained step by step in the videos.

Although the TBL method might initially be unfamiliar to the learner, and its effectiveness dependent on the size of the group and its members, one student described his/her learning experience as follows: "Working in teams seemed intimidating; first, I thought it would not be an effective way of learning. After some classroom meetings, I was pleasantly surprised – this learning method worked well for me. In the team, we could discuss things more thoroughly than in regular lectures, and as a result, I gained a better understanding of the topics."

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Bridging the gap between Research in Science Education and Student Learning

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Research about student learning refers to issues such as (1) cognitive and affective skills, (2) motivation vs. learning difficulties, and (3) misconceptions and alternative conceptions. It is connected to the curriculum by asking questions, such as: Is it relevant to students' lives? Is it up-dated according to scientific and technological discoveries? Society is constantly changing, scientific knowledge is accumulating owing to new discoveries and innovations, and information and communication technologies (ICT) has become an intrinsic part of our lives.

The challenges for teaching and learning science increase and teachers need a constant in order to be prepared for different teaching strategies and assessment skills. Such skills need to improve their ability to teach and understand their students learning difficulties, since they are better able to understand the goals, strategies and rationale of the curriculum.

In the presentation, an example is given of how research in science education influences the active learning, which we strive in order to stimulate and motivate students towards developing of scientific literacy, and which also stimulates and motivates the teachers. The example refers to one of the objectives of "Addressing Attractiveness of Science Career Awareness (SciCar)", an EU-*Horizon 2020* funded project: To reflect the combination of expertise in educational research, making science-teaching careers attractive, and promoting science-related careers through encouraging attractive science teaching in schools.

Promoting Health Literacy through Chemistry Education: Chemistry for Health Education

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In Estonia, the overall scienitifc literacy level of gymnasium graduates has been determined not to be high (Ploomipuu & Holbrook, 2017). To combat that, educational interventions with more inclusive and active teaching/learning methods are suggested (Araújo, *et al*., 2018), seeking to gaining competences to solve complex personal, community and global problems individually, or collaboratively with others (Choi *et al*., 2011). Scientific literacy encompasses, or overlaps with other forms of literacy, such as health literacy (Ploomipuu *et al*., 2019) and can thus form a meaningful foundation for studies in a range of careers and endeavours in everyday life.

This presentation promotes a teaching approach that is deemed to be motivational and enhancing students' health literacy piloted through a module-based chemistry course with two groups of first year health-care college students. Based on an 'education through science' approach (Holbrook, 2010), meaningfully enacted via the effective use of a context-based, 3-stage model teaching approach (Holbrook & Rannikmäe, 2010), a motivational model to enhance students' health literacy is proposed to initiate the teaching via a relevant social issue and subsequent active involvement by enacting a stage 2, which focusses on conceptual science learning approached through student-involved inquiry-based activities. Stage 3 involves the resolving of the initial concern/issue through the process of argumentation on the socio-scientific issue.

Feedback from students suggested the adopted 3-stage approach was meaningful and motivating. However, students' comments tended to focus on specific topics or details from the course and almost not on the approach. Students strongly expressed the appeal of experimental and practical activities for them which led to decision that the module-based approach is suitable and can be carried out in future courses.

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More than just a Laboratory Course in Advanced Organic Chemistry – Preparation for Writing a BSc Thesis in Style

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Students of Medicinal Chemistry in the Faculty of Chemistry, Jagiellonian University take part in the specialization laboratory course in synthetic organic chemistry (105 teaching hours). The course takes place in the 5th semester, just before the students start preparing their bachelor's theses in the 6th semester. During the presentation, I present the assumptions and organization of this course for two reasons: firstly, it includes elements of a *flipped classroom*, and secondly, it is conducted in such a way as to prepare the participants to write their BSc theses correctly in terms of form and style.

The range of topics for the BSc is very wide. One aspect, however, remains common: their form and style, similar to a scientific article. Starting from this point, I show the students how to properly prepare for exercises (research), extract as much information as possible from experiments and describe them in the right style.

The first stage of preparing the students for classes is an independent analysis of the instruction and the literature attached to it (in English). I devote some time to analyse a sample instruction and to show how to obtain information from scientific articles effectively. After performing the experiment, the students prepare reports containing parts typical for a scientific article. By providing quick and comprehensive feedback, including corrections, comments and tips to each part of the report and an extensive final commentary, I show how the presented reports can be improved.

Since the cycle described above is repeated several times during subsequent exercises, the rules of the correct style of writing the reports in the form of scientific articles can be consolidated and then used by the students during other laboratory courses, and above all, the students can improve the quality of their bachelor theses.

Transdisciplinarity in Chemistry Education

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While an interdisciplinary or multidisciplinary approach within chemistry education have become increasingly familiar and can promote subject contextualization linked to relevance (Gilbert, 2006). promoting career awareness, (Horizon 2020 – Multico project) and portray the role of chemistry in the world of the future, it tends to limit input to global sustainability – A major attribute of transciplinarity lies in providing an approach towards addressing wicked problems '*beyond*' the local society, extending to a global societal dimension. However, a transdisciplinary approach has yet to be strongly integrated within chemistry learning situations. This is especially the case if the perception is of 'chemistry through education', rather than 'education through chemistry' and the teaching limits the 'beyond' to a problem cycle, rather than related to decisions to be made, which while impacting on future scientific careers, avoids global societal aspects.

A trans-disciplinary approach is seen as having the intention of enabling the transference of learning to extend *beyond* any disciplinary boundaries and towards the resolving of complex, socially relevant, real-world problems (Scholz & Steiner, 2015, p. 528). Key attributes are seen as – dealing with complexity, liberation beyond the institution, inclusion of education through chemistry, yet transcendence beyond education and also reflection on epistemic perspectives encompassing a resolution that has an intended impact on the global society.

Potentially transdisciplinarity can be based on the integration of multiple epistemic beliefs, especially those social, political and cultural which shape the larger society' (Strong *et al*., 2016 p. 227). Hence transdisciplinarity is transcending, transgressing and transforming; it is theoretical, critical, integrative and restructuring, but, as a consequence of that, it is also broader and more exogenous. (Alvargonzález, 2011 p. 389).

The importance of transdisciplinarity within chemistry education is seen as enabling students to identify and address wicked problems from combining multiple epistemic perspectives, as well as through multiple disciplinary teaching orientations within chemistry learning e.g. social, economic, political, promoting career awareness and the role of chemistry in the world of the future, seeking resolutions positively impacting on the global society.

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Climate Change Awareness – A key to Climate Change Mitigation and Adaptation

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Climate change presents significant threats to both natural and human systems. The scientific consensus is unambiguous: urgent action is required to mitigate these risks. However, the effectiveness of climate action is hindered by a lack of suitable expertise. Estonia, in particular, faces a notable prevalence of climate scepticism, emphasizing the necessity for a well-defined national policy to educate the population on climate change, as well as its mitigation and adaptation measures.

The project, "KLIIMATEADLIK – Climate Change Education to Promote Climate Action," funded by the European Environment Agency (EEA), is dedicated to advancing climate change education in both formal and non-formal settings. The primary goal is to enhance the knowledge and skills required for climate change mitigation and adaptation. Efforts are focused on integrating climate change education across all levels of education in Estonia and being actively involved in developing educational strategies, crafting learning materials and supporting educators and teachers to effectively deliver climate change education.

The primary focus is to assess the state of climate change education in Estonia and as a first step the national curricula is examined. It is observed that climate change is currently addressed as a standalone topic exclusively within the natural sciences curriculum. Furthermore, the concept of climate is limited to the local context without establishing connections to the global climate system. Moving forward, the current state of teaching practices is examined. The investigation involves analysing textbooks and conducting surveys among teachers. Regrettably, findings reveal that the textbooks lack a comprehensive scientific understanding of climate change. They lack explanations regarding the causes and impacts of climate change, and, even more concerning, they do not address climate change mitigation and adaptation at all.

The proposed solution entails providing education and training to teachers while developing comprehensive study materials. These materials encompass the causes and impacts of climate change, as well as climate change mitigation and adaptation strategies. By equipping teachers with the necessary knowledge and resources, the aim is to foster a deep understanding of climate change among students. The ultimate objective is to promote widespread climate change awareness throughout the Estonian society.

The Myriad Positive Impacts of Smart Worksheets on Laboratory Classes, Quantitative Chemistry Methods and Physical Chemistry Courses

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Smart worksheets are e-enabled worksheets that guide students through calculations and key concepts, providing instant feedback and marking where appropriate. Smart worksheets represent all the knowledge an academic has in terms of areas where students struggle, their typical misconceptions and feedback and support that guides them to a complete and correct understanding. In this presentation, we focus on the implementation of smart worksheets in two courses. First, a second-year kinetics course and demonstrate the transformation of student cognition before and after implementation. Second, in a first-year quantitative chemistry (QC) course that seeks to develop all the mathematical skills that students need for their degree, taught in the context of chemistry. For both courses, the smart worksheets, provide invaluable information to the tutor on areas in which students are struggling and allows the shaping of workshops and drop-in sessions that then focus on this area.

For kinetics, the students who used the worksheets were extremely well prepared for workshops and saw their scores in assessment increase (statistically significant) compared with those who did not. Students using the smart worksheets did not make the common mistakes associated with this course. For QC, students were in two groups, those with post-16 mathematics and those without. Through the identification of areas of weakness for both groups, particularly translating mathematics skills into chemical contexts, both cohorts improved through the year and in the final assessment were indistinguishable in scores (statistically insignificant). This was achieved with the backdrop of the global pandemic and variable access to face-to-face sessions with students.

Surveys suggest that students enjoyed working in this unbiased environment that provided instant feedback and support. Students felt well prepared for subsequent workshops and assessments.

An Exploratory Study of Factors Influencing Acceptance of Technology in Teaching Climate Change Issues

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Climate change is a pressing challenge for humanity and impacts education systems (Henderson *et al*., 2017). It poses significant challenges for chemistry teachers due to the lack of adequate learning materials to support them in dealing with this issue and the overwhelming media information when teaching about it. Therefore, it is crucial to equip students and teachers with skills to evaluate and critique information for better decision-making (Walsh & McGowan, 2017; Rap *et al*., 2022).

The program "Chemistry, Climate & Numbers in Between" aimed to shift climate and environmental discussions among high school chemistry students towards a data-driven dialogue, grounded in chemical knowledge. The units exposed students to digital data and chemical explanations of phenomena, while emphasizing developing critical skills, such as digital literacy (Rap *et al*., Submitted).

The study

As science educators, we must consider the challenges teachers face when implementing a curriculum based on data that keeps changing. The current study highlights the significance of incorporating up-to-date technological tools that deliver current data when teaching climate change content. The research question is: Which features do teachers consider helpful or hindering in teaching climate change while utilizing technological tools?

Methodology

We conducted in two phases. Initially, we introduced the program to three teacher-leaders, emphasizing the technological tools, enabling learners to generate and analyze data to establish their knowledge and opinions regarding climate change dilemmas. In the second phase, we repeated the same procedure for the PLC teachers (N=15). Data were analyzed using a bottom-up approach, guided by the theoretical framework of the Technology-Acceptance-Model (TAM) (Davis, 1989).

During the presentation, we discuss the promoting and hindering factors teachers have identified in assimilating technology and their connection with the TAM model. Moreover, we provide an overview of the program and the unique application employed in our research.

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How to Learn More from Environmental Chemistry Research Papers?

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One of the aims of higher education is to foster students' development of conceptual knowledge, information processing, and critical thinking skills (Lucia & Swanberg, 2018). Research papers have been used in higher education teaching to support the development of these qualities with the aim of introducing and discussing the evidence from science (Bimczok & Graves, 2019). The traditional format of adopting research papers in the learning process is the following: the teacher chooses the article, one or two students present the article, and during the meeting, participants are expected to discuss the article (Rodriguez & Hawley-Molly, 2017). The main limitation of this approach is the lack of students' engagement in the learning process and the discussion, especially among those who have not read or do not present the article (Bimczok & Graves, 2019). Therefore, it is vital to support and guide students in the process of selecting, reading, and discussing the papers.

We developed two formats for adopting research papers in teaching the courses to encourage students' engagement and learning while reading and discussing the research papers in environmental chemistry courses. Student feedback was gathered and used to analyze students' learning experiences related to the new learning formats.

Preliminary findings indicate that sharing the aim, and the focus of the task, giving a possibility to make choices, guiding the process of choosing, reading, and concluding the paper, and offering space for discussion are vital for engagement and more deeper learning.

Our experience indicates that it is possible to adopt research papers in the learning process in a way that encourages students' engagement and learning. However, it is vital to consider different aspects of the format that support engagement.

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Renewable Energy Day for Secondary School Students

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Important transversal skills for university students are teaching skills and explanations of their academic knowledge to the wider society. Chemistry plays an important role in innovative energy technologies, especially in utilization of renewable energies. Renewable energy is gaining attention, but the understanding of it is superficial. A 5-hour Renewable Energy Day for secondary school students was developed to help them understand the underlying science, current global challenges and possible solutions for future energetics. The day included an introductory lecture, a role-play and practical activities in the hydrogen lab.

Role-play is a dynamic and engaging activity that encourages critical thinking and improves discussion skills. In this role-play, the students discuss the pros and cons of an offshore wind farm in the gulf of Riga. They represent different interest groups, such as the oil shale industry, the Ministry of Economic Affairs, wind farm construction companies, and local residents. After familiarizing themselves with the role, the students present their viewpoints to others. They listen to opposing teams, ask questions, and aim to persuade others. This activity fosters the exploration of different perspectives and encourages evidence-based reasoning. The hydrogen lab. activities are focused on practical problem-solving. Students analyze whether the collaborative activities foster effective communication and undertake sharing of ideas. The renewable energy day gives students an all-around overview of potential clean energy applications and helps to develop transversal skills for finding sustainable solutions. The Renewable Energy Day concludes with a short quiz and a demonstration of hydrogen technology in everyday life, powering a pancake machine with a hydrogen fuel cell.

Analyzing the Relevance of Learning Outcomes associated with the Concept of Energy in Estonian (Grade 7–9 Science/Chemistry Curriculum)

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This study investigates the Estonian lower secondary (7–9th grade) science curricula, seen as an important framework for educators preparing students as tomorrow's citizens able to reflect on sustainable energy development. As the curriculum is taken to be the major document allowing insights into Estonian educational standards, this study analyzes components of the lower secondary science curricula in the subjects of biology, chemistry, earth science, physics, and interdisciplinary science. Using document analysis, verbs associated with career-related learning outcomes are detected, allowing the relatedness of the energy concepts and determination of their cognitive level utilizing SOLO (Structure of Observed Learning Outcomes) taxonomy. A team of coders identify a total of 782 learning outcomes across three learning domains: psychomotor (176), affective (32), cognitive (574) at unistructural (33), multistructural (225), relational (276), and extended abstract (40) levels. The majority of energy concept learning outcomes (274) are identified in the source (form) and transfer (transform) categories. Very few career-related learning outcomes are detected with the science education relevance dimensions (individual, societal, career). The suitability of the findings is discussed. The current method of analysing can be applied to other educational disciplines for raising awareness of disciplinary cross-cutting concepts.

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