Chapter 9
Getting Ready to Work with Socio-Scientific Issues in the Classroom: A Study with Argentine Teachers

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9.1 Introduction

Many voices argue that there is a disconnect between the way science is traditionally taught in many school classrooms and the complex and creative approaches required to solve socio-scientific problems in real life. Research shows that in the Latin American region in general and Argentina, the context of this study, in particular, typical science lessons involve students spending most of their time memorizing facts and definitions, or 'proving' pre-existing relationships through demonstrative practicals (Valverde and Näslund-Hadley 2011; Furman 2018; Furman et al. 2018). This approach dominates despite most science curricula in the region stating their intention of using science education as an opportunity to develop conscientious citizens capable of the critical thinking skills needed to navigate the twenty-first century (Miller 2000).

One way of promoting those critical thinking skills in students within science education is through the incorporation of socio-scientific issues (SSI). Approaching science education from an SSI standpoint allows students to start to view problems for the complex, messy and multi-faceted challenges they truly are (and therefore more closely resemble the challenges faced by actual scientists and critical citizens). For this chapter, we define SSI as those which invite students to think in more complex ways, requiring them to discuss, debate, negotiate and understand connections to resolve conflicts (Zeidler and Nichols 2009). Through SSI, students can be

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encouraged to develop new thinking habits, such as skepticism, accepting ambiguity and open-mindedness, whilst searching for answers to complex problems (Zeidler et al. 2005). Importantly, using a SSI standpoint invites students to contemplate, amongst other things, their moral and ethical opinions about scientific topics through social interaction and discourse (Lee et al. 2013; Zeidler and Keefer 2003). SSI approaches also have the potential to achieve other goals of science education more generally (Sadler 2011), such as encouraging students to make data -or evidence-based decisions, whilst also evaluating the quality of available information. As such, SSI can be viewed as an approach to science education that provides students with the chance to develop the skills required to be full members of society (Díaz-Moreno and Jiménez-Liso 2013; Sadler et al. 2007). This chapter explores how Argentine teachers responded to a first introduction to teaching with socio-scientific issues. Following an initial workshop held in the province of Buenos Aires, we explored teachers´ perceptions of the challenges and opportunities associated with incorporating these strategies into their regular lessons. A case study of three teachers is then explored in more detail as they introduce SSI approaches to their classrooms.

9.2 Background

As teachers move away from more fact-based and 'black or white' science teaching, as is the norm in Latin America, there is a need for different pedagogical tools to help students address the sophistication and uncertainty involved in dealing with complex issues. For this change to happen, teachers need to use various pedagogical approaches and lines of questioning to expose students to different opinions and viewpoints in the classroom, particularly regarding those topics which most impact and engage young people in political debate (Gray and Bryce 2006; Nielsen and Evans 2015).

However, although research has shown that working with socio-scientific issues in the classroom is an effective way of promoting aspects of scientific literacy and students' understanding of the nature of science (España Ramos and Prieto Ruz 2010; Wongsri and Nuangchalerm 2010), studies also indicate that teachers find this approach challenging (Pitiporntapin et al. 2016). In particular, teachers have been found to be reluctant to teach using SSI approaches due to concerns about their abilities, time constraints and lack of support materials (Pitiporntapin and Topcu 2016). This is particularly the case in Argentina, where teachers tend to favor an encyclopedic approach to science, focusing on learning facts and definitions and seldom promoting higher-order thinking skills in authentic contexts. For example, a recent study by Furman et al. (2018) found that teachers spend 80% of their science lessons undertaking activities that only promote lower-order thinking skills, as opposed to activities which foment creativity, evaluation or synthesis of problems.

One of the reasons that this type of teaching might prevail may be that, despite Argentine curriculum documents mentioning the value of incorporating SSI, teacher education programs in the country (either pre- or in-service) do not often include this approach with sufficient depth or prepare teachers for engaging students in the debate of socio-scientific dilemmas (Labate 2007). As research has shown, supporting teachers in reviewing and transforming their teaching practices is a constructive process which depends on where teachers are in their current practice, from which they must make sense of new pedagogical approaches in terms of their existing beliefs (Pugh et al. 2017). For teachers to be able to adapt or fully appropriate new pedagogical approaches or even teaching techniques, they first need to be introduced and initiated before moving along subsequent phases of teacher expertise (Dwyer et al. 1991).

Another challenge may be due to the views that Argentine teachers commonly hold regarding the nature of science. As is the case with many countries, this view of science, which differs from the complex, humanist view suggested by the SSI approach, presents science as a static body of knowledge which needs to be memorized, rather than a complex, adaptable agglomeration of ideas (Pujalte et al. 2015). Teachers' views on the nature of science are shown to influence their practices (Caga-anan and O'Toole 2015), and this impact is heightened by the fact that tertiary teacher training colleges (pre-service teaching) do little to challenge these views, allowing this conception of science to go unquestioned right until teachers find themselves at the front of a new classroom (Cofré et al. 2015).

Despite this state of affairs, Argentina also presents several context-specific opportunities with respect to introducing SSI in the classroom. As national examinations are anonymous and results are not publicly published, teachers and schools are free of the pressures and accountabilities related to preparing students for high-stake examinations. Also, although teachers have a prescribed national curriculum they are responsible for covering throughout the year, systematic teacher performance reviews are infrequent and not linked to pay, meaning that teachers have a remarkably high degree of autonomy in terms of what and how to teach. As a result, one could argue that this scenario opens the possibility of introducing new ways of understanding and teaching science, such as through SSI approaches.

Given the above state of affairs, in this study we aimed to understand how teachers started to incorporate elements of SSI approaches in their science lessons following a professional development program.[1] We devised an in-service professional development workshop that focused on teaching science creatively through the use of SSI. Subsequently we arranged a personalized follow-up which supported teachers in the introduction of elements of the workshop back to their classrooms. We were interested in understanding how teachers started to implement SSI approaches, including the challenges and opportunities they identified, as well as the effect that these approaches had on students´ perspectives of their engagement with science

[1]This was part of a wider initiative undertaken in collaboration with Donald Gray and Laura Colucci-Gray from the University of Aberdeen, generously financed by an International Partnership and Mobility grant from the British Academy (2013–2016). The joint project aimed to foment creative practices in science more generally, including a focus on SSI, in both Scotland and Argentina.

lessons. Lastly, we explored how teachers' use of SSI approaches changed and developed over a 2-year period. As such, our research questions were:

1. How do teachers incorporate SSI approaches in their own practices following a workshop? How are these changes sustained over time?
2. How do students respond to the introduction of socio-scientific issues? In what ways do their perceptions of their engagement with science lessons change?

9.3 Methods

9.3.1 Research Design Overview

To answer our research questions we divided the study into two parts. In the first part, an in-service teacher development program was conducted. All 50 participating teachers filled in a post-workshop survey, and were invited to volunteer for a follow-up study.

For the second part of the study, follow-up teachers worked collaboratively with researchers to plan and then implement lessons with an SSI focus. Following the implementation and observation of the lessons, teachers completed an in-depth semi-structured interview. Lastly, one year after the initial workshop, teachers were invited to participate in a final lesson observation and interview.

9.3.2 Part 1: In-Service Professional Development Workshop

For this study, two 3-h twilight workshops were designed during which teachers were introduced to the idea of SSI perspectives with an additional focus on using creativity to enrich science lessons. The sessions included concrete examples of teaching activities that could serve as good models for similar approaches in their lessons. Teachers were recruited via usual university outreach mechanisms, including mailing lists and social media posts. Teachers were from a variety of professional backgrounds, although predominantly from private institutions, ranging from several preschool and primary generalists looking to approach science teaching differently, to secondary school biology and chemistry teachers with specific subject matter interests.

9.3.2.1 Workshop Contents and Activities

The program was designed by the authors in collaboration with the two colleagues from the University of Aberdeen. When designing the overall course, several features of effective teacher training served as guiding principles. As stated by Gray and Bryce (2006, p.187):

> just as 'top-down' transmission of facts from teacher to student is inappropriate, so 'top-down' delivery of CPD from 'expert' to teacher is inappropriate without a concomitant commitment to explore the issues and provide opportunities for reflection and personal feedback on them, as well as exploration of appropriate pedagogical approaches to be used in the classroom.

As such, our CPD incorporated expert input, as well as individual and group activities, with opportunities to debate and listen to others from an active learning and reflective standpoint.

Teacher professional development research shows that for changes in teaching practice to occur and be mastered, a minimum of 14 hours of training is needed, as well as many instances for practice (Joyce and Showers 2002; Yoon et al. 2016). As such, these workshops were designed to be introductory in nature, rather than transformative in terms of teacher practice, and to explore teachers' perceptions of how SSI approaches might fit into their teaching more broadly.

The workshops were based around the topic of agricultural practices, which was framed as a complex socio-scientific issue, taking into account the way it connects to issues surrounding equity, land distribution, impact on the environment, conservation, health and community. The problems selected were also purposefully chosen to be 'messy', that is, those that involve multiple-causality and require the analysis of different perspectives in order to reach one of many possible solutions.

The first workshop session invited teachers to explore the relationship between soil and agricultural practices. This was also explicitly linked to 2015 (the year when the workshop was conducted) being the United Nations 'International Year of Soil'. By looking at soil and its intricate relationship with agricultural practices relating to food production, survival of communities and sustainability, teachers were invited to evaluate the context of different countries and the practices they chose, as well as consider how different agents and stakeholders value the diverse range of opportunities available to them through different agricultural practices.

Teachers began the workshop by considering the role of soil in our society. This topic was introduced through the use of a video that outlined how soil shapes and sustains many human activities, told from the perspective of the soil itself and ending with a plea to consider its importance. Teachers used further information to mind-map the intimate relationship between soil quality and human survival. Following this introduction, they were invited to complete a self-designed experiment in groups, for which they were given four soil samples of different constitutions (comprised of sandy, clay-based, and mixed soil samples) and asked to evaluate the permeability of each soil type to water using their own methods. With the results garnered from their own data, each group was asked to decide which of a choice of several crops they would recommend for growth in each soil type, taking into account the specific social, cultural, economic and environmental factors which had been outlined for each case.

Throughout the workshop (see Fig. 9.1), teachers were encouraged to view how this topic and approach, taken from a real world perspective with multiple standpoints on the problem of deciding which crops to plant where, invited different teaching and learning skills. For example, teachers had to use creativity and col-

Fig. 9.1 Images from the first workshop

Fig. 9.2 Images from the debate

laboration to design their 'measure of water permeability experiment', as they had not been given a method to follow, but rather a large choice of everyday equipment with which they had to design their experiment.

The second workshop session expanded upon the topic of soil and food production and was based around a debate regarding the use of organic versus industrial production techniques. For this session, teachers were split into groups and given a position and an identity from which to argue their point, along with background information on which to base their characters. For the side that was promoting the use of industrial production, teams were asked to embody and present the views of a biochemical engineer, a large-scale industrial farmer and a FAO (Food and Agriculture Organization) representative. For the side that was promoting organic production, teachers were asked to take the perspectives of an organic farmer, a parent and a bee. From each of these given positions, teachers had to prepare a 3-min exposition, followed by a question-and-answer session where the views, preferences and interests of their character were presented (see Fig. 9.2). At the end of the workshop, following a general debate, teachers had to place themselves in the role of legislators, and vote on whether to expand or retract the use of industrial practices in their local constituencies, having listened to the views of all the various characters. This workshop therefore centered on the themes of looking at problems from multiple perspectives, encouraging empathy and problem-solving, as well as working in teams to collect, analyze and present information.

Another theme that was maintained across both workshops was critical reflection. In both sessions, teachers were invited to reflect not only on their classroom practices, but also on their experiences as active learners in the workshops. As such, teachers were encouraged to think about what they learnt but also how they learnt it. Teachers were also asked to imagine how their students might react and respond to similar activities should they implement them in their schools.

9.3.2.2 Final Survey

At the end of the workshop, all the teachers completed an exit survey to explore the possibilities and challenges they anticipated with regards to introducing socio-scientific approaches to their current science pedagogies, and the contexts and factors that could shape their implementation.

9.3.3 Part 2: Follow-Up: Lesson Planning and Implementation

All teachers who participated in the workshops were asked if they were interested in participating in a follow-up study aimed at supporting teachers in the planning and implementation of workshop strategies regarding SSI approaches in their classrooms.

9.3.3.1 Participating Teachers

Ten teachers signed up to participate in the follow-up. For this study, we will focus on the three teachers who continued to work with us over the course of both years (see Table 9.1). Other teachers did not choose or were unable to continue the full

Table 9.1 Follow-up teacher characteristics

Teacher	Level	Education degree	Teaching context
Julia	Secondary	BSc Chemistry	Private school
			Chemistry, Physics and Physical Chemistry
Sofia	Secondary	BSc Biology	Private trilingual school
			Teaches Biology, Chemistry and "Health and Adolescence"
Clara	Kindergarten	BA in Kindergarten teaching	Private bilingual school
			Teaches 3-year-olds all subject areas

program for a variety of reasons, such as leaving teaching the following year, focusing on other school subjects (in the case of primary teachers) or having conflicting schedules.

9.3.3.2 Content and Activities of the Follow-Up Program

Teachers who participated in the follow-up worked with researchers to develop a series of lesson plans that involved socio-scientific issues. They worked together to analyze effective ways of undertaking the topics selected, and then to plan lessons for their respective age groups. In part, this follow-up was created as a way of accompanying teachers as they tried this novel approach for the first time, as 'implementation dips' can bring about frustration during the process of applying new approaches (Gulamhussein 2013), especially before seeing changes in student learning which may in turn convince teachers of their value (Guskey 2002). In this sense, having the researchers available to co-plan and support teachers during this initial phase encouraged teachers to plan ambitious lessons without feeling unsupported.

Once lesson plans were completed, all teachers were then observed when teaching their co-planned lessons, and given brief coaching feedback following implementation. During observations, researchers took notes and photographs, looking at student engagement and outcomes. In total, the follow-up program had a duration of over 20 h, above the minimum required to begin to see changes in teacher practice (Yoon et al. 2016). Table 9.2 below presents a synthesis of the methods of data collection used and the characteristics of the observed lessons in each case.

Table 9.2 Methods of data collection and characteristics of lessons observed by researchers per case

		Sofia	Julia	Clara
Grade		Secondary School	Secondary School	Kindergarten (3 year olds)
Subject		Biology	Chemistry	Science (interdisciplinary projects)
Year 1	Teacher interviews	1	1	1
	Class observations	2 (weekly, 60 min)	2 (weekly, 120 min)	2 (weekly, 30 min)
	Student interviews	1 focus group (4 students)	1 focus group (5 students)	1 focus group (3 students)
Year 2	Teacher interview	1	1	1
	Observation and subject	1 – Health and Adolescence	N/A	N/A
	Student interview	1 focus group (4 students)	N/A	N/A

9.3.3.3 Teacher Interviews

Following the secondary school lessons, teachers participated in a 45-min semi-structured interview, aimed at understanding their views about science and approaching science from a socio-scientific perspective, as well as the challenges and opportunities they found. In addition, we asked background questions to establish their professional biographies and work trajectories both within and beyond teaching. In order to gain a more tangible sense of the changes to their practice as a result of the workshops, we also asked and collected information regarding their previous lesson plans and approaches.

All interviews were transcribed verbatim and then analyzed by researchers. Data was analyzed through thematic analysis, and then coded according to the themes of motivational drivers, current science practice, beliefs on the purpose and nature of science education as well as professional experience and expectations. A mixed approach to coding was undertaken, with researchers searching for codes deductively (such as their views and beliefs on the purpose and nature of science, concerns and experience of starting new approaches and participating in professional development, and current teaching practices in science lessons), as well as including other themes that emerged through an inductive process of looking at the data. Interviews attempted to provide further insight into school characteristics, including opportunities for professional development, collaboration with colleagues, evaluation and assessment practices and support available.

One year later, all three teachers agreed to a second round of interviews. In addition, Sofia invited us to a further observation of a lesson. Both the interviews and observations followed the guidelines, topics and main questions of the previous year.

9.4 Results

9.4.1 How Do Teachers Incorporate SSI Approaches to Their Own Practice?

Teachers identified several aspects of the workshop that they believed could provide positive opportunities for their students, such as teaching in contextualized, authentic ways, promoting creativity and problem-solving, as well as increasing student engagement. However, one of the main perceived challenges was around time – both in terms of "imagining and planning" as well as implementing longer SSI-type lessons.

We then looked at how teachers took what they had learned in the initial workshop and examined the process by which they incorporated SSI approaches into their own practices, and how they evolved over time and persisted one year later. The three teachers who participated for the year-long follow-up came to the workshop for different reasons. Although all three mentioned wanting to increase student motivation, in the case of the secondary school teachers this was geared towards bringing the content alive in new ways, whereas Clara, the kindergarten teacher, sought more conceptual tools to be able to honor her students 'fascination with science' (which she personally struggled with).

As we will describe below, the way the teachers incorporated and sustained these approaches was profoundly shaped by their starting point regarding their content knowledge and their views on the nature of science learning.

9.4.2 Case Study 1: Clara – A Kindergarten Teacher

Clara was a kindergarten teacher at a private boys' school (her students were 3-years-old at the time of the study) who, by her own admission, regularly 'skived' science despite knowing that her students were very motivated and interested in learning about the natural world around them. As an early-years practitioner, she was already used to looking at contextualized problems (the Argentine early-years curriculum focuses on 'investigation of the natural, social and technological environment', rather than suggest particular or specific contents), but identified herself as being weak in science content knowledge.

She said she had left the workshop motivated, feeling like the experience had 'opened a window' to teach more and better science lessons. At the beginning of the follow-up process, Clara said she felt a little lost, both with the content and about how the unit would work with her children. As she noted: *'I was afraid because I was thinking "how will it go?", "will it interest them?", "will I be able to explain well?", "will I achieve what I want?", "how can I reach my learning objectives and be able to ask the kids good questions so that they can think, reason?'*

With the help of the researchers, she created a unit on the topic of soil and water discussed in the workshop. In the first lesson she introduced the idea of how water and the soil can be polluted and how to avoid this from happening, based on a story that involved the viewpoints of several human and animal characters that lived near a polluted water source. After listening to the story, children discussed what would be a good way to clean the 'dirty' water, which led the way to an experiment during which students first modeled polluting an existing water source (by throwing garbage into a large pail of water), and then working in small groups to filter the water using several different materials. This activity was similar in spirit to the activity teachers experienced in the workshop. Then, Clara worked with the physical education teacher to plan an interdisciplinary experiential activity, where students played 'catch' as either water molecules or pollutants – when 'waters' were tagged by 'pollutants' (who added a small velcro cloth to their clothes) it meant they then needed to go through a tunnel to get filtered to undo their being contaminated.

Throughout the unit there were several moments when Clara linked the science content with the SSI strategies suggested at the workshop, encouraging students to consider how it affected the world around them from different points of view.

Despite their young age, children discussed in their own terms who was responsible for looking after our water sources, how to avoid them getting more polluted, the consequences of having polluted water sources in terms of the dangers to the wildlife and human health, and how we can filter and improve water sources.

One of the interesting aspects of working with SSI approaches in kindergarten is that teachers are already used to working in contextual and embodied ways. In the case of Clara, she often reflected on how integrating the approach felt 'natural' and aligned with her usual practice and teaching mindset. Clara attributed her 'success' to the provision of detailed guidelines and materials at the workshop and the support given by the researchers with regards to how to best adapt these activities for kindergarten: *'I use your materials as examples of what to do. It's just better because it's already planned.'*

However, Clara also highlighted that she would not have felt confident enough to try these types of lessons on her own without the support of the researcher ('*I wouldn't manage to do it alone')*, especially on new science topics that went beyond those covered in the workshop. In fact, she mentioned having repeated the same unit in the second year but reported that she did not invent or develop further units or activities on new science topics.

9.4.3 Case Study 2: Julia – A Secondary School Chemistry and Physics Teacher

Julia was a secondary school Chemistry and Physics teacher who arrived at the workshop aiming to find new strategies to involve her students more during lessons. She was very confident in her content knowledge and wished to 'demystify' science, encouraging her students to feel comfortable with and enjoy learning it.

Over the follow-up process we noted that her first draft lesson plans implied that her lessons tended toward more traditional approaches, spending a large amount of time resolving formulaic exercises and memorizing content. This was confirmed by her students' comments from the subsequent interview, which described their role in the classroom as mostly passive: '*We don't usually do much, just sit around, listen, nothing'*.

For her follow-up unit Julia chose to work with her final year Chemistry class, where she had to teach the topic of colligative properties. As she described, she had taught the same topic in the previous year in a traditional manner: '*This was a topic I used to skim over. We'd discuss the properties theoretically, then look at the formulas and complete the exercises, followed by going to the lab. Classic format*'. This time around, she planned to introduce an overarching theme of 'how chemical and physical properties are present in real life situations'.

During her lessons, she was able to introduce new pedagogical strategies and resources, such as several group-work dynamics, videos, quick experiments and case studies, based around broad questions that aimed to connect the topic to real life situations such as ‘should we throw salt on the ground when it’s icy?’ (encouraging students to analyze city policies in winter). Yet, a large part of her lessons were still based on traditional teacher exposition, and, in fact, her lessons were somewhat characterized by going over the same topics using different activities, rather than truly looking at a complex topic from multiple perspectives or encouraging reflection on the impact of science and technology advances on the environment and the community, which are the key characteristics of the SSI approach. In this case, it appeared that the activities planned with the SSI focus in mind were added as a complement or ‘additional’ aspect to the more central and fundamental learning goals.

Julia expressed enjoying teaching the follow-up lessons and, whilst stressing that she did not feel that these lessons had differed considerably from her normal practice, she did highlight the change she felt in her role as a teacher, which she perceived as having been ‘*removed from the center of knowledge, so that knowledge then gets created by everyone, which is also liberating for a teacher to be able to get out of the spotlight*’ and incorporating more explicit links to everyday situations. With regards to how her students responded to the lessons, she felt that her students ‘*participated more, and thought more for themselves*’. This perception was echoed by several of her students, who also mentioned that they had ‘copied out’ much less in the new unit, and particularly enjoyed working in groups as this was not common practice.

Julia found the experience of planning and implementing the SSI approach to her lessons more challenging than anticipated (albeit with our support). In particular, one of her greatest concerns was with regards to the time required to plan and ‘think’ about these types of lessons, which coincides with the initial responses of the teachers in the workshop. As she said: ‘*I had to give myself space which I didn’t have to be able to do this, it took time. I got a bit stressed*’. She added that she would value the institutions giving her more (paid) time to collaborate with colleagues and develop new strategies:

> Time is the scarcest resource, and in this case I had a lot of facilitators, I know. I mean, just resources, but I need time to go buy the rope, to get the materials. To think! Teachers need time to think. Time is the biggest obstacle.

In the second year, Julia commented on the changes she had sustained over the course of both years, and she mostly made reference to using several active learning strategies from the workshop (such as using a worksheet she had received, or using teaching stations and getting the students to move) to other science topics. However, as in the first year, the SSI approaches were not integral to the core of her teaching units.

Some of her comments from the second year echoed the views of other teachers who had participated in the workshop, who felt SSI approaches were not ‘rigorous’ enough when teaching specific chemical formulas and would ‘water down’ the science content. Julia felt that sometimes more active pedagogies interfere with the main science objectives: ‘*It’s good to think and discuss, but how do we take that to the concrete formula they need to learn?’*. This comment seems to suggest that although she values the more participative approaches as a complement to traditional teaching, she does not appear to fully trust them since they are not aligned with her views of learning (that is, what content should be learned and how).

9.4.4 Case Study 3: Sofia – A Secondary School Biology Teacher

Sofia was also a secondary school teacher who had only recently entered teaching following a career as a research biologist. Perhaps due to her professional experience, her views on science teaching were considerably different to those held by Clara and Julia in that she intrinsically viewed science and science learning as a creative and social process, which she therefore tried to replicate in the classroom, showing students that science was 'real':

> As I always did research and I'm not a teacher […] from that place I try to transmit that to them. I always tell loads of personal things about my own research, for them to realize that it's real, it's not something that we only stage for a science lesson artificially. I look for a lot of current information, I try to bring new things; newspaper articles, especially in health and environmental matters, we always work with new material and almost never with the books.

However, she recognized she lacked pedagogical strategies and generally relied on traditional activities without asking too much about the meaning of what she taught and about the relevance of what they were learning for the lives of the students. She signed up to the workshop as part of her wider goals to develop her teaching practice, but made specific reference to feeling she needed more tools and ideas to be able to 'reach' her students in different ways.

After the workshop, Sofia replicated every single one of the activities introduced with her classes (not as part of the 'official' follow-up, but on her own terms across different year groups).

For the follow-up, she chose to work with her most challenging group on DNA, which she said they were struggling with. She chose this class as she felt the group was struggling, identifying challenging behavior, weak academic skills and poor study habits as the main factor to explain this. Also, she felt that the topic itself was challenging and 'very conceptual', and somewhat harder to bring down to concrete simple examples, and would benefit from being learned in a more concrete and contextualized way. As she said:

> For me, my concern was the group. They are very good guys but they have quite bad study habits, they have a hard time understanding many things compared to other groups I have, they are quite disorganized. I was afraid they would disband or be lazy […]. The other issue is that for me the subject is difficult, it is a conceptually difficult topic and super important. This helped me think about priorities, lower my anxiety and ask: 'Is it important that they understand this at the molecular level?' and just focus on the stuff that actually matters. Make them realize how important everything is and what is it for? That it's not something abstract, and that cells have to do with your life itself and your health and a lot of things.

The students had recently been learning about DNA and gene structure, and she used this as the content starting point to introduce the concept of genetically modified plants and animals to best suit human needs. The students watched an engaging TED talk on the topic of bioengineering and were then asked to get into groups of four. The activity reflected the key attributes of the SSI approach: examining a socio-scientific problem under multiple perspectives, using data to make decisions and reflecting on the impact of science and technology on human lives and the environment. The scene was set so that the students were asked to be an interdisciplinary team working for the government of a fictional developing country, whose characteristics were given on a factsheet (such as having a famine, low water supply, low immunization rates, to name but a few). Students were then invited to propose the creation of a genetically modified organism that could help solve some of the country's hardships. Students each had a role and a part they needed to explain (a scientist to explain the biology, a lawyer for ethics, a PR specialist to present the project in a public-friendly way, and graphic designer for the poster). Students presented in the second lesson, and then voted on which was most likely to effectively alleviate some of the problems the country was facing.

In line with our observations, Sofia perceived that the lessons had been successful, with all groups presenting a reasonable solution to the situation, and taking into account multiple viewpoints as well as the pros and cons of each suggestion made. Sofia felt that she had had more fun and enjoyed teaching more than in her previous lessons, as well as feeling that her students had been more engaged and better behaved during the lesson. Particularly she felt that assigning the student roles had worked well, as, although it required more careful planning and effort from the teacher beforehand, it then meant that the students were more autonomous and made the lesson 'less tiring' to teach.

In the following year, we could see how Sofia took the SSI approach a step further. She developed a new unit based on strategies introduced in the workshop for her Health and Adolescence subject. For that unit, she used the same debate format on the topic of abortion, a highly controversial topic for Argentine society, which is rarely included in secondary school lessons) from the point of view of several different roles (parents, religious leaders, a baby, a medical professional and a legislator). This unit was very socio-scientific in nature, with students fully embodying the different viewpoints and sustaining their roles based on evidence-based arguments. She also used the debate format with older students in her Environment, Development and Society classes on the topic of open mining:

> And after the format of the debate that you saw today, I used it last year with the same theme of abortion and I used it in Environment, Development and Society in the 6th grade. That worked really well as they're older. I used it for open pit mining, and we had the different characters; one was the governor of San Juan, another was the CEO of a mining company, another was a worker who had got a job thanks to mining. And then there was a Greenpeace representative, a vicuña [NB: an Argentine llama] – I remembered the bee and I liked that about the animal, and a native inhabitant who had his goats, for whom the changes in the area were a problem.

Sofia reflected on how, more than a year after the workshop and the initial follow-up process, she felt more open and willing to incorporate SSI approaches in her lessons, and that she looked for opportunities to be able to incorporate it in different topics. She shared how, at the beginning of the school year, she had looked over the curriculum searching for opportunities within which to incorporate the approaches she had learnt:

> At the beginning of the year I sat down with the syllabus and everything, I rethought about how to do many things in a different way from what I had been doing so far with the aim of incorporating these type of tools and approach to new topics.

Although she had full institutional support to teach in different ways with new strategies, similarly to Julia, Sofia also identified a lack of time in which to teach using these methods, particularly for the younger students:

> The truth is that we have to comply with the curriculum and I need more Biology hours for each class (which is impossible) or I need to convince myself that I don't care about the curriculum and it really is an internal decision to sacrifice content, to be able to do more meaningful things because they take more time. And more personal time too, because it's a lot of my own time and work. But if something works you can use it again, it's an initial effort but it's an investment.

9.5 Conclusions: What Does It all Mean for Science Teaching?

As has been found in previous studies, our results suggest that the introduction of socio-scientific issues was a new approach which teachers found challenging and different to their usual practice, but worthwhile (Tidemand and Nielsen 2017). Overall, our findings show that the teachers in our study were able to use teaching strategies presented at a workshop to create lessons of their own based on new socio-scientific cases they developed, and reflect on the possibilities and challenges of introducing this topic in science teaching. Also, the teachers felt that the introduction of SSI approaches generated enthusiasm and learning in their students.

We found, as is often the case with the introduction to new techniques in teaching, that the ways in which teachers appropriated SSI approaches into their science teaching varied greatly depending on their starting points with regards to their content knowledge but also, particularly, their views on the nature of science learning (Evagorou and Puig Mauriz 2017). In this sense, we propose that the successful and sustained incorporation of SSI approaches depends on two factors; on the one hand, having strong content knowledge and, on the other, valuing learning science in more active and contextualized ways.

Following our model, we would therefore argue that Clara, who did not consider herself as a science content specialist, was able to incorporate the initiatives suggested in the workshop to kindergarten level teaching since her view of teaching more generally (and science teaching as a part of that) already incorporated the idea that students should learn in a contextualized and authentic way. We saw how (with the help of the researchers) she was able to create a whole science unit on the topic of soil and water (that is, the topic of the workshop) that incorporated the SSI approaches and repeat the activity in the following year. However, we believe these changes in her practice were not widened to other science topics over time due to a lack of science content knowledge, for which she would have needed a way to either deepen it, or have access to further 'step by step' teaching materials or ongoing support from the researchers.

Clara's experience was considerably different to Julia who, despite having solid foundational content knowledge in chemistry, did not integrate the SSI approach as a central part of her regular lessons but rather used them to 'sugarcoat' the lessons and make the topics more appealing to her students. One possible explanation for this outcome would be that as her views on the nature of science learning prioritized the direct acquisition of facts, formulas and concepts, introducing SSI approaches which favour a more ambivalent, complex and 'debatable' view of science did not fit into her 'pedagogical creed', as she put it. We feel that for her to have progressed further into the adaptation or appropriation phases of teacher learning she would have required more profound changes in her views on the nature of science learning.

Lastly, we believe Sofia was able to successfully appropriate the fundamental aspects of SSI approaches due to her solid content knowledge and her views on the nature of science learning as a contextualized and authentic endeavor. Our data shows how Sofia used and adapted several activities and sustained them over time, expanding the approach to new units and subjects, even when no longer having researchers to guide or assist her in co-planning new topics.

Our results suggest that for these changes to endure over time and real appropriation to take place teachers need to truly value the SSI approach and find it to be in tune with their pre-existing mindset regarding science learning. This prerequisite is especially important since using SSI approach can take more time than fact-based, transmissive teaching. Given that the lack of time for planning and covering the national standards is frequently cited as a large barrier to the incorporation of classroom innovations, we agree with others who argue that whenever those new approaches are in tension with a teacher's pedagogical creed, there is a lower chance of them taking root.

Finally, our study points toward several suggestions. First, as in prior studies, we found that having teachers participate first-hand in SSI activities (Evagorou et al. 2014), and then taking home guidelines and student materials, encourages teachers to take a first step towards replicating and adapting these types of activities in their own classrooms, particularly for teachers who are new to the approach (Gray and Bryce 2006). All the teachers implemented some of the workshop activities 'by the book' (be it to support science content knowledge or to suggest novel approaches) and valued being given concrete physical or digital resources to just 'implement' in their classrooms. We would therefore consider this one of the fundamental stages of preparing teachers to implement SSI issues whatever their starting points.

However, we also found that in order to create changes in practice that are sustained over time, it is fundamental to tailor the follow-up to teachers' initial starting points, taking into account both their content knowledge and views of science learning. This approach might allow teachers to strengthen their practice in a stepwise way; starting with the implementation of given or co-planned activities, before moving on to more individual adaptations and full adoption of the different techniques and strategies while, at the same time, helping them to deepen their content knowledge or revising their views of learning when necessary. In turn, this has the potential to increase the engagement, interest and perception of relevance of science education for students.

Therefore, to finish, our study shows that with focused, systematic and strategic interventions, the skills involved in the complex problem-solving undertaken by scientists, citizens and government officials in the face of global challenges might, eventually, make their way to the everyday Argentine science classroom.

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