Preface

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Frontiers of research in chemistry education for the benefit of chemistry teachers

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An understanding of how students learn chemistry and what can support better chemistry learning is a research field that has continuously developed during the last 50 years. Chemistry education researchers study how different teaching strategies either support or inhibit chemistry learning. They study the role of models and the process of modeling in chemistry learning and teaching. They examine ways in which technology can be integrated into chemistry teaching to surmount the difficulties associated with learning abstract chemistry concepts, which was recently demonstrated during the Covid-19 pandemic. They look for assessment approaches that can guide teaching, reflect goals, and promote learning of scientific concepts and skills.

These studies, which enhance our understanding of learning and teaching chemistry, should be part of chemistry teachers' toolbox and support their professional development. However, these studies seldom reach teachers and therefore are usually not put into practice as much as they should. In this special issue we aim to bridge this gap and to bring the contemporary studies in chemistry education, which were presented in the 15 ECRICE 2022 conference, the European Conference on Research in Chemical Education, which was held at the Weizmann Institute of Science in July 2022, to the international community of chemistry teachers. This collection of papers presents six contemporary issues in chemistry education research: teaching strategies, models and modeling, technology for chemistry teaching and learning, development of student skills, personalization of chemistry teaching for including a variety of students in the chemistry classroom, and finally, assessment, which is an essential component of any learning process.

1 Teaching strategies

The diversity of students in chemistry classes requires a variety of teaching strategies in order to properly address the needs and learning styles of every student (Blonder & Sakhnini, 2012). A variety of assignments enables students to be at their best with certain assignments, and to succeed less with others (Mamlok-Naaman et al., 2007).

One of the papers in the special issue (SI) deals with the development of “unmathematical” instructional material aimed at reducing students’ anxiety during the complex procedure of determining the spontaneity of chemical reactions. Another paper addresses research gaps on the question of how digital collaborative processes should be designed to foster students’ learning of complex subjects. Here, the authors developed a digital

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collaborative intervention in which students first work by themselves with interactive learning videos and then create concept maps. A multimodal interactional analysis of videos at the micro level regarding the process of distilling an ethanol-water mixture is also described in this SI. After the analysis, the reconstructed pre-concepts of the students are in agreement with the scientific perspective and the didactic structuring of the topic of distillation. There is also a paper dealing with the strategy of scientific fiction (Sci-Fi); it is a study aimed at investigating how the Sci-Fi context influences pre-service teachers’ attitudes and perceptions regarding the use of Sci-Fi for teaching and learning science, focusing on chemistry, as a result of a 15-week novel elective Sci-Fi course for pre-service teachers.

2 Models in science

High-school students are usually unaware of the roles of science and scientists in building models and theories as tools to better understand nature. A literature review of students’ and teachers’ understanding of models and modelling in chemistry highlights the importance of incorporating the epistemological aspects of related chemical concepts (Erduran et al., 2007). The rise and fall of the phlogiston theory, described in one of the papers, serves as an example of the chemical heritage, as well as to the need to have models to better understand scientific phenomena – models that change according to new scientific discoveries and new technological developments.

In addition to scientific models, the chemistry teaching and learning also includes the use of didactic models. One paper describes a reconstruction of a course’s content in introductory chemistry, at a university of applied sciences. The course aimed at highlighting the role of models, assuming that this would result not only in greater student learning gains overall, but that students who learned the most chemistry content would be the ones with the most sophisticated meta-knowledge about scientific models. In another paper, the authors elaborate on a model of teaching chemistry. Based on a Universal Design for Learning (UDL) and on established approaches to lesson planning in chemistry education, they developed a planning model with 15 different functions that teachers can use for practicing the planning of accessible lessons, for example, creating transparency, or reflecting on learning goals or on work processes. This planning model is taught as part of a master university seminar in preparation for a semester-long practical phase at school.

3 Technology

Today, with the frequent changes in technology and the accompanying advancements, it is crucial for classroom teachers to know how to harness technology for the benefit of their pedagogical objectives while teaching abstract chemical concepts. Teachers should familiarize themselves with the advanced technologies available. Moreover, it is important to know how to effectively utilize technology for the specific needs of chemistry educators (Tuvi-Arad & Blonder, 2019) and to continue developing and updating it in order to maximize the potential technology and to benefit chemistry students (Harris & Hofer, 2011; Mishra & Koehler, 2006). Of course, the use and acceptance of these technologies are not immediate and are dependent on various factors, such as teacher beliefs, orientation, and context, also known as amplifiers and inhibitors (Gess-Newsome, 2015).

In this SI you will find some of the latest research in the field of technology in chemistry education. Familiarity with these articles is the primary and most significant factor that will ultimately initiate the process of integrating technology in chemistry classrooms. It will also expose teachers to the success and utility of these technologies, potentially influencing their implementation. In one of the papers, the researchers claim that although online learning allows greater flexibility, studies show that this flexibility is also a challenge for individual learners who must manage their own schedules and complete specific tasks independently. Therefore, learner’s self-regulated learning (SRL) and the ability to act independently and be active in the learning process may support an online learning environment.

Among the articles, one may find an analysis of a questionnaire that refers to students’ individual beliefs and their personal motivation to use digital educational content in STEM. The results showed that science students
rated their digital skills lower and expected more difficulties compared with other STEM students, but did not differ in terms of their motivation.

Chemical safety is also an issue in one of the papers. The authors developed an online resource with information and tools for various aspects of chemical safety, such as legislation, risk assessment, storage, labeling, and waste handling, including a framework for routines and training for staff and students. The content is published in five languages and is freely available at https://chesse.org.

4 Skills

Chemistry teachers not only impart chemical knowledge in their classrooms—they also serve as educators. It is important to educate the future generation and provide them with the tools and skills they will need throughout their lives as future citizens. These skills encompass a variety of abilities, including cognitive, meta-cognitive, social, and emotional skills (OECD, 2018). Thus, it is essential for teachers to be familiar with these skills and provide opportunities for their development during the chemistry learning process. This issue contains several articles that provide applied research in this field. For example, one article maps the cognitive skills present in a curriculum, focusing on climate change, allowing teachers to implement these skills in the classroom. Another article discusses the skills of sharing and collaborating. During lockdowns implemented to contain the COVID-19 pandemic, schools were forced to implement Emergency Remote Teaching. Professional Learning Communities (PLCs) were a means that established relationships between teachers and promoted collaboration and networking.

5 Teaching personalization

Diversity and differences between students are the reality that chemistry teachers deal with daily. To address this reality, there is a need to provide teachers with the awareness, knowledge, and requisite skills needed to address the variety of student needs in heterogeneous chemistry classrooms (Tomlinson, 2015). This will make teaching more inclusive, as emphasized recently (Kassam, 2022). A chemistry teacher who wishes to personalize her teaching to different students in the class is required to constantly adapt her teaching to the changing needs of each student in the class. This huge demand can be supported by preparing diagnostic tools that can monitor student understanding, motivation, or the preferred learning style. This pedagogy can also be supported by preparing teaching materials designed to address diagnosed student needs (Easa & Blonder, 2022).

Three papers in the SI could provide chemistry teachers with tools and insights that will better equip them to personalize their chemistry teaching.

One of the papers deals with misconceptions of chemistry concepts among high-school students. The authors claim that these misconceptions may inhibit completing the learning and understanding process in the classroom, especially in heterogeneous classes. This study focuses on the cognitive aspects of student learning; its purpose is to evaluate the influence of the development and activation of Customized Pedagogical Kits (CPKs). The main goal of the CPKs is to overcome students’ misconceptions by using a diversity of teaching strategies according to student needs. It is suggested that CPKs will also enhance teachers’ own personalization. Another paper refers to misconceptions that students encounter in combustion processes, due to confusion between macro and micro relationships in chemical reactions. Therefore, the researchers developed an “unmathematical” instructional material that aims at reducing students’ cognitive load, and enhances their learning and self-efficacy beliefs. Another study refers to linguistic problems in chemistry. An Erasmus+ project, sensiMINT, was launched to cope with this problem. Experts in science and language education met with science and language teachers in communities of practice, using an adapted action-research design. The cross-disciplinary team provided successive levels of language support, which may help students gradually become more scientifically literate.
6 Assessment

Instructional techniques in science should 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 (Blonder, 2018; Mamlok-Naaman et al., 2018).

The construction of a reliable test to assess learners’ knowledge regarding the Bronsted-Lowry acid-base concept, by using methods from Item Response Theory, is described in one of the papers. The test is based on an educational reconstruction of the concept. Another paper investigated chemistry teachers’ types of knowledge by analyzing their online assessment tasks using a designated novel rubric. This paper also describes a validated rubric for evaluating and mapping teachers’ types of knowledge, which is also described in this study. Another study describes a laboratory platform as a unique tool for engaging and encouraging students to develop critical thinking skills and guided self-evaluation abilities. A rubric score of eight parameters was developed, and it was supposed to be completed in each lab session, both by the students and the teacher assistant (TA), to evaluate student performance during the laboratory work. Among the papers, one dealt with understanding teachers’ implementation of assessment for learning (AfL), along with online teaching as a key for transforming online teaching and learning processes into self-regulated learning (SRL) during both routine and crisis times.

7 Summary

In summary, we hope that while reading the studies published in this SI, you will be able to reflect on your own chemistry teaching and select some ideas that you would like to integrate in your teaching. Trying a new teaching practice or a different approach for assessment is not a trivial task for any teacher. The challenge in introducing any innovation in school is tremendous. However, in this SI the new ideas and the innovations are supported by methodological studies that examined both their benefits and pitfalls. Thus, this makes their implementation and adaptation to different educational settings easier and less risky.

We hope that you will find the SI relevant and will enjoy reading it.

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References

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK summit. In A. Berry, P. J. Friedrichsen, & J. J. Loughran (Eds.), Re-examining pedagogical content knowledge in science education (pp. 28–42). Routledge.


OECD (2018, April, 5). *The future of education and skills Education 2030*. OECD.
