Chapter 53
Socio-scientific Issues in Science Education: Contexts for the Promotion of Key Learning Outcomes

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Throughout the history of science education, scholars and practitioners have called for the contextualization of science content through the exploration of socially relevant issues. Over time, responses to these calls have varied from pockets of acceptance and implementation to outright rejection because of a perceived need to return to basics (DeBoer 1991). The Science-Technology-Society (STS) movement, originally established in the 1970s, has been the most widespread and recognizable movement within science education for prioritizing the social significance of science. By the time of publication of the first edition of the *International Handbook of Science Education* (Fraser and Tobin 1998), STS was a well-established trend in school systems and research programs across the globe. Although STS was not the primary focus of a chapter in the first edition, STS themes were represented in several chapters throughout the volume (at least 12 of 72 chapters).

In the 10 years since the publication of the *International Handbook*'s first edition, a new framework has emerged for teaching and research associated with socially relevant science: socio-scientific issues (SSI). The phrase socio-scientific issues was used in the science education literature as early as 1986 (Fleming 1986), but it did not come to represent a recognizable framework for research and practice until the late 1990s. Research originating from countries around the world has helped to shape this movement. Dana Zeidler, Troy Sadler, Michael Simmons, and Elaine Howes have argued that the SSI movement marks an advancement over previous efforts to feature socially relevant issues in science education because of explicit grounding in theory

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(Zeidler et al. 2005). More specifically, much of the SSI research has been based on theory derived from cognitive and developmental psychology. More recently, researchers exploring SSI have adopted sociocultural theories and situated learning perspectives to inform and shape their work (Sadler 2009).

Much of the early work related to SSI has focused on learner practices in the context of socio-scientific controversy. For example, researchers have explored how students negotiate information provided in reference to SSI, engage in argumentation regarding SSI, conceptualize the nature of science in the context of SSI, and apply science content knowledge in the negotiation of SSI. The first author reviewed and synthesized a subset of this work in an earlier report that offers an empirical analysis of informal reasoning practices in the context of SSI (Sadler 2004). This analysis informs questions related to how learners react to, negotiate, and resolve SSI, but it does not directly address questions related to the use of SSI as contexts for learning. Several SSI researchers and advocates have argued that SSI can and ought to be used as contexts for learning science. They suggest that contemporary social issues with conceptual ties to science can serve as a basis for student understandings of science and nature of science, generate interest and motivation for learning science, and support development of argumentation practices. The focus of this chapter is reviewing and synthesizing evidence amassed through investigations of these learning outcomes in the context of SSI-based education.

Our aim is to explore the effectiveness of SSI as contexts for science education. Advocates have written about the potential of SSI-based education for positively impacting desirable learning goals. Here, we will review reports that have put these ideas and assumptions to test through empirical investigation of learning outcomes associated with SSI-based educational interventions. This chapter does not provide a fully comprehensive summary of all research related to SSI; rather, our intent is to describe and synthesize a focused sample of research that illuminates student learning associated with several widely assumed goals for science education: science content knowledge, nature of science, interest and motivation, and argumentation.

In order to identify relevant literature for inclusion in this review, we established several criteria for guiding the selection of studies to be featured in this chapter. We sought reports that: (1) focused on SSI, (2) were empirical in nature, (3) involved the study of interventions, (4) focused on outcome variables of interest, and (5) met standard expectations for rigor. Although we support the shift toward the theoretically oriented SSI framework, we acknowledge that strong work related to socially relevant issues is carried out using various labels. Therefore, we considered studies that used several different names to indicate their focus on socially relevant issues with connections to science including SSI, science–technology–society-, and context-based. We included papers that addressed research questions through the analysis of empirical data, and purposefully sought reports drawing on diverse methods and perspectives. We prioritized research that focused on the effects of SSI-based interventions on specific learning outcomes that have been consistently highlighted as significant issues for science education and likely targets of SSI education (i.e., science content knowledge, nature of science, interest and motivation, and argumentation). Finally, we made selective decisions based on the quality and rigor of research presented.

Content Knowledge

A chief goal for most science educators is student development of science content understandings. SSI advocates have argued that SSI can provide learning opportunities that promote the development of sophisticated ideas about science. Yehudit Dori et al. (2003) investigated this claim in the context of an SSI module that featured biotechnology in eight Israeli schools. Students completed pre/post assessments of their understandings of biotechnology concepts. The researchers grouped students by academic ability levels (high, intermediate, and low) for the analyses. Test results indicated a large and statistically significant gain (effect size = 2.27) across all three groups. The percentage gain was more pronounced for the low ability group followed by the intermediate and high groups. The authors suggested that this result highlighted the potential of SSI-related curricula as a means of reducing achievement gaps among diverse students.

Stuart Yager et al. (2006) also assessed content knowledge gains for students involved in an SSI-related intervention. The researchers created case studies of two middle school teachers in the USA. Over the course of a semester, one teacher structured her classes around exploration of a local STS issue (i.e., determining the site for a new landfill). Her colleague followed the standard science curriculum. Students in both classes completed pre/post content tests, and both groups demonstrated large gains that were statistically significant. Differences between groups were not statistically significant. Students in both classes learned science content, but neither approach produced demonstrably different results.

Grady Venville and Vaille Dawson (2010) explored science content learning among secondary students participating in an SSI intervention in Australia. They worked with a teacher, who implemented lessons related to genetic technologies and explicitly addressed argumentation practices. Intervention students ($n = 46$) completed pre/posttests for conceptual understanding of genetics. A comparison group ($n = 46$) that studied the same genetics topic without participating in argumentation and SSI activities also completed the assessments. Repeated measures ANOVA indicated that intervention students scored statistically significantly higher on the test of genetics content than comparison students. From a practical perspective, the authors classified the gains as modest but significant.

Rather than using a pretest–posttest design, Astrid Bulte et al. (2006) used a criterion-based model in their research. This design-based research project, conducted in the Netherlands, involved three iterations of curriculum design, implementation, and assessment. The evolving unit focused on water quality issues as a context for chemistry learning. A variety of data sources were used including video analyses of lesson enactment, field notes, teacher interviews, and student surveys. In the final iteration of unit enactments, the researchers concluded that large proportions of participating students ($n = 22$) demonstrated adequate understandings of the following knowledge categories: content knowledge related to the unit (80%), parameters for evaluating and interpreting water quality (70%), and experimental design (60%). The authors also concluded that by the final iteration, the unit sufficiently generated a need-to-know among students, that is, the experiences had successfully used context to stimulate students to a critical point of recognizing and embracing a need to know more about the science content underlying the issue.

Anat Zohar and Flora Nemet (2002) conducted an intervention study in two Israeli junior high schools. They compared student learning in response to a genetic engineering unit with an explicit focus on argumentation as well as a more traditional unit that covered the same genetics content; 99 students in five classes followed the SSI-related intervention, and 87 students in four classes followed a traditional curriculum. The researchers administered a test of genetics knowledge following unit implementation. Students in the SSI-related intervention performed statistically significantly better than the comparison students. Comparison of the raw scores indicates that the difference was practically significant as well.

The results discussed thus far provide evidence that students involved in SSI-related interventions can learn science content, but most of the content assessments related closely to the interventions. Two other reports, both conducted in the USA, documented these kinds of gains associated with SSI instructional units, but the researchers also administered more distanced assessments that were not directly aligned with the curricula. The authors argued that this approach provided a more valid tool for answering the question of how the interventions affected general knowledge structures not specifically tied to the interventions. In one study, students did not demonstrate statistically significant gains on the distanced test (Barab et al. 2007). In the other, researchers documented statistically significant changes with a moderate effect size (Klosterman and Sadler 2010). This result suggested that students developed understandings of science content as applied to the specific context of the intervention as well as in more generalized forms as would be expected on standardized tests.

Salters Advanced Chemistry (SAC) is a secondary science course developed in the UK that prioritizes the contextualization of chemistry and is consistent with an SSI approach. Barber (2001) investigated content learning of students participating in SAC and comparison students, who had completed traditional chemistry classes, through the use of a distanced test. The comparison students performed statistically significantly better than the SAC students. In discussing these results, Barber suggested that the test better reflected the focus and approach of more traditional chemistry courses. Although the SAC students did not perform as well as their peers, Barber reported that the SAC students outperformed their peers in university-level science courses.

Nature of Science

Several authors have proposed relationships between individuals' understandings of the nature of science (NOS) and their SSI decision-making, but few have investigated SSI as contexts for learning about NOS. Rola Khishfe and Norm Lederman (2006) explored NOS learning outcomes associated with a 6-week SSI intervention. Two classes received explicit NOS instruction, but for one class, NOS instruction was related to the issue of global warming. The researchers assessed pre- and post-intervention understandings of NOS by means of an open-ended questionnaire and student interviews. Results indicated that students in both groups made gains in their NOS understandings (related to NOS tenets such as creative, empirical, tentative). The authors reported some slight differences in the patterns that emerged in the two groups, but there was no indication that either setting provided an inherently better learning context for promoting sophisticated ideas about NOS.

Kim Walker and Dana Zeidler (2007) also investigated student development of NOS understandings in the context of an SSI-related intervention in a US high school. Walker and Zeidler designed a curriculum based on genetically modified foods such that NOS themes were highlighted and that assessment of NOS ideas was embedded in the learning activities. The authors concluded that students developed NOS ideas particularly in the areas of the tentative/developmental and creative/subjective aspects of science. However, when presented with an opportunity to apply these understandings (i.e., an SSI debate), students did not invoke NOS ideas. Walker and Zeidler concluded that the SSI-based unit promoted exploration of NOS ideas and some learning gains but that students ultimately did not develop robust enough frameworks for NOS to apply these ideas in more general decision-making opportunities.

Investigations of NOS are fundamentally about epistemology in that they deal with the nature of scientific knowledge and the generation of that knowledge. One other study explored epistemology but employed a more general framework as compared to typical NOS investigations. Dana Zeidler et al. (2009) studied the effects of a year-long SSI-driven intervention on reflective judgment, a construct that represents epistemological development. This research was situated in four US high school anatomy and physiology classes (two intervention and two comparison classes). The researchers collected and analyzed interview data using standard procedures for assessing reflective judgment (including qualitative and statistical analyses). Whereas students in the comparison classes demonstrated no changes in reflective judgment, students in the intervention classes demonstrated qualitatively and quantitatively significant differences over the year. The researchers concluded that prolonged and continuous opportunities to explore a variety of SSI over the course of an academic year likely stimulated epistemological development within this sample of students.

Interest and Motivation

A common claim advanced by SSI advocates is that students will be more interested and motivated to learn when science is presented in socially relevant contexts (i.e., SSI). Several reports have explored this assumption. Yehudit Dori et al. (2003) investigated student interest in SSI-based learning experiences in their study of a biotechnology module. The module prioritized and highlighted the controversial and ethically contentious aspects of genetics issues. The authors suggested that the explicit focus on controversial aspects of SSI is essential for building student interest. Students created porfolios, and 96% of the students (n = 200) explicitly discussed their interest in biotechnology. Many of these students referred to the personal and/or global relevance of these issues and actively petitioned to see more examples of science embedded in social problems.

Astrid Bulte et al. (2006) reported similar findings in their design-based, SSI research project. They concluded that as the unit was modified to make instruction driven more by the issue (as opposed to more traditional approach of science content driving instruction), learning activities became more meaningful to students, and that students became more engaged learners. Student survey data supported these claims in that the overwhelming majority of respondents reported that they found the contextualized learning opportunity more interesting and motivating than traditional approaches.

Judith Bennett et al. (2005) studied affective learning outcomes in the context of SAC. Survey data collected from experienced SAC teachers (n = 222) indicated that students in SAC demonstrated more positive responses to science lessons and activities, were more interested in science, and were more likely to pursue science studies at the university level than their peers in non-context-based courses. Barber (2001) also studied outcomes associated with SAC. Barber concluded that SAC students expressed higher levels of interest in and more positive appraisals of their learning experiences than the comparison students. In addition, Barber found that a greater proportion of SAC students went on to take chemistry-related courses at the university level.

Like SAC, Chemie im Kontext (ChiK) is a context-based chemistry curriculum. It has been developed and implemented over the last decade in Germany. Ilka Parchmann et al. (2006) reported research associated with continuing redesign and implementation of ChiK units over a 3-year period. They collected data from teachers (n = 37) and students (n = 216) involved with ChiK as well as comparison data from students (n = 183) taking more traditional courses. The teachers tended to see their use of ChiK units as highly innovative and as a significant departure from traditional approaches to science education. However, most students tended to see ChiK units as unique in terms of context but generally consistent with other science learning experiences. Despite these perceptions, ChiK students demonstrated statistically significantly higher motivations to learn chemistry than the comparison students.

In two studies of similar SSI interventions, researchers documented statistically significant differences in pre- and post-surveys of science attitudes (Lee and Erdogan 2007; Yager et al. 2006). Stuart Yager, Gilsum Lim, and Rober Yager also collected data related to student participation in a number of home and community-based science activities like talking about science at home, contacting scientists, and participating in public forums. The intervention students participated in these events at much higher frequencies than their peers who participated in traditional classes.

Argumentation

Given the status of SSI as ill-structured, open-ended problems, SSI are ideal contexts for scientific argumentation, and advocates for SSI education have frequently suggested that SSI-based instruction can support development of argumentation practices. Several studies cited in previous sections also explored student argumentation. Anat Zohar and Flora Nemet's (2002) study investigated the effects of an SSI-related unit with an explicit focus on argumentation. A pre/post argumentation assessment was administered and scored based on the number of justifications provided, argument structure, counterarguments, and rebuttals. Intervention students performed statistically significantly better on the posttest than the pretest. These changes were described as having a large effect size. In contrast, comparison students showed no gains. The researchers also examined argumentation with small groups serving as the unit of analysis and noted "dramatic changes in the quality of students' arguments" (p. 46).

Dawson and Venville (2010) studied an Australian high school teacher who had participated in professional development focused on SSI and argumentation. The teacher employed a range of strategies for promoting classroom argumentation including encouragement of discussion, modeling argument, valuing different positions, prompting for evidence to justify claims, and promoting counterarguments. The argumentation practices of students ($n = 46$) participating in an SSI (related to genetic technologies) and argumentation intervention were compared with students ($n = 46$) who received genetics instruction with no explicit attention on SSI or argumentation. The intervention students produced statistically significantly more complex arguments to justify their decisions than students who studied genetics only. Factors attributed to the improvement of argumentation were the ability of the teacher to facilitate whole class discussion, the use of writing frames, the context and relevance of the SSI, and the motivation and interest of the students.

Virginie Albe (2008) investigated argumentation with a class of 11th grade students in a French school involved in the study of health effects related to the use of cell phones. Albe conducted a micro-ethnography with a focus on the dialogical and rhetorical aspects of discourse. She analyzed student argumentation through analysis of audio recordings and transcripts. Results indicated that the SSI provided a compelling context for student engagement in "collaborative argumentation" (p. 86). Students challenged one another to explain their views and consider the perspectives of others. Albe also documented ways in which students' naïve epistemological representations limited argumentation and suggested that, "students' work on socio-scientific controversies should be accompanied by an examination of the way in which scientific knowledge is produced within a community and, in particular the role of controversy in the process" (p. 86).

In a pair of studies conducted in Israel, Revital Tal and colleagues explored argumentation as students progressed through SSI-based units. In the first study, researchers administered pre/post questionnaires and analyzed portfolios constructed by students to showcase their argumentation practices. The researchers used a rubric for assessing argumentation with the following criteria: generativity, elaboration, justifications, explanations, logical coherence, and synthesis. Students performed much better in the post-intervention assessment for all criteria on the rubric except synthesis. Synthesis, which involved synthesizing diverse perspectives into more complex, coherent ideas, represented one of the more cognitively challenging criteria, and students scored relatively low on this in both tests (Tal and Hochberg 2003). In the second study, researchers worked with six classes ($n = 128$) of 10th and 11th grade students. The SSI-related intervention dealt with using the sea as a resource for agriculture and the environmental problems of local coasts and waters. In comparing pre- and post-intervention performance of groups of students engaged in discussions regarding SSI, the researchers concluded that group argumentation improved. These claims were based on frequency comparisons of the number of justifications used, the extent of use of scientific knowledge, the number of aspects incorporated, and the synthesis of counterarguments and rebuttals. Statistically significant differences were found for each of these criteria except the synthesis of counterarguments and rebuttals (Tal and Kedmi 2006).

Marcus Grace (2009) also examined changes in student argumentation and reasoning in response to an SSI-related intervention. In this study, students ($n = 131$) were engaged in relatively short "group decision-making discussions guided by a structured framework" (p. 1). The discussions related to biological conservation issues. Data were collected through pre- and post-intervention questionnaires and audiotapes of the group discussions; 52 of the participants demonstrated the same level of argumentation in the pretest and posttest questionnaires, seven students unexpectedly dropped one argumentation level, but 67 individuals improved one or two levels. Grace concluded that the intervention, which prioritized student reflection on their own ideas, produced substantial differences in argumentation practices.

Erminia Pedretti (1999) conducted a case study with a mixed class of fifth and sixth grade students ($n = 27$) studying the mining of natural resources in Canada. In this experience students completed a number of classroom-based activities about the topic including role playing, independent research, and debate and took a field trip to a local museum. Data sources included field notes and interviews with students and educators involved with the project. Pedretti framed the study in terms of decision-making, but much of what she examined was consistent with some of the argumentation frameworks presented above. She concluded that through the experience, students demonstrated positive improvements in their ability to consider multiple perspectives and compromise. Students also became more likely to be aware of and thoughtfully consider ethical considerations associated with their decisions.

A final argumentation study explored student argumentation in the context of scientific issues and as well as SSI (Aufschnaiter et al. 2008). This study involved six teachers who had participated in professional development about scientific argumentation and who successfully implemented a series of nine argumentation lessons. Data were collected through video and audio records of small group conversations in the lessons. The authors concluded that students demonstrated higher levels of argument when arguing about SSI as compared to science contexts. The authors suggested that the more familiar contexts provided by SSI likely contributed to the documented differences.

Conclusions

Overall, the research reviewed as a part of this chapter provides compelling evidence supporting the efficacy of SSI as contexts for learning science. Science learning can be defined in many ways, but we chose to operationalize learning in terms of four outcome variables that we believe are critical aspects of science education and that have been positioned as likely outcomes of SSI education based on the theoretical commitments that have guided this movement. We examined eight studies that explored science content knowledge, and all of these reports documented gains associated with SSI-based instruction. Many of these studies used a pre/post design. The four studies that utilized comparison groups (i.e., students studying science without an SSI focus) offered conflicting results. Two of these studies found that intervention students out-performed comparison students (Venville and Dawson submitted; Zohar and Nemet 2002); one study found no significant differences (Yager et al. 2006); and the final study found that comparison students demonstrated greater content gains than the intervention students. Additional work using well-established assessment instruments and frameworks will be necessary to decipher these relationships.

The oft-presumed association between SSI and NOS has been discussed conceptually much more than it has been tested empirically. The two studies that explicitly examine this link through an intervention study provided limited supporting evidence. In the first study, an SSI instructional context did not seem to significantly enhance or detract from an explicit NOS approach (Khishfe and Lederman 2006). In the second report, an SSI intervention supported student understanding of NOS, but the developed ideas were not robust enough to serve as conceptual resources as students participated in an SSI debate (Walker and Zeidler 2007). The final study in this section documented student gains in reflective judgment associated with SSI education (Zeidler et al. 2009). If prolonged SSI-based instruction can promote epistemological development, then it is reasonable to hypothesize, that under appropriate conditions, that NOS constructs could also be supported. Research that investigates differential effects of various issues and instructional models will be needed to further explore these issues.

The studies that examined generation of student interest and motivation to learn science provided the most consistent evidence supporting the efficacy of SSI-based instruction. The seven studies reviewed in this section documented student interest in learning science in the context of SSI especially as compared to learning science with more traditional approaches. Interesting support for this claim was also provided through assessments of student participation in the community relative to SSI (Yager et al. 2006) and pursuit of science-related college majors (Barber 2001). This research provides strong evidence for a positive relationship between SSI-based instruction and generation of student interest. It would be interesting to explore how educators might leverage this relationship for supporting science education.

Argumentation has been frequently invoked as a framework for exploring development of advanced ways of thinking among learners in the context of

SSI-related interventions. The eight studies that addressed argumentation produced evidence of student gains in argumentation, but at least of these reports highlighted student struggles with advanced argumentation practices in the context of SSI (Albe 2008) that have been documented more generally in investigations of scientific argumentation. These results suggest that SSI-related interventions can serve as effective contexts for development of argumentation practices, but the extent to which these interventions will be successful is highly dependent on the nature and quality of supports provided to students.

In conclusion, this chapter provides compelling evidence to support the integration of SSI in school science education. The inclusion of SSI in science supports the development of key learning outcomes: science content knowledge, nature of science, interest and motivation, and argumentation. At the same time However, there remains an urgent need for targeted classroom-based research to identify the relative impact of factors affecting the quality of instruction and the achievement of desired outcomes using SSI.

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