Chapter 8
Science Teachers as Proponents of Socio-Scientific Inquiry-Based Learning: From Professional Development to Classroom Enactment

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8.1 Introduction

In many aspects, twenty-first century science constitutes a dominant and pervasive factor in people's lives, the extent and reach of which extend well beyond the professional scientific community to influence societies, the environment and the lives of individuals. The pervasiveness of scientific and technological advances is exemplified by continuing discussions in the public sphere that focus on current issues such as climate change, access to clean water, food shortages, genetic modification, and other critical issues that mandate all citizens' critical attention. Since these topics raise questions that relate both to their scientific and social dimensions, they have been termed as socio-scientific issues (SSI). Because of their immediate effect on society, SSI necessitate increased public awareness and practical involvedness from all citizens. Without citizens' active participation, the safety of our lives, societies and the environment may be jeopardized (Bencze and Carter 2011). Therefore, knowledge of and about the connections between science and society is a necessity for all citizens – scientists and non-scientists alike. Moreover, when dealing with SSI, students are required to engage actively and responsibly with science and to offer scientifically informed solutions where social implications appear to exist with the purpose of working toward providing a safer world (Aikenhead 2005; Kolstø 2001; Zeidler et al. 2005). Advancing the notion of scientific understanding for active and responsible citizenship is, therefore, a central concern of the science education community.

As is the case with other instructional demands, teachers have an integral role in answering the mandate to support the development of students' ability to engage actively and responsibly with SSI. Teachers are therefore key agents in any attempts

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to implement SSI instruction in classrooms. However, since school science has traditionally separated science content from the social implications of science, teachers also require adequate preparation for these attempts to succeed (Bencze and Sperling 2012; Lee et al. 2012).

This chapter begins with a review concerning the literature on SSI and how the implementation of SSI into classroom practice could facilitate increased civic participation. This discussion is followed by a presentation and rationale for an educational approach that integrates SSI with inquiry-based learning as a practical and pragmatic approach to promote active citizenship in science education. This approach was developed in the course of the EU-funded PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education) project and was termed socio-scientific inquiry based learning (SSIBL) (Levinson and PARRISE-Consortium 2014). Subsequently, the role of teachers' professional development for preparing to teach science in the context of SSIBL is discussed and a model for a teacher professional development course designed to familiarise teachers with SSIBL and to prepare them for implementing this approach in their classrooms is explicated. To make sense of this model, the experiences of two case study teachers who participated in a course that was designed based on this model are described.

8.2 Theoretical Framework

8.2.1 Socio-Scientific Issues and the Role of Students as Active Citizens

While recent scientific and technological developments have positively contributed to our overall wellbeing (consider for example the longer human life span), they also represent social complications and new risks that individuals and communities need to learn how to deal with. These include, for example, impacts of genetic interventions both in health management and in agriculture that have yet to be systematically analysed; certain human populations that are at risk of having low access to clean water and diminished food security; and the increased production of greenhouse gasses and the subsequent increase in earth temperature that has raised anxieties about the future wellbeing of individuals, society, and the environment. All of these issues share a unique characteristic in that they involve one or more cultural, ethical, moral, economic or political concerns and therefore pose an inherent social significance. Because of their social complexity, the inclusion of SSI teaching in science education has a potential for promoting competencies essential for active citizenship (Berkowitz and Simmons 2003). It is not surprising then that science education researchers, as well as various national curricula around the world, call for increased attention to SSI in science education (Bencze et al. 2012; Hodson 2003; Levinson 2010).

In research, efforts for addressing SSI in science education have been formulated in terms of developing students' scientific literacy (Aikenhead 2005; Dos Santos 2009; Hodson 2003; Kolstø 2001; Sadler and Zeidler 2009; Zeidler et al. 2005). The definition of scientific literacy is well known to be subjected to multiple and varying interpretations and not all of them reflect on SSI. In fact, when looking at the types of scientific knowledge that are emphasised inside schools, the educational pendulum is still leaning towards what Roberts (2013) described as Vision I scientific literacy, meaning a scientific literacy that mainly focuses on canonical laws and theories; while Vision II, which focuses on the role of science and scientific knowledge for everyday life, is still scarcely exercised (Bencze and Carter 2011).

Though still not representing the status quo in school science practice, the type of scientific literacy contained within Roberts' Vision II has gained considerable recognition over the years and current formulations of scientific literacy emphasise the social dimension of science as pertaining to proficient scientific literacy (Hofstein et al. 2011). Within this school of thought, several contemporary and prominent formulations explicitly emphasise the role of science education as a tool for empowering students to react to SSI as responsible citizens. For example, in their proposed framework for SSI instruction, Zeidler et al. (2005) argue that proficient scientific literacy should provide students with opportunities to make informed decisions regarding SSI, thus making them active actors who can negotiate and resolve criteria about SSI. In Israel, this performative notion of science literacy for informed decision making also had a curricular response. In 1992, the Israeli Ministry of Education appointed a committee to observe the country-wide status of science education (Israeli Ministry of Education 1992). As a response to earlier reflections on the interactions between science and society that are rooted in the STS movement, the outcome of this committee's work, the 'Tomorrow 98' report, presents a more engaging pedagogy for science teaching through placing a special emphasis on social aspects of science and science laden technology. The report makes an argument for science as an exercise connected to everyday life in a way that mandates students' decision making regarding current science and technology issues (ibid.).

A more explicit focus on students' active participation as citizens affected by science can be found in Hodson's (2003) seminal paper in which he emphasised the importance of students' action as integral to the promotion of scientific literacy. He argued that we need to consider scientific literacy as a concept that should promote students' 'capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern' (Hodson 2003, p. 658). A similar argument is presented by Dos Santos (2009) who proposed a humanistic perspective on science literacy that emphasises students' social action for the common good. He argued that science education should reflect on issues of social injustice and inequity, and consequently be aimed at the transformation and creation of a better society. Another clear view of scientific literacy for civic change can be found in Aikenhead's (2005) position which highlights social responsibility and students' practical actions. In all these publications, the conceptualisation of scientific literacy shares an objective and a vision of science education that encourage students to make appropriate decisions and to take participatory action on issues that involve science and society.

Several studies have shown the utility of engagement with SSI in terms of advancing the role of students as active and responsible citizens. For example, Roth and Lee (2004) investigated an educational programme which involved students learning science through participation in an environmental project set in their community. When students acquire knowledge by contributing to their community, they argued, it can pave the way to lifelong participation and learning of science. Barton and Tan (2010) argued that students' participation in a science project that includes a component of activism for the benefit of their community afforded participating youths to frame themselves as 'community science experts' thus providing them a sense of empowerment to act as concerned citizens. Similar results were presented by Zafrani and Yarden (2017), who showed how an activity structured around an SSI that deals with global hunger promoted student motivation and willingness to act in order to resolve this issue by means of scientific inquiry and humanitarian work. These and other studies converge on the conclusion that when science education is embedded in community contexts, it can be meaningful in terms of students' participation both in school as science learners, as well as in their communities as active citizens.

8.2.2 Socioscientific Inquiry Based Learning

Taking a more active stance on scientific issues requires students to make the transition from discussing SSI in theory to making informed decisions and proposing concrete solutions that address the examined issue and result in some kind of change. Because these issues originate from a dilemma informed by science, students' solutions ought to rely on formulation and interpretation of scientific evidence (Bencze et al. 2012). As well, for students to be able to propose informed solutions they are required to understand how scientific knowledge pertaining to the dilemma was constructed (Hodson 2003; Walker and Zeidler 2007). Furthermore, the combination of scientific and social dimensions, which together formulate ongoing controversies, raise many open questions and provide valuable possibilities for scientific inquiry that are embedded in real-world issues (Sadler et al. 2007).

Inquiry-based learning, in various adaptations, was previously discussed in connections with SSI instruction. For example, Walker and Zeidler (2007) designed a learning unit that challenges students to engage in web-based inquiry about SSI in the context of genetically modified organisms in agriculture and to apply their understandings in a discussion about policymaking regarding this issue. Students who engaged with this unit therefore applied knowledge attained from inquiry towards civic decision making. Sadler et al. (2007) also utilised a web-based learning environment for inquiry into the issue of water pollution. Bencze et al. (2012), documented the works of teachers who directed both open end correlational inquiries and web-based inquiries in the context of different SSI.

One way to consider inquiry-based learning as a means for contextualizing SSI instruction is through socio-scientific inquiry based learning, an approach that integrates the teaching of science using socio-scientific issues (SSI) with inquiry-based learning. This combination of contextual engagement with SSI and application of knowledge through scientific inquiry processes is therefore argued to increase students' understanding of SSI in a way that will allow them to enact their civic responsibilities and to propose solutions that are accountable to scientific theory and knowledge (Levinson and PARRISE-Consortium 2017).

8.2.3 Teacher Preparation and Learning to Teach SSIBL

Despite curricular mandates and extensive representation and academic justifications in research, implementation of education regarding SSI in schools has been limited (Levinson and PARRISE-Consortium 2017). When the SSI approach is adopted as a legitimate object of reflection in the classroom, the instruction is mostly constrained to a presentation of the social dilemma, with no attempt to promote students' meaningful participatory engagement or action (Bencze et al. 2012) which makes the implementation of SSIBL more difficult. Since teachers are the primary intermediaries for the curriculum, and since they are in proximity to the instructional situations – they choose how to implement curricula and how to work with students – they are considered key actors in any attempt to promote engagement with SSI in the classroom, both as an instructional practice or when contextualized as inquiry (Bencze and Sperling 2012).

By allowing SSI and IBL to meet, SSIBL introduces new concepts to science teaching that are novel to many teachers. In order to be able to conduct lessons that focus on SSIBL, teachers must have the required content understandings (e.g., knowledge of and about different SSI), the pedagogical knowledge needed for conducting a scientific inquiry about these issues as well as to internalize the attitudes needed to prepare students to take informed actions on SSI. This approach, therefore, challenges teachers to re-examine and to adapt their instructional practices which raises the need for teacher professional development programmes to prepare teachers to face these challenges. This need is all the more reinforced considering that SSI instruction is misrepresented in current professional development programmes (Hofstein et al. 2011).

The main objective of this chapter is to present and discuss the educational effectiveness of a teachers' professional development (TPD) model aimed at the development of science teachers' knowledge about SSIBL and about means to incorporate SSIBL into the teachers' practice. To address this objective, we subsequently present the design of a TPD model in two rounds.

8.3 Design of the TPD Model

The TPD course was developed in two rounds during two consecutive academic years (2015–2016, and 2016–2017). The National Center for High School Biology Teachers, located at the Weizmann Institute of Science and funded by the Israeli Ministry of Education, published the TPD course along with other professional development courses offered to biology teachers during each academic year. Twenty-two teachers from all over the country responded and participated in each of the two TPD courses (12 females, 10 males). During each round, the TPD course ran for 30 hours and included four face-to-face full-day meetings and one synchronous on-line meeting. The meetings took place during school holidays and were spread throughout the academic year (December to April), allowing the teachers time to implement projects in their classrooms between the third and the fourth meetings.

In the first round, the course was composed of two parts: (i) SSIBL implicit, and (ii) SSIBL explicit (Table 8.1). The first part of the course was SSIBL implicit and included two phases: Orientation and Experimentation. We began the TPD (the Orientation phase) with lectures from experts on complex social issues. We collaborated with one of the high schools in a central city in the middle of our country in order to exemplify a SSIBL-like project that runs in this school. In this project the cyanobacteria Arthrospira (Spirulina) is suggested as one solution to end world hunger. In the second day of the TPD (the Experimentation phase) the participants

Table 8.1 Outline of the two consecutive rounds of the TPD

	1st meeting Orientation	**2nd meeting Experimentation**	**3rd meeting Conceptualization**	**4th meeting Reflection**
	1st round of TPD course			
Activities	Lectures about current SSI	Lectures about current SSI	Introduction to the SSIBL framework	Teachers' presentations
	Controversy mapping	Inquiry activity	Examples of SSIBL in practice	Bridging between science and industry
	Exposure to student led SSIBL project	Discussion	Discussion	Discussion
	2nd round of TPD course			
	Lectures about current SSI	Examples of SSIBL in practice by graduate teachers	Examples of SSIBL in practice, planning for final projects	Controversy mapping
	Simulated inquiry activity	Conceptualization of core concepts	Assessment	Teachers' presentations
	Introduction to the SSIBL framework	Discussion	Discussion	Discussion
Epistemological explicitness			Implicit	Explicit

Grey backgrounds represent explicit presentation of SSIBL, while white backgrounds represent implicit presentation of SSIBL, in various parts of the TPD experienced a one-day IBL activity, which allowed them to perform experiments in the context of the high-school students' ongoing SSI spirulina project. We led lab experiments specifically intended to explore the optimal conditions for the spirulina's growth and protein content. The second part of the course was SSIBL explicit and included two phases: Conceptual and Reflection. On the third day of the TPD (the Conceptual phase) the participants were introduced to the practical and theoretical elements of SSIBL. This event marks the first time the teachers were provided with explicit details in relation to the theoretical thinking behind the PARRISE project. By the end of the third meeting, teachers were asked to prepare their own SSIBL projects to be implemented in their classrooms. On the fourth day (the Reflection phase), the teachers presented their planned projects, with subsequent reflection and discussion sessions.

In the second round, the TPD course was composed of the same four phases, namely Orientation, Experimentation, Conceptualisation and Reflection, but each part was modified according to the experience gathered in the previous year, and an Evaluation phase was added with the aim of connecting the SSIBL idea to the school curricula (Table 8.1). During the Orientation phase, expert lectures were delivered and the inspiring spirulina project was introduced as an example for an SSI project. However, this time the spirulina project was introduced as a 'dry' laboratory aimed to explore the optimal conditions for the spirulina's growth and for obtaining optimum protein content through minds-on instead of the hands-on experiences, used in the previous round. This day ended with discussions of the SSIBL idea.

During the second day of the TPD (the Experimentation phase), the teachers were exposed to several SSIBL examples. Two teachers who attended the TPD in the previous year each presented an example. These examples were of SSIBL projects the teachers had enacted in their classes during the previous year TPD (one of these teachers is presented as one of the case studies below). This day ended with discussions of the SSIBL theory, thus the Conceptual Phase started by the end of the second day. The teachers were then asked to plan potential opportunities for SSIBL projects that may be incorporated into the high school biology or environmental sciences curricula and to start designing projects that were in line with the SSIBL idea to be implemented in their schools. During the third day of the TPD, the conceptualisation phase continued with introducing the teachers to the ENGAGE (Equipping the Next Generation for Active Engagement in Science) project (ENGAGE 2014), as an example of another project in which social and scientific issues are combined including the evaluation methods used in this project. To complement the Evaluation Phase, which was added in this round of the TPD, we collaborated with the national supervisors for biology and environmental sciences education from the Ministry of Education and introduced a new initiative to examine students' abilities to answer 'OMER' (which stands for the terms Values, Involvement and Relevancy in Hebrew) questions into the national matriculation examinations. Thus, promoting the linkage and ensuring an alignment with the school curriculum. During the fourth day, the Reflection phase, the teachers learned from each other about their plans to execute SSIBL projects. The participating teachers presented their projects, shared their experiences, brought evidences from class, reflected on them, and proposed constructive recommendations for integrating SSIBL-projects in various high-school settings.

8.4 Overview of the Research Approach

In order to study the educational effectiveness of the TPD model presented above for the development of science teachers' knowledge about SSIBL, we conducted a qualitative study of two teachers' experiences, one who had participated in the first round of TPD and the other who had participated in the second round. As described above, the TPD was structured to educate and support the implementation of SSIBL in classrooms. Accordingly, in the second round, a few teachers participating in the first round were invited to present the implementation of SSIBL in their classrooms, thus making the SSIBL approach more concrete to the participants of the second round.

The results are discussed in relation to the following question: What can the experiences of teachers tell us about the educational effectiveness of a TPD model aimed at promoting the implementation of SSIBL in science classrooms?

8.5 Method

8.5.1 Participants and Data Sources

Experienced in-service high-school science (biology and environmental sciences) teachers participated in the TPD (30 h, 4 days, n = 22 in the first round and n = 12 in the second round). Here we focus on two case studies: (i) a teacher who participated in the first round of the TPD; and (ii) a teacher who participated in the second round. These two teachers were selected since in certain aspects they shared the same concerns in regards to teaching science, but their experiences from the course and the methods of implementing the SSIBL pedagogy in their classrooms were different. In addition, these two teachers were relatively more involved in the course discussions.

Data sources were in-depth interviews with the two teachers, their written projects, their reflections on the TPD, and their oral presentations. Teacher interviews, and TPD observation were audiotaped and later transcribed, analysed, and interpreted. The use of multiple data sources allowed for triangulation of data and were used as a strategy for the validation of results.

The next section presents the cases of the two teachers, David and Ruth. David participated in the first round of the course and Ruth participated in the second round.

8.6 Results

8.6.1 Case Study 1: David

David has been a biology teacher for 7 years. He teaches students aged 13–18 at a school that emphasises the importance of democracy as part of the fundamental values by which it operates. There are approximately 480 students in the school, which is located in a kibbutz-agricultural environment that specialises in fish farming by intensive cultivation. In addition, there is an ecological site near the school that is used by teachers and students for various educational purposes.

David was a prominent participant in the first round of the TPD course. It was evident that, regardless of his participation in the course, he believes certain aspects of civic education are linked with science education. He was one of the teachers who were invited to the second round of the TPD to present the SSIBL project he chose to implement in his school during the first round of the TPD. He is currently working to promote social relationships that revolve around topical issues of science and society, between schools serving different populations in Israel.

David sees himself as an unorthodox teacher. He describes an educational climate in which a pedagogical change is required, but is also difficult to attain. As a young teacher his pedagogical approach was mostly traditional, focusing on content from textbooks and ‘cookbook’ laboratory activities. Over time, this method of teaching became difficult for him, therefore, of his own initiative, his lesson plans were gradually directed towards the ecological site nearby his school. This method of teaching received the support of the school principal, which encouraged David to attempt to disseminate this method among the rest of the teaching staff and the subject supervisor. However, these attempts were unsuccessful.

The attempts to receive collegial legitimacy for his innovative teaching methods were part of his motivation for participation in the TPD course, which he describes as related to a ‘pedagogy of change’. During the course, David met people of various professions as well as other teachers who possess the same interests and beliefs concerning science education, and his need to belong to a pedagogical milieu and to receive legitimacy for his teaching methods, was met.

> In this course you meet people who are not only people of science, but also people who share the same moral values. People who have interesting projects and stories. You meet all sorts of people in this course. So, I would recommend it, even if it is just for the moral value of it. It is more than focusing on technicalities of schooling, you learn something else. (David, interview)

For David, the integration of science education with moral and civic virtue seemed natural. His motivation to participate in the course and to conduct socio-scientific inquiry with his students is consistent, in part, with how he sees himself as a teacher and with his own personal vision regarding ‘good’ science education.

Receiving legitimacy in the TPD course setting and the new knowledge he acquired allowed him to deepen and expand his lesson plans. For his final project, David presented a plan for a socio-scientific inquiry project with his students that centred on aquaponics. The project aligned with the school's local community and lived experiences as some of the agricultural efforts in the local environment are dedicated to intensive fish farming. The interaction between the students and their surrounding community, and conducting a scientific inquiry project that would benefit this community were important elements in David's project. In his presentation to teachers participating in the second round TPD, he made sure to establish the importance of fish farming in terms of human consumption and the need for sustainable food sources, presented the environmental damage that this type of agriculture system – from the pollution of nearby rivers to the wellbeing of the cultivated fish. His research project was thus aimed at finding a solution that would minimise these damages while still benefiting from the Kibbutz's economy and social fabric.

> When I work with the students we try to think what solution best serves us. The question is which solution can combine society, environment and economics? Just as I want this solution to be sustainable – it must meet these three terms. It must also be economical so that it would interest the fish farmers […] We must create some interest (with the fish farmers), some shared interest for working together. (David, first round of the TPD course)

In their research project, David and his students tested the efficacy of a biological filter that purifies the water of harmful substances. Moreover, as a by-product, the process of pumping and purifying the water supports the growth of fruits and vegetables on a bed of purified water in what David described as 'green' hydroponic agriculture. David emphasised the importance of this type of agriculture, as it is not only sustainable, but could also provide the school's community with the option of purchasing organic vegetables at a relatively low price. That is, the solution that David and his students developed for the issue of intensive fish farming takes into consideration the economic interests of the fish farmers and the community's needs on a wider scale.

> The pool that creates the food, it can potentially produce 2,500 lettuce plants per month and we want this food to go somewhere for a nominal price, a place that needs this food. To our school, to schools with a population of weaker socio-economic backgrounds, or a population with disabilities, and some can go to our dining hall for a very very low price. (David, interview).

Although his inquiry project was operationally complex and required constant attention and maintenance by himself and his students, David did not view this as the project's weak point, but as a challenge for his students to face and solve – when he was asked about the option of commercial distribution, he said that 'as the years progress I strive to advance (my students) even further'. Much to his satisfaction, David's students were invited to give a workshop on their research to teachers and other professionals from other schools. This invitation, together with the fact that David was invited to present in the second round of the TPD course, further established the legitimacy of David's actions as a teacher and enabled the dissemination of his pedagogical ideas.

Although, at the time of writing, he is currently on sabbatical for a year, David is already planning additional far-reaching research activities that will connect with his research project in the future and he also plans to incorporate the mathematics teaching staff into these efforts.

> We will also study the effects of growing plants on a bed of rainwater and not just with drinking water. We also have this mathematical element of how to calculate […] We have a rooftop that collects the rainwater, we have a certain amount of storage tanks, a certain amount of containers that we can keep, and a certain amount of trees and plants that need watering. How do we configure this as a system? How do we create a mathematical model that can tell us according to our roof's surface area and according to the average amount of rain in our area per year, how much storage we require? And how many trees and plants this could serve? (David, interview)

In addition to expanding the breadth and depth of his research project, David intends to continue to relate his students' scientific knowledge and activities to their own lives, their world, and the school's community. For David, this connection is viewed as both the means and the aim of scientific education and he states that in the upcoming year he plans to emphasise this connection.

> This is the point of taking a scientific issue and connecting it to the reality of our lives and to some basic needs that we possess. It's easy to lean onto some instructional routine that is familiar. Most of the times, my students don't care for the same things that I care about. They aren't interested in environmental issues. The challenge here is to keep an open mind. Not say 'Okay, I'm offering you these and that issues to work on', but to actually try (and connect with the students' interests), and it's challenging. You need to have the right tools to do this, how to start a conversation, how to focus the conversation around students' interests, and then see how you can connect their interests to some scientific research. Remember that our goal here is to involve the students with science and with social issues. This involvement doesn't simply happen by asking them on these issues in tests, but by providing them with something fundamental that will give them a sense of accomplishment and belief in their abilities. (David, interview)

In this excerpt, David summarized his view for appropriate science learning and instruction. For him, tapping into students' interests was a strategy to not only promote their civic participation but also to prevent their possible alienation from science and scientific practices. To achieve this aim, David was willing to put in the additional effort and to relate their experiences from outside of the school to their science learning experiences and the design of his inquiry activity was structured around that notion.

8.6.2 Case Study 2: Ruth

Ruth is a teacher with 25 years' teaching experience, who has been teaching biology for 16 years. She teaches young people aged 13–18 at a boarding school that serves approximately 800 students. The school emphasises an atmosphere of tolerance, sharing and openness and is located in the central area of Israel in an urban environment. The goal of the school, according to its credo, is to cultivate alumni who will be contributing and productive citizens, who will march society forward. For this reason, the school emphasises independence, maturity and initiative taking as core values. They emphasise respect for the law and democracy, and make sure to maintain human dignity.

Despite being a veteran teacher, Ruth participates in TPD courses since she believes it is important to be up-to-date on subject matter knowledge. Ruth states that she possesses a great deal of professional responsibility, which motivated her to be updated, advance her skills and sign up for TPD courses. Before the course she did not consider incorporating socio-scientific aspects into her science instruction. She came to the TPD course due recent educational policy demands, which required an emphasis on values, students' engagement with both the subject knowledge and civil life, and the relevancy of instructional content to the lives of students (the 'OMER' questions mentioned above). Unlike past years, students are planned to be tested and evaluated on these elements in future matriculation exams, which therefore support the implementation of SSI instruction in science classrooms. In a different manner to David, Ruth's motive for participation in the TPD course was therefore external and composed of changes in the policy and guidelines of the Ministry of Education.

Though she stated her satisfaction with the TPD saying that it represented 'a new point of view', the concept of SSIBL did not appeal to her. In theory, she supports a pedagogical approach that integrates inquiry with SSI, but does not envision it in practice in the educational field with large groups of students, as in her class. It is apparent that Ruth's instructional approach is mostly directed towards improving students' test scores on the matriculation exams.

> [For example], in the Bio-inquiry, I mainly focus on "let's do an experiment, let's write an essay". That, in itself, is not easy at all with the students, and this year I have 38 students who are divided into 16 small groups. We have to be focused, so I wasn't looking to add on something extra to this. [I only wanted to] focus on the familiar and known content and to finish this task. (Ruth, interview)

Nonetheless, she did find ways to combine materials from the TPD course in her activities at school, but she stated that she will implement SSIBL in the future only if it will be mandated by the subject superintendent or by the Ministry of Education. Though not supportive of SSIBL in practice, her participation in the TPD did allow her to cope with new policy demands to implement SSI in science instruction.

> [The new policy demands] *appealed to me and I implement it in my classroom. Also, it's easy for me to think of questions (that suit that new policy), I can improvise them very quickly.* (Ruth, interview)

Ruth said that she added discussions of SSI to her lessons on several occasions. She mentioned an example from a lesson in which she and her students discussed the question of using pig heart valves transplants for people with heart conditions in life-threatening situations.

For her final project in the TPD course, Ruth presented a plan for a socio-scientific project with her students, concerning the support and care of children with heart conditions in under-developed countries, within the setting of the Save a Child's Heart NGO. This voluntary organisation conducts an international humanitarian project, which locates children from developing countries who require life-saving heart surgery, and provides them with medical care and follow-up. For a whole year, Ruth and her students supported children with heart conditions from this organisation.

Ruth believes that the discussion of SSI enhances the students' motivation to learn science because it engages them with issues that are relevant to their lives and also develops their critical thinking. However, she had reservations regarding the intellectual level that is required of students to effectively participate in this activity. In her opinion, although it is important to incorporate this activity, it is only suitable for the high-level students in different age groups.

> It doesn't really suit students who are struggling with the basics, right? It is more suitable for the stronger kids in both junior high school and high school. (Ruth, interview)

Despite these reservations, Ruth made sure to distribute the knowledge she acquired in the TPD, and shared lesson plans and activities she conducted pursuant to the course with the community of teachers in her area.

8.7 Conclusions and Discussion

The two case studies presented above tell the stories of two high school biology teachers who experienced the SSIBL TPD. One of them, the less experienced teacher – David – had previous experience as well as an internal drive to incorporate SSI into his teaching prior to the TPD course. The integration of science education with moral and civic virtue seem natural for him. Indeed, during the course David implemented an ambitious project with his students. In this project his students experienced scientific inquiry which was tightly linked to their surrounding community, namely David's students had a purely SSIBL experience. In contrast, the other teacher, the more experienced teacher – Ruth – had no prior experience in incorporating SSI into her teaching prior to participating in the course. Ruth also had no internal drive to do so. Her motivation for participation in the course was external, as she herself stated that changes in the policy and guidelines of the Ministry of Education towards the matriculation examinations might enforce her to incorporate SSI into her teaching in the near future. She also claimed that the concept of SSIBL did not appeal to her and that she will implement SSIBL only if the Ministry of Education will mandate it. Accordingly, during the course Ruth carried out a purely SSI project with her students, namely supporting and caring for children with heart problems from under-developed countries. Taken together, these two case studies point to an advance in both teachers' practice as both of them incorporated new pedagogical approaches. But, it seems that the course enabled the 'SSI experienced' teacher to move towards implementing SSIBL while it enabled the 'non-SSI experienced' teacher to implement SSI, but not to implement SSIBL. Since the guidelines from the Ministry of Education do not mention SSIBL as part of the high school biology program, this conclusion should be taken with caution, as these guidelines seem to influence one of the teachers (Ruth) and not the other (David).

It was previously reported that when the SSI approach is adopted in schools, the instruction is mostly constrained to a presentation of the social dilemma with no attempt to promote students' meaningful participatory engagement or action (Bencze et al. 2012). This does not seem to be the case here. Since both teachers' approaches led students to engage with action, either in their attempt to grow fruits and vegetables using the purified water they prepared in the course of their project in David's case, or by supporting children with heart problems in Ruth's case. We assume that the practical aspect of the course, with the emphasis on implementing projects in schools and reporting on them, made the implementation of SSIBL practical to the participating teachers. Thus making SSI instruction practical and overcoming the previously reported claim that SSI is misrepresented in professional development programmes (Hofstein et al. 2011).

The two teachers presented here differed in several aspects including their motivation for participation in the TPD course, their prior teaching experience and their experience in integrating SSI into their teaching. As a result, they reached different levels of implementation of the SSIBL idea during the course. In future, in such TPD courses, the following aspects should be taken into account: (i) In the Orientation phase, an emphasis should be given to connecting the topics discussed to the national curricula (if they exist) and to the matriculation examinations, taking into account both content knowledge as well as the ethical aspects that are included in the syllabi; (ii) In the Experimentation phase, provide more concrete examples of SSIBL projects that were carried out in schools by graduates of the previous SSIBL TPD courses, as well as bring wet lab experiments that can be carried out in the school laboratory (instead of the 'dry' lab experience described here for the second round TPD); (iii) In the Conceptualisation phase, express the SSIBL components explicitly and make sure the teachers will use them in their projects in schools; (iv) In the Evaluation phase, provide in-depth opportunities to experience and to develop questions for the matriculation examination part that is focused on SSI issues (the 'OMER' questions part). A discussion as to how to evaluate the students' project should be added to the course as well; (v) In the Reflection phase, the participating teachers should present the projects they carried out in their schools. As mentioned above, we found this part to be one of the most important aspects in the course as, in addition to the importance of reflection to the teachers' practice, it also enables all other teachers to hear about practical ideas that they may be able to implement in future years.

Clearly, new approaches to science education and science learning pose critical challenges for teachers, especially ambitious and time-consuming approaches such as SSIBL. The TPD may have provided both David and Ruth with considerable knowledge and tools for effective implementation of SSIBL in their classrooms, as well as confidence in their abilities as teachers of SSI, however, the findings reported here are not an example of instant transformation. Though their experiences as TPD practitioners diverged in motivation and ways of classroom implementation, both David and Ruth felt that the legitimisation of SSIBL based instruction would ease the transition from their current classroom practices to be more in line with SSIBL. While David was seeking his own community of practice where this approach is perceived as integral to science education, Ruth legitimised her actions by connecting them to external national policy mandates. Therefore, even though both teachers showed implementation efforts and signs of commitment towards SSIBL, the lack of such perceived legitimacy might impede effective implementation. For the same reasons, sharing the products of their endeavours as TPD practitioners and hearing other teachers' stories of implementation was considered an important aspect of the TPD – it granted a much-needed legitimacy for teachers' actions and ways of teaching. However, in light of previous studies (Bencze et al. 2012; Bencze and Sperling 2012; Zeidler et al. 2005), it is likely that efforts promoted by these teachers will face some difficulties to achieve legitimacy in school systems. It can therefore be inferred that SSIBL will not be the norm in science classrooms without being first legitimized by school systems. Additional legitimising agents may include a coherent and focused representation in national curriculum and matriculation exams as well as the availability of SSIBL focused teaching materials.

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