Contributions from Science Education Research 6

Eilish McLoughlin
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Bridging Research and Practice in Science Education

Selected Papers from the ESERA 2017 Conference

Springer

Contributions from Science Education Research

Volume 6

Contributions from Science Education Research is the international, multidisciplinary book series of the European Science Education Research Association (ESERA). The aim of the series is to synthesize, for the benefit of the scholarly community, the findings of high quality, theoretically-framed research in the domain of science education as well as comprehensive explorations of specific methodological strands in science education research. The series aims to publish books that are innovative in attempting to forge new ways of representing emergent knowledge in the field. The series includes edited collections of chapters, monographs and handbooks that are evaluated on the basis of originality, scientific rigor and significance for science education research. The book series is intended to focus mainly on work carried out in Europe. However, contributions from researchers affiliated with non-European institutions and non-members of the European Science Education Research Association are welcomed. The series is designed to appeal to a wide audience of researchers and post-graduate students in science education. Book proposals for this series may be submitted to the Publishing Editor: Claudia Acuna E-mail: Claudia.Acuna@springer.com

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Introduction

This edited volume is composed of selected papers that were presented at the 12th European Science Education Research Association (ESERA) Conference, held in Dublin, Ireland from 21 to 25 August 2017. The ESERA community consists of professionals with diverse disciplinary backgrounds, ranging from natural sciences to social sciences. Such diversity provides a broad range of research, practice and policy of science teaching and learning as reflected in this volume.

ESERA is an international organization for science education researchers and science educators, and it aims to (i) enhance the range and quality of research and research training in science education; (ii) provide a forum for collaboration in science education research; (iii) represent the professional interests of science education researchers in Europe; (iv) seek to relate research to the policy and practice of science education in Europe; and (v) foster links between science education researchers in Europe and elsewhere in the world (www.esera.org). The biennial ESERA conference is the main forum for direct scientific discourse within the community, for exchange of insightful practices, and for extending networks among the researchers and educators.

The contributions in this volume showcase current orientations of research in science education. Overall, this book will be of interest to an international audience of science teachers, teacher educators and science education researchers who have a commitment to evidence-based and innovative science teaching and learning.

Reflecting on the ESERA 2017 Conference

The ESERA 2017 Conference theme was Research, Practice and Collaboration in Science Education, and underlying aspects that are of great relevance in contemporary science education research. The conference theme called on researchers to reflect on different approaches to enhancing our knowledge of learning processes and the role of context, designed or circumstantial in learning and instruction - across formal, informal and non-formal contexts.

The organization of the ESERA 2017 conference was jointly undertaken by Dublin City University and the University of Limerick through their STEM education research centers of CASTeL and EPI-STEM. In total, 1519 single and multi-paper proposals were submitted to the conference in early 2017. Of the 986 proposals submitted for single oral presentations, 663 were presented as such at the conference. A total of 260 proposals were presented as interactive posters and this included contributions from 62 young researchers who had attended the ESERA summer schools - 39 of the participants of the ESERA 2016 Summer School and 23 of the participants of the ESERA 2017 Summer School. In total, 59 symposia (each with four papers) were presented at the conference, of which 16 were invited symposia. Each symposium was organized by a coordinator around a specific topic and each of the papers addressed the topic from different perspectives by authors from different countries. Twelve sessions were presented in the format of an ICT demonstration, hands-on workshop or as a World Café.

The conference week was thus highly scheduled with single oral presentations, symposia, interactive posters, ICT demonstrations and workshops divided into 18 different strands based on their topic (see www.esera2017.org). In addition, the conference also invited four plenary talks by prominent researchers, focusing on (i) Equity in Science Education: Science as a Tool Rather than a Destination; (ii) Science Education: A Balancing Act Between Research in University, Daily Instruction in Schools and Politics in Education Ministries; (iii) The Good Science Teaching Quest(ion): Constructions and Contestations; and (iv) Broadening our understanding of transformative science learning contexts: the role of design, collaboration, and digital technologies. After the conference, all presenters were invited to submit revised and extended papers on their conference presentation to the electronic proceedings of the ESERA 2017 Conference, which is available at https://www.esera.org/publications/esera-conference-proceedings (Finlayson, O.E., McLoughlin, E., Erduran, S., & Childs, P.E. (Eds.) (2018). Electronic proceedings of the ESERA 2017 Conference: Research, Practice and Collaboration in Science Education. Dublin, Ireland: Dublin City University ISBN 978-1-873769-84-3).

The ESERA 2017 Conference was attended by 1522 science education researchers from 53 countries around the world and thus the conference was indeed a very international meeting. About two thirds of the participants came from 29 European countries, with the remainder of the participants coming from 24 different countries across North America, South America, Asia, Australia, Africa, and Middle East. While presenting one's own research and engaging with others in discussion was one of the most important aspects of the conference, having an opportunity to meet other science education researchers was just as valuable. The discussions at conference sessions provided opportunities for researchers and practitioners to exchange their experiences and approaches. The countless encounters with other researchers throughout the week enabled the participants to strengthen their existing networks, make new acquaintances and set seeds for future cooperation. For the first time in an ESERA conference, one of the workshop sessions was conducted in the form of a World Café discussion on how to combine content knowledge and pedagogical content knowledge learning during university teacher education. At thematic discussion tables, the participants at this World Café were invited to present their ideas (e.g., using printed materials or short oral/poster presentations) and to co-develop ideas for how to improve the integration of different aspects of teachers´ professional knowledge and competencies across the participating countries.

In addition to the formal conference program, the participants had an opportunity to attend pre-conference workshops and different receptions, and take part in other excursions around Dublin City and other Irish tourist destinations. The general atmosphere at the conference was one of collaboration and collegiality. The participants were delighted to be at ESERA in Ireland for the first time and received a "Céad Míle Fáilte"—a hundred thousand welcomes—from the local organizers. A local group of 54 individuals formed the support team for presenters throughout the conference week. This team consisted of academic faculty members, postdoctoral researchers, postgraduate and undergraduate students in science education from the two host universities of Dublin City University and the University of Limerick. ESERA 2017 participants got the opportunity to flavor the famous Irish "ceol agus craic" (music and fun) at the Traditional Irish Céilí night on the evening before the final conference day and it was wonderful to see hundreds of participants joining in Traditional Irish Dancing—an experience they will hopefully cherish for many years to come.

Highlights of the Chapters

This volume presents research identified at the ESERA 2017 conference as particularly interesting in the field of science education. The topics discussed will generate interest and spark debate within the community of science education researchers and science educators. We, the editors, are very grateful for all the work carried out by the international panel of strand chairs and reviewers who made it possible to include these selected papers in this compilation. Following the conference, the strand chairs recommended interesting conference contributions as possible papers for this book. We invited 44 recommended authors to submit full manuscripts. Based on at least two reviewer reports, we determined the 22 papers selected for this book. Thus, the papers underwent a rigorous scientific review process, guided by the editors, before being accepted into this volume in their final form.

This volume contains 22 papers as chapters that each take a specific perspective of an aspect of contemporary science education. The chapters are multifaceted and examine different science education phenomena. To help the reader, the chapters are discussed under four themes: Innovative Approaches to School Science, Emerging Identities in Science Education, Learning Progressions and Competences, and Enhancing Science Teacher Education.

In what follows, we will highlight the main aspects in each particular theme. This will provide the reader with an overview of the variety of different subjects, contexts, and research approaches.

Innovative Approaches to School Science

The volume begins with a collection of six contributions that discuss approaches for bridging research and practice to enhance science education in our schools and report on a range of innovative approaches carried out with students aged from 5 to 16 years old. In this context of enhancing science teaching and learning in our schools, **Peter Labudde**, one of the keynote speakers at ESERA 2017, highlights eight foci that are pertinent for science educators to consider. Each of these foci is presented and illustrated by paradigmatic examples from recent research projects in science education. Foci 1 to 4 consider how research in science education can be translated into everyday practice and policy, e.g., developing concepts for instruction and responding to the needs of schools. Foci 5 to 8 are concerned with how everyday practice and policy can influence research in science education, e.g., reframing recent scientific research as science content for schools, considering non-formal teaching-learning processes.

In their chapter, **Manuel Bächtold** and **Valérie Munier** present an example of a strategy for teaching the concept of energy at high school based on history and philosophy of science and building on the historical research of Joule and Rankine. This teaching-learning sequence was created through a researcher–teacher collaboration. Evidence of the effect of this history and philosophy of science approach on student understanding in this context is presented. This chapter highlights this approach could be an effective teaching strategy for other topics in science.

The next two chapters propose that embedding multiple external representations (MERs) in science education is key to developing students' understanding of science and scientific literacy. **Marie-Annette Geyer** and **Gesche Pospiech** discuss an explorative, qualitative laboratory study in which 17 pairs of students (aged about 14 years) worked on physical-mathematical tasks requiring different transformations of representations of functional dependencies. Qualitative content analysis was used to examine students' written work and discussions to elucidate possible strategies and thinking patterns of the students while they were transforming representations. **Christina Beck** and **Claudia Nerdel** remind us that science can be understood as a multimodal discourse, and dealing with multiple external representations becomes a premise for learning and developing representational competence. Their study analyzes the use of different representations (diagram, schema) and the relationship between representational competences (information selection and interpretation, construction, translation, and transformation) in three different biological contexts (ecology, physiology, genetics).

The authors **Andreas Larsson**, **Matilda Stafstedt,** and **Konrad J. Schönborn** remind us that our everyday language is filled with all sorts of metaphoric relations (e.g., analogies, metaphors, and metonyms). Metaphoric relations—the idioms in which we talk about one phenomenon in terms of another—are linguistic units that are an important constituent in the way we reason about and understand the world around us. Their study investigated eight groups (3–4 pupils per group) of fourth-grade pupils' use of metaphoric relations while using thermal cameras to explore "heat" at a science center. The pupils' use of the thermal cameras provided them access to thermodynamic phenomena through unique sensory and nonsensory experiences in an informal learning context. The authors raised the need for future research to explore how these metaphoric relations can be exploited as sense-making activities in the classroom.

Estelle Blanquet and **Eric Picholle** discuss a study involving 62 five-year-old children. These young learners were presented with a bottle in which a hole had been pierced and asked if it was possible to stop the water from flowing through the hole without closing it. The pupils were then shown that this result can be obtained by screwing the bottle's cap. The focus of this study was to investigate the ability of children to consider a counterintuitive experiment as "science," and able to consider its reproducibility—or do they consider this experiment as magic? Are the children able to justify their position? How do they consider the necessity of testing the reproducibility of an experiment? The authors raised the need for further observations to establish whether an explicit focus on the reproducibility of an experiment performed in the frame of scientific inquiry would allow pupils to get a better grasp of scientific concepts and the notion of reproducibility.

Emerging Identities in Science Education

This section of the book includes six chapters that deal with a range of issues and themes related to students' learning of science. The themes covered include not only foundational issues such as motivation and self-efficacy but also particular skills such as computing skills and the ability to engage in scientific inquiry. The authors use a range of methods including qualitative and quantitative methods to highlight how science teaching and learning can be improved. An emerging theme is the newly conceptualized account of activism in science to encourage students to take an active role in social matters that have scientific undertones such as climate change. In her chapter, **Jenny M. Hellgren** highlights the importance of students' motivation in science lessons, and proposes a new model for considering motivation in science education. The author conceptualizes motivation as a multi-level and dynamic construct, and captures contextual and situational motivation of relevance for the science classroom. The proposed model combines multiple theoretical perspectives to produce a model of motivation that supports a multi-perspective view of motivation of relevance to complex classroom situations. The proposed model supports multiple methodological perspectives to study motivation in science classroom situations.

The authors **Anssi Salonen, Anu Hartikainen-Ahia, Tuula Keinonen, Inês Direito, John Connolly, Annette Scheersoi,** and **Lara Weiser** examine lower secondary school students' knowledge of specific working life skills. The authors report on a multinational research project involving a large sample of participants from the UK, Finland, and Germany. Using open-ended questions and content analysis, they examine students' perceptions of working life skills needed in science-related careers. The results reveal that the students have a great deal of knowledge about working life skills - often stereotypical. The authors suggest that students need learning experiences including presentation of working life skills such as interacting with professionals and their real work-life problems, open-ended inquiries, and balanced team working to increase their awareness and perceived relevance of careers.

Anne-Kathrin Peters draws attention to students' computing skills and reports a longitudinal study conducted with the aim of exploring computing students' changing relationship to their field of study during their university education. Students from two study programs were selected to follow through interviews at the end of the first three study years. An early insight was that students' reflections on their interests in computing can change drastically, for example, from being someone interested in combining art and computing to being interested in back-end problem solving. Hence, the author uses social identity theories to reason about changes in student reflections.

Albert Zeyer, Nuria Álvaro, Julia Arnold, J. Christian Benninghaus, Helen Hasslöf, Kerstin Kremer, Mats Lundström, Olga Mayoral, Jesper Sjöström, Sandra Sprenger, Valentín Gavidia, and **Alla Keselman** capitalize on the expertise and experiences of an international group of science educators to investigate complexity as a key feature for understanding the role of science knowledge in environmental and health contexts. The authors point to the fact that complex systems are, in principle, not predictable. In different contexts, different mechanisms produce various, sometimes completely unexpected results. The role of complexity in fields such as science, health, and environment implies the need to develop future citizens who understand the delicate relation between predictability and uncertainty and to empower them for wise decisions about societal and personal well-being. The authors present a series of studies which illustrate the importance and challenges of introducing the issue of complexity into science education.

The chapter from **Larry Bencze, Lyn Carter, Audrey Groleau, Mirjan Krstovic, Ralph Levinson, Jenny Martin, Isabel Martins, Chantal Pouliot,** and **Matthew Weinstein** introduces a fairly unique focus that deals with potential harms to various individuals, societies, and environments. As an example, they highlight the devastation from climate change linked to fossil fuel uses. Given apparent roles of many governments in supporting powerful problematic networks that involve fields of science and technology, many science educators recommend that school science should not only enlighten students about harms and encourage them to make logical personal decisions about associated controversies, but also prepare them to take sociopolitical actions that might contribute to their conceptions of a better world. The chapter then brings together international science education researchers to discuss their uses and analyses of a curriculum framework called "STEPWISE" which is intended to facilitate such critical and activist science education.

The final chapter in this part from **Judith S. Lederman, Norman G. Lederman, Selina L. Bartels**, and **Juan P. Jimanez** reports on a large-scale international project on students' learning of scientific inquiry during their elementary school years. Eighteen countries or regions spanning six continents including over 2000 students participated in the study. The results overwhelmingly show that students around the world at the beginning of grade 7 have very little understanding about scientific inquiry. Some countries do show reasonable understanding in certain aspects but the overall picture of understanding of scientific inquiry is not what is hoped for after completing six years of elementary education in any country. Collectively, the studies reported highlight the need for innovation in science teaching and learning to ensure that future citizens are equipped with appropriate skills and identities in dealing with scientific and socioscientific issues.

Learning Progressions and Competences

The third section of the book includes six chapters that deal with a range of issues relating to learning progressions and competences. To enhance student learning and to develop appropriate learning sequences, various models of student learning have been proposed and discussed throughout the literature. In this section, student learning is examined through various contexts.

The area of Futures Studies, a research area which investigates "building the future" is the background for the chapter presented by the authors **Giulia Tasquier, Laura Branchetti,** and **Olivia Levrini.** They propose the use of science as the source of knowledge to develop future-scaffolding skills. Having developed and implemented a module on climate change with a group of second level students at a summer camp, the study was evaluated to determine students' perception of time (both present and future) and also to further define the future-scaffolding skills. Interestingly, the authors highlight that their most relevant finding from the analysis of the evaluation of the module was the sense of hope and calm expressed by the students on completion of the module, suggesting the role that science education can play in supporting young people in a world where there can be negativity about the future.

According to the authors **John Airey, Josefine Grundström Lindqvist,** and **Rebecca Lippmann Kung,** physicists can view the world using a web of equations that can be considered as the culmination of a range of actions, assumptions, and historical discoveries. However, how does the undergraduate student understand these equations and what does it mean to "understand an equation"? Using data from a study of undergraduates in three countries, the authors found similar interpretations in each country, which led them to suggest eight distinct themes with regard to students' understanding of a physics equation. Using these themes, they proposed a set of questions for students to ask themselves so that they can check their own understanding of what a particular physics equation represents. This work is continuing to determine if the expert opinion, i.e., from physics lecturers, on what it means to "understand an equation" agrees with that of the undergraduate student.

Studies on learning progressions that show the sequential development of student ideas have been used in a variety of contexts in the literature including design of classroom activities, assessments and student ideas and thinking. The chapter by **Erin Marie Furtak** and **Kelsey Tayne** examines how a number of teacher communities used learning progressions to support the design of formative assessment tasks, including interpretation of student ideas and planning feedback. The authors discuss the work of the group involved and highlight the use of learning progressions to explore student ideas and setting learning goals by the group with less emphasis in using the learning progressions to interpret the student ideas and in identifying the next steps in the learning.

The development of models of student learning can influence and inform teaching strategies, curricula, and assessment practices. In the chapter presented by authors **Annette Upmeier zu Belzen, Alicia C. Alonzo, Moritz Krell,** and **Dirk Krüger**, they present the two approaches to model student learning, namely Learning Progressions and Competence Model. The chapter outlines the origin of the two models and draws comparisons between them. They conclude that while both models are valuable and worthwhile in their contribution to teaching and learning, the subtle differences between the approaches can be informative, particularly in terms of curriculum emphasis, and student achievement.

The process of learning was investigated in the chapter by **Eva Pennegård**, within the context of the physics classroom at lower second level. Using videotaped lessons, the teachers could discuss and reflect on their actions that facilitated learning by their students; using the same video lessons, the students involved also reflected on their learning and the teacher actions that facilitated their learning. Teachers were then able to reflect on the responses from the students in terms of their practice. The inclusion of the student voice was an important element for professional development of the teachers.

The final chapter in this section by authors **Anni Loukomies, Kalle Juuti, Jari Lavonen,** and **Katariina Salmela-Aro** emphasizes that the science-related competence beliefs of young students (in this study 7–8 years of age) can be increased by participation in science and technology workshops. In this study, the students were involved in three workshops—on electrical circuits, programming with Lego Mindstorm robots, and on computer-based data logging. It was argued that these workshops could be included in the main curriculum.

Enhancing Science Teacher Education

It is now widely acknowledged that the key to improving science education and successful curriculum development is the quality and involvement of science teachers. The same is true of science education research: instead of being done on teachers it is most effective if done with and by practicing science teachers. The failure to improve science teaching and learning, despite decades of science education research, is largely due to a failure to involve and resource science teachers, and to make research findings available in an accessible and relevant form. The four chapters in this final section are all connected to science teacher education.

The chapter from authors **Irina Kudenko, Pauline Hoyle,** and **Ben Dunn** makes the case for subject-specific professional development (PD) in science for primary teachers in the UK. It compares two models of delivering such PD: through school-led PD partnerships and through external-led PD by primary STEM experts. This chapter is based on sizable data sets for each model and each provides evidence of improvement in teachers, schools, and pupils STEM experience, although each model has its weaknesses. The evidence presented shows that the two approaches are complementary and that the research has led to modifications in the programs, in a blended approach, tackling the weaknesses and drawing on the strengths of each model. It is good to see research actually changing practice as examined in this study.

Hannah Sevian and **Vesal Dini** use a design-based research (DBR) approach to evaluate the way experienced secondary chemistry teachers use formative assessment in their science teaching and to develop a Principled Practice Knowledge (PPR) resource. This chapter gives a clear description of a DBR approach to improving teachers' competence in using formative assessment (FA). It describes a 6-year project, conducted in four phases, which developed a PD resource to help teachers use FA more effectively. The focus on the importance of the teacher as the key player in the process is a significant conclusion. The chapter shows how DBR can used to create a useful, practical resource of Principled Practice Knowledge (PPK) to help teachers implement changes in practice.

The authors **Giannis Sgouros** and **Dimitris Stavrou** focus on developing teaching modules in Nanoscience and Nanotechnology (NST) in conjunction with secondary science teachers, science education researchers, communication experts, and subject experts in NST, as a Community of Learning (CoL). As well as introducing a new topic into school science, the modules also included aspects of Responsible Research and Innovation (RRI), in the context of the IRRESTIBLE project, and also out-of-school activities. The work is a good example of collaborative curriculum design and a key finding was the importance of teachers' reflection on their own professional practice.

Iztok Devetak, Sonja Posega Devetak, and **Tina Vesel Tajnšek** discuss how to develop the competences of pre-service teachers in managing students' allergies. This topic is somewhat outside the usual scope of science education and deals with an aspect of a teacher's professional responsibility for their students' welfare. The chapter describes a program to develop the medical competence of pre-service teachers in a classroom setting. It has no specific reference to science education but clearly the topic has a place within a science course, especially if we take chemical and biological sensitivities into account.

All these four, very different, chapters highlight the importance of the teacher in the classroom and their interaction with their students but also with the wider educational community and society.

Concluding Remarks

As the reader can see, this volume deals with a wide variety of topics and research approaches, conducted in various contexts and settings, all contributing to our shared knowledge of science education. As the editors, we trust this volume will invoke discussion and ignite further interest in developing new collaborative research studies, practices, and policy in Science Education.

The internet and other digital applications and media make it possible, feasible, and attractive to organize collaborative international research groups that can jointly carry out science education research from physically distant locations. The ESERA biennial conference provides an outstanding forum for science education researchers and practitioners to present their research and expose it for discussion and examination, and further build their networks—not only within Europe but all over the world. We want to extend a sincere thank you to the ESERA Board for the opportunity and for the confidence bestowed on us to enable us to host a successful ESERA 2017 Conference in Dublin, Ireland.

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About the Editors

Eilish McLoughlin is Associate Professor in the School of Physical Sciences and Director of the Research Centre for the Advancement of STEM Teaching and Learning (CASTeL) at Dublin City University. She received her PhD in Experimental Surface Physics in 2000. Her research interests are focussed on the development of curriculum, instruction, and assessment models in Physics/STEM education, at all levels of education, from primary school to PhD level. She has led and collaborated on many research projects at EU, national, and local levels, including coordination of EU FP-7 project ESTABLISH and partner in EU projects 3DIPhE, OSOS and SAILS. She co-leads the physics initial teacher education program at Dublin City University and has led several projects that support teachers, both in-service and pre-service, in adopting innovative practices in their classrooms and enhance student identity in Physics. She has received recognition for her leadership in STEM Education and engagement across formal and informal contexts, including the NAIRTL National Award for Teaching Excellence (2010), Institute of Physics Lise Meitner Medal (2018), Institute of Physics Young Professional Physicist of the Year (2006), and Dublin City University's President Awards for Public Engagement (2017) and for Teaching and Learning (2005).

Odilla E. Finlayson is Associate Professor of Science Education in the School of Chemical Sciences at Dublin City University. She is one of the founding members of CASTeL (Centre for the Advancement of STEM Teaching and Learning) in Dublin City University and plays an active part in its management and development. She is involved in teaching (mainly physical) chemistry to undergraduate science students and to pre-service teachers. She is interested in curriculum development at second level and was a member of the Board of Science Studies in NCCA (National Council for Curriculum and Assessment). She sits on the Council of the Institute of Chemistry of Ireland, where she is Registrar and also convenor of the Education Committee. Her current research interests are in sustaining science across transitions and in particular in development of appropriate science (chemistry) curricula and assessment. She is also involved in co-ordinating Ireland's involvement in science Olympiads, namely International Junior Science Olympiad, European Union Science Olympiad and the International Chemistry Olympiad, as Country Co-ordinator and mentor. She has been involved in many local and international research projects, including EU FP-7 project ESTABLISH and co-ordinator of EU FP-7 project SAILS.

Sibel Erduran is Professor of Science Education at University of Oxford and a Fellow of St Cross College. She also holds Visiting Professorship positions at University of Oslo, Norway and Zhejiang Normal University, China. She is an Editor for *International Journal of Science Education,* Section Editor for *Science Education*, and serves on the Executive Board of European Science Education Research Association. Her work experience includes positions in the USA (University of Pittsburgh), Ireland (University of Limerick) as well as other universities in the UK (King's College London and University of Bristol). Previously she held Visiting Professorships at Oxford Brookes University; National Taiwan Normal University; Kristianstad University, Sweden; and Bogazici University, Turkey. Her higher education was completed in the USA at Vanderbilt (PhD, Science Education and Philosophy), Cornell (MSc, Food chemistry and Chemistry), and Northwestern (BA, Biochemistry) Universities. She has worked as a chemistry teacher in a high school in Northern Cyprus. Her research interests focus on the infusion of epistemic practices of science in science education, in particular chemistry education. Her work has received international recognition through awards from NARST and EASE. She is currently the Principal Investigator of projects funded by the Wellcome Trust and Templeton World Charity Foundation. Her edited book on *Argumentation in Chemistry Education: Research, Policy and Practice* (Royal Society of Chemistry) and co-authored book on *Transforming Teacher Education through the Epistemic Core of Chemistry: Empirical Evidence and Practical Strategies* (Springer) were published in 2019.

Peter E. Childs has been involved in the work of EPI-STEM, the National Centre for Science Education at the University of Limerick, since its inception in 2008. After reading Chemistry at Oxford (1965) and completing a DPhil in Solid State Chemistry (1967), he spent 2 years in North Western University on a postdoctoral fellow with a Fulbright scholarship. He then spent 6 years teaching chemistry from 1970 at Makerere University, Kampala, Uganda, where he became interested in working with teachers to improve school chemical education. Returning to the UK he had one year each at York and Leeds on research fellowships, before coming to Ireland in 1978. Initially, he taught chemistry and chemical education at Thomond College of Education to intending second-level teachers, and in 1990 joined the chemistry department in the University of Limerick, when the two institutions merged. He then taught inorganic and environmental chemistry, and worked with intending chemistry teachers, until 2009 when he retired. Since he began his retirement he has directed the Chemistry Education Research Group and been involved in three EU-funded projects: SALiS, a Tempus project (2010–2012); TEMI, an FP7 project, 2013–2016; ARTIST, an Erasmus+ project, 2017–2019. He has worked intensively with chemistry teachers since coming to Ireland; he started the magazine Chemistry *in Action!* in 1980, the ChemEd-Ireland conferences in 1982, and the Chemistry Demonstration Workshops in 2004, as well as running many in-service courses and workshops and industry study tours. A number of people have gained PhDs and Master's in science/chemical education under his supervision. He is past Chair of the EuCheMS Division of Chemical Education, and Past-President of the Irish Science Teachers Association and of the Institute of Chemistry of Ireland. His work in chemical education has been recognized by the BP Science Educator of the year award by the ISTA, the Boyle-Higgins Gold Medal of the Institute of Chemistry of Ireland, and an education award from Pharmachemical Ireland. In addition to chemical education he is also interested in the history of chemistry, the chemical industry, and science education.

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