Chapter 1
Introduction: Socio-scientific Issues as Promoting Responsible Citizenship and the Relevance of Science

Maria Evagorou and Justin Dillon

1.1 Introduction

Socioscientic issues (SSI) and teacher professional development have been part of our research agendas for at least the last decade, and as we (Maria, Jan and Justin) crossed our paths as researchers, we started working together on a European Commission funded project titled *Preparing Science Educators for Everyday Science* (PreSEES). The aim of the project was to prepare pre-service science teachers (PST) in their effort to teach SSI, and with a group of researchers from around Europe we shared our ideas, questions and concerns and designed modules aiming to introduce SSI; help PSTs design and teach SSI related activities; and support PSTs in assessing learning in SSI (Evagorou et al. 2014a, b, also Chap. 10 in this book). During the project we realized that the international science education research community mostly explored how students engage in SSI (Patronis et al. 1999; Sadler et al. 2007; Sadler and Zeidler 2004; Sampson et al. 2011; Simonneaux and Simonneaux 2008; Shoulders and Myer 2013), but studies on teachers, their practices and how they can support their students to engage in SSI was still limited (Evagorou and Puig 2017; Tidemand and Nielsen 2016). At the same time in Europe, where all three of us live and work, various reform documents (EU Commission 2015; Owen et al. 2012) were shifting the emphasis of research agendas to responsible citizenship and the notion of making science relevant to students. The need to make science relevant to students came from reports showing that the numbers of students choosing science as a future career, or being interested in science, was

M. Evagorou (✉)
Department of Education, University of Nicosia, Nicosia, Cyprus
e-mail: evagorou.m@unic.ac.cy

J. Dillon
Graduate School of Education, Exeter University, Exeter, UK
e-mail: J.S.Dillon@exeter.ac.uk

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declining (EC 2004), whilst the shift to responsible citizenship is linked to the idea of scientists and society sharing the outcomes of science in an effort to promote responsible research and innovation (Owen et al. 2012). Based on our understanding of SSI literature, we support that by engaging students and teachers in SSI we can actually achieve making science relevant, and promote responsible citizenship, and therefore as part of our on-going discussions and our findings from the PreSEES project we decided to explore the issue and invite researchers working on SSI and teacher professional development to present their work as part of this edited volume.

The purpose of this book is to bring together researchers working on teacher professional development, with an emphasis on SSI, to share their work, experiences and findings in terms of the pedagogies and pedagogical designs, and teaching strategies they are applying in their work in order to promote relevance of science and responsible citizenship. Therefore, our invitation was extended to researchers around the world, making an effort to include work from all continents to represent the abundance of work, and possibly different approaches in the different educational systems. The call for chapters was targeted to researchers whose work we were familiar with and believe represent different pedagogical and methodological approaches in introducing SSI to teachers. In this chapter we briefly present SSI and its importance, the importance of preparing science educators to teach SSI, and introduce the various chapters that are included in this book.

1.2 Socioscientific Issues, Relevance of Science and Responsible Citizenship

Socioscientific (SSI) issues are ill-structured problems that involve moral, ethical, and financial aspects, and lack clear-cut solutions (Lee and Grace 2012; Topcu et al. 2010), are usually topics that emerge from the nexus of science and society (Sadler and Zeidler 2004), and have a degree of uncertainty. Some of the topics include stem cell research, environmental issues and their possible solutions (i.e. fracking, renewable energy) and genetically modified organisms. According to Zeidler et al. (2005), by discussing such topics the SSI movement aims to empower students to consider how decisions made concerning science-based issues reflect "the moral principles and qualities of virtue that encompass their own lives, as well and the physical and social world around them" (p. 360). The ability to deal with socioscientific issues has been recognized as an important goal of science education (Zeidler 2014) and by engaging learners with SSI, we can potentially help them understand the relevance of science to their lives (Stuckey et al. 2013), understand aspects of the nature of science and how people use it, and develop their capacity to be critical consumers of scientific information (Kolstø 2001; Levinson 2006). Hence, SSI education is either concerned with ethics and involves moral judgment about issues of scientific concern, or represents those social issues and problems that are conceptually influenced by science and require the integration of science concepts

and processes (Sadler et al. 2007). According to Simonneaux and Simonneaux (2008) when we teach SSI we aim:

> to improve knowledge understanding, to contribute to citizenship education, to help students to make an informed decision, to empower them to participate in debates, to help them to be able to deal with complexity, and to understand better the nature of science (p. 181).

Therefore, socioscientific issues enable learners to recognize that there is a human dimension to the practice of science, see the connections of science to everyday life (Zeidler et al. 2003) and take action on issues relevant to their everyday lives (Bencze and Carter 2011). The effort to introduce socioscientific issues in the curriculum was first evident as part of the Science Technology Society (STS) movement as far as back in the 1980s by making school science more reflective of the society (Sadler 2004). However, the main difference between STS and SSI, is that SSI focuses on empowering students to handle the socioscientific issues by understanding the various aspects of the issue, and making informed decisions (Kolstø 2001). Introducing SSI in science teaching can also be supported by Roberts' (2007) Vision II of science which aims to promote the understanding of the usefulness of scientific knowledge by using meaningful content (more about Vision II can be found in Chaps. 3, 4 and 9). More recently, European research agendas have been placing an emphasis on Responsible Research and Innovation (RRI), which is "an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation" (EU Commission 2015). The main emphases of RRI is on science with and for society (Owen et al. 2012), and highlights the importance of presenting the societal aspects of science to our learners (Evagorou and Puig 2017) and inviting them to take action. With the two movements (RRI and SSI) sharing the common goal of discussing and understanding the societal aspects of science, researchers link RRI to socioscientific issues and responsible citizenship (Owen et al. 2012). The main ideas behind RRI (also presented in Chaps. 4 and 8), and socioscientific issues is that by including socioscientific issues in science learning and teaching we could move science classes towards unwrapping and engaging discussions about the intersections of science and society, promote scientific practices, and potentially invite students to act responsibly and participate actively. This "knowing in action" (Aikenhead 2006) aspect of RRI and SSI is related to what Sjöström and Eilks (2018) define as Vision III scientific literacy – one that includes socio-political action and moral-philosophical perspectives. Therefore, the inclusion of socioscientific issues in the curriculum offers a means of expanding both the curriculum and the range of instructional practices commonly experienced in the school science classroom, and in some cases also involves taking action on issues of concern.

Responsible citizenship, or thinking in scientifically responsible ways requires the students to form specific features of characters, and, "depends upon the character of both the scientists and the public at large, and that character includes reflexive judgment applied to scientific knowledge and ethical standards" (Zeidler et al. 2014,

p. 83). According to the same researchers, our character and experiences are shaped by our interactions in multiple cultures, and since science education is considered a distinct culture (Aikenhead 2006) we aim through socioscientific education to form characters that are ready to act in scientifically responsible ways (EU Commission 2015). Despite the effort to include SSI in schools, according to Alsop and Bencze (2012) SSI instruction is still constrained to a presentation of the social dilemma, with no attempt to promote engagement, participation or action. There is minimal research in the area of teacher education and the pedagogy associated with the relevance of science and responsible citizenship through their use (Evagorou and Puig 2017). Studies have shown that teachers do not make the connection between science and students everyday life since they find it difficult to relate scientific data and the social aspects of the problem which bring uncertainty into the discussions (Evagorou 2011; Forbes and Davis 2007). Research studies suggest that science teachers find it challenging to guide student learning in SSI (Evagorou 2011; Levinson 2006) and this is mainly because teaching SSI puts a demand on science teachers to use information and knowledge from outside their scientific domains (i.e., moral, financial, ethical dilemmas) (Simonneaux and Simonneaux 2008). Therefore, teacher professional development programs have started focusing on the pedagogical challenges of teaching SSI (Forbes and Davis 2007), but so far there is limited research on SSI teaching as part of either in-service or pre-service teacher education and this is the gap that we seek to address in this edited volume.

1.3 The Structure of the Book

This edited volume consists of 12 chapters. In Chaps. 1 and 2 we (as editors) introduce the notion of socioscientific issues, responsible citizenship and relevance of science and briefly discuss research on teacher professional development and SSI. In Chaps. 3, 4, 5, 6, 7, 8, 9, 10, and 11 we bring together the work of researchers from around the world (Australia, Argentina, Canada, Hong Kong, Israel, Spain, South Africa, UK, USA) to share their practices, examples of pedagogical approaches in teacher education (both pre- and in-service), and experiences on how to promote relevance and responsible citizenship through SSI. The final chapter concludes by summarizing new perspectives for addressing socioscientific issues in teacher education.

When considering the order of the chapters we decided against grouping them based on the type of professional development (pre- or in-service), or on the type of methodologies used. Instead, we decided to start with Chap. 2 as an overview of recent empirical research in SSI, follow with Leung and colleagues who set the basis by exploring teachers beliefs about teaching SSI and connecting them to Vision 2. The chapter to follow (Amos and colleagues) includes references to Vision 2 and then each subsequent chapter is linked to the following in a similar way.

In Chaps. 1 and 2 we (Maria, Jan and Justin) explain our views of socioscientific issues, and discuss recent research on teacher professional development and SSI. In

our Chapters we use the term socioscientific instead of socio-scientific (see Zeidler 2014 for explanation) but we did not require the same from the Chapter authors.

In Chap. 3 (Pre-service secondary science teachers' beliefs about teaching socio-scientific issues), Leung, Wong and Chan examined 18 PSTs beliefs about the importance of SSI teaching in the local science curriculum and identifies their key learning experiences during a course on Nature of Science and SSI. Their results suggest that at the end of the course, most of the PSTs considered SSI as a key component of the science curriculum. In addition, the data analysis revealed three reasons why the PSTs did not prioritize SSI teaching in the curriculum: the complexity of SSI teaching, the shared curricular objectives of SSI with subjects (e.g. Liberal Arts in the case of Hong Kong) and their belief that SSI does not have an important role in content knowledge (CK) and nature of science (NOS). Furthermore, the results show that having a unidirectional view about the relationship between SSI, NOS and CK could lead PSTs to consider SSI teaching as less important to teaching CK and NOS. Therefore, Leung, Wong and Chan highlight the need to address the interrelationship between SSI, NOS and CK. An important aspect of this chapter is that the authors explain the context of Hong Kong and that even though the country adopted the STS movement in science teaching, SSI are not included in the science curricula, but are included instead in the Liberal Arts. Furthermore, an important finding that is highlighted in the discussion of the authors is that of the lack of assessment on SSI, which according to some PSTs is an important reason leading them to not include SSI in their teaching.

In Chap. 4 (Socio-scientific inquiry-based learning: possibilities and challenges for teacher education), Amos, Knippels and Levinson explore the implementation of a pedagogical approach for teaching through socially responsible inquiry embedded in socioscientific issues with pre-service teachers. More specifically, the work presented in this chapter comes from an European Commission funded project focusing on elaborating pedagogies which bring together, under the umbrella of Responsible Research and Innovation, the following: inquiry based science education (IBSE), earning of socio-scientific issues (SSI) and incorporating Citizenship Education (CE). More specifically, the authors of the chapter present how three pre-service teachers implemented socioscientific lessons. The studies showcase the complex steps involved in implementing SSI in the classroom, and more specifically the steps the pre-service teachers need to go through before they use science knowledge or structure inquiry based teaching. According to the authors, pre-service teachers need special scaffolding for these steps. An interesting aspect of this chapter is the teaching framework they present that is based on SSI and inquiry based learning.

In Chap. 5 (Critical and Active Public Engagement in Addressing Socioscientific Problems Through Science Teacher Education), Bencze, Halwany and Zouda present three collaborative case studies of science educators implementing the STEPWISE programme in different educational contexts. Their three very diverse case studies explain how different science educators, working with students of different ages and backgrounds are trying to incorporate Science Technology and Society and Nature of Science in their teaching. Important aspects of this chapter

and the work by Bencze and colleagues is that: (a) they explain the differences between SSI and STS and (b) their work is more on the activist side with students taking actions for the problems they are exploring, making the connection in that way to responsible citizenship. Also, the way they work with science educators to support them is different from most of the other chapters, with long term collaborations and self-selected teachers.

In Chap. 6 (Supporting teachers in the design and enactment of socio-scientific issues based teaching in the US), Friedrichsen, Sadler and Zangori describe how using a collaborative professional development (PD) design supports teachers as they co-design and implement SSI curricula. In this chapter the authors present three case studies of how their work evolved over 3 years through the collaborative PD process. In the first case study they worked with an exemplar secondary school teacher to co-design curriculum materials placing an emphasis on SSI and also on the modeling practice. The second case study focused on working with a group of 19 secondary school teachers from diverse backgrounds (biology, chemistry, environmental science) and the third case study focused on working with elementary school teachers in a school to co-design and teach a unit on the monarch butterfly, using the modeling practice as part of the curriculum. An important aspect of this chapter is that the authors are collaborating with exemplar teachers and together are co-designing lessons. Another note is that the emphasis of this work is also on practices and the Next Generation Science Standards (Achieve 2013), with an emphasis also on the content. The authors discuss how including different practices when engaging students with SSI can work, or impede the teaching.

In Chap. 7 (Gamification of SSI's as a Science Pedagogy), Davis and Bellocchi propose a gamification approach as a strategy for teaching SSI with the aim to enhance science literacy and critical rationality. More specifically, through their work that has developed over the years, James and Alberto focus on strategies and pedagogical tools that might assist teachers to become producers of SSI games to be implemented in schools, and the possibilities that their strategies contribute to critical rationality. James and Alberto work with pre-service teachers in Australia. In their definition of SSI they mostly focus on Socially Acute Questions (ASQ) (Simonneaux 2014). When they refer to games, they mostly refer to Alternative Reality Games which combine virtual with real situations. They describe the way in which they used the games with pre-service teachers, a way that promotes not only SSI but also the use of technology. The way the researchers introduce SSI to their pre-service teachers means that the teachers need to get actively involved to understand the topic and solutions, and in this way they promote activism, responsible citizenship, and they make science relevant to students.

In Chap. 8 (Science teachers as proponents of socio-scientific inquiry-based learning: From professional development to classroom enactment) Cohen, Zafrani and Yarden discuss responsible and active citizenship through the implementation of the a specific pedagogical framework (also discussed in Chap. 4) with upper-secondary school teachers in Israel. By implementing the SSIBL framework, according to the authors the teachers must have the required content knowledge of and about SSI, the pedagogical knowledge needed for SSI inquiry, and attitudes

needed to prepare students to make informed actions on SSI. The authors present two case studies, one with a teacher expert in SSI, and one with a teacher novice in SSI, and discuss the different ways in which these teachers implement the framework. The teachers were involved in professional that had a duration of 4 days and within this time they had to also implement in their classes an SSI lesson. Based on the findings, teachers with expertise in SSI find it easier to implement lessons framework, probably as SSI is more in accordance to their personal beliefs about teaching and learning. In their chapter the authors emphasize especially on active citizenship and explain Vision 1 and Vision 2 of science and how active citizenship is closer to vision 2 but this is not exercised in schools.

In Chap. 9 (Getting ready to work with socio-scientific issues in the classroom: a study with Argentine teachers) Furman, Taylor, Luzuriaga and Podesta present a professional development program implemented with in-service Argentinian teachers to support them in implementing SSI in their teaching. The authors of this chapter focus on following three teachers over 1 year as they implement SSI with their students, and reflect on struggles they face. The initial workshop had a duration of 2, 3 h twilight sessions. The teachers who decided to continue working with the researchers co-developed their lessons with the researchers. The final program has a duration of 20 h. The first teacher (kindergarten teacher) reports that she would have not been able to implement the SSI lesson without the help of the researchers, the second teacher (chemistry teacher) who was used at giving lectures mostly found it more difficult to implement SSI but according to her students she became a more hands-on teacher in her pedagogies. She reported however that SSI interfered with the content she wanted to teach. The third teacher, a biology teacher who used to be a researcher and did not have a pedagogical background was more open and more able to implement SSI in her class. Furthermore, the authors suggest that "the successful and sustained incorporation of SSI approaches depends on teachers' content knowledge and a more social understanding of science. Furman and colleagues explain the context in Argentina and how teachers in their country have a view of science as facts (Vision 1) and not as active participation (Vision 2). This is similar to what is reported in other chapters about teachers in other countries (Hong Kong, Israel, UK).

In Chap. 10 (Introducing SSI in primary pre-service teacher education: scientific practices to learn the big ideas of science) Garrido and Couso discuss how they have implemented a pre-service program aiming to prepare elementary school teachers to teach SSI, and how these teachers implement SSI activities in their classes. Specifically, Garrido and Couso designed and implemented a research-based training for pre-service primary school teachers. The aim was to help the PSTs to understand SSI, and enable them to teach them. In their study, linked to the PrESEES project) three pre-service teachers designed and implemented SSI lesson plans in primary schools, and reflected on the process. The results highlight that the SSI context supports the development of more innovative lesson plans in aspects as introducing the problem, including the scientific content and using formative assessment. The findings from this study also highlight difficulties implementing the lessons, similar to the ones reported in Chaps. 6 and 9.

In Chap. 11 (Re-thinking the integration of socioscientific issues in life sciences classrooms within the context of decolonizing the curriculum) Mudaly discusses the integration of indigenous knowledge into the curriculum in South Africa, explaining the rationale for introducing socioscientific issues within the South African context. Specifically she uses tenets from critical pedagogy to explore how novice teachers developed and taught science lessons which focussed on socioscientific issues within the context of decolonising the curriculum. Data collected include teachers' lesson plans and implementation and reflections on the process. According to Mudaly, teachers identified socioscientific issues based on their in-depth knowledge of the socio-cultural contexts of learners and their communities. This is the only chapter in the book making special reference to indigenous contexts, and novice teachers.

1.4 Summarizing

The collection of chapters showcase how researchers from around the globe apply different approaches for professional development, with most of the approaches being context related. For example in the US (Chap. 6) professional development is driven by the reform efforts and the Next Generation Science Standards. In Chaps 4 and 8 the professional development is driven by European Commission reports, and funding schemes placing an emphasis on responsible research and innovation and active citizenship in science. Similarly, in Chap. 3 the professional development is influenced by how SSI is implemented in the science curriculum (or not, given that it is not included as part of science, but as part of Liberal Arts), and also by the fact that SSI is not included as part of students' assessment. In Chap. 11 the professional development is arising from the need to decolonize the curriculum in South Africa and find ways to include indigenous knowledge as part of teaching science.

Most of the examples in this edited volume focus on long term professional development and working with self-selected and exemplar teachers. We have also included research studies emphasizing on pre-service and in-service professional development, with one of the studies making special reference to novice teachers. Despite the differences in the context, there are also many similarities across the chapters. For example the pedagogical framework adopted in Chaps. 4, 8 and 6 is similar in the sense that they focus on inquiry-based learning, or scientific practices, and include experimentation as part of the teaching process. Likewise, the professional development approaches in Chaps. 5 and 7 are similar in the sense that they focus on active engagement with the problem and the solution. Finally, an important theme across the chapters is that that different teachers apply the SSI pedagogies in different ways, and this might differ because of their personal characteristics (i.e. teaching philosophies, different nature of science views, content understanding). Findings from all chapters are critically discussed and summarized in Chap. 13 to refer to new perspectives for addressing SSI in teacher education.

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Maria Evagorou is an Associate Professor at the University of Nicosia, Cyprus. Her scholarly activity focuses on exploring and enhancing young students'and pre-service teachers' argumentation skills within socioscientific issues. More specifically, the emphasis of her work is on students' and teachers' talk when they engage in the discussion of SSI and aims to explore ways in which teachers can be supported in their effort to include SSI in their teaching s. She has worked as a principal investigator and senior researcher on various EU and local research projects, served as a member on the JRST editorial board, and as a strand coordinator for ESERA, and has published widely.

Justin Dillon is professor of science and environmental education at the University of Exeter. After studying for a degree in chemistry, he trained as a science teacher at Chelsea College and taught in six inner London schools. Justin joined King's College London in 1989 and was promoted to professor in 2009. He is editor-in-chief of Studies in Science Education and co-edits the International Journal of Science Education. In 2007, Justin was elected President of the European Science Education Research Association. He has co-edited 18 books including Becoming a Teacher, Bad Education and the International Handbook of Research on Environmental Education. Justin has published around 100 papers in peer-reviewed journals and almost the same number of book chapters.