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A Framework for Socio-scientific Issues Based Education

Abstract

Science instruction based on student exploration of socio-scientific issues (SSI) has been presented as a powerful strategy for supporting science learning and the development of scientific literacy. This paper presents an instructional framework for SSI based education. The framework is based on a series of research studies conducted in a diverse range of classrooms that made use of several different SSI. Based on the findings and recommendations of these studies, a framework that captures key elements of successful SSI based teaching and learning is advanced. The framework consists of three core aspects – design elements, learner experiences, and teacher attributes which together are shaped by various contexts such as the classroom, the school/district, the community, and state/national policy. The paper describes each of these aspects and provides relevant examples. The framework presents elements necessary for SSI-based instruction with the aim of informing classroom practice, curriculum design, professional development and future research.

Introduction

The science education community generally endorses the promotion of *scientific literacy*, but debate persists over what exactly scientific literacy entails. Roberts (2007) describes the historical development of the construct and groups different viewpoints on scientific literacy into two "visions." Vision I scientific literacy includes an understanding of scientific processes, practices and basic principles within a strictly scientific context. Vision II, on the other hand, takes into account other contexts – "real-life" situations that are scientific in nature but are influenced by other factors, such as social, political and ethical issues. This perspective focuses on decision-making and negotiation of scientific issues for all citizens, not just those who will enter a scientific career. Vision II scientific literacy is consistent with the Next Generation Science Standards particularly in terms of scientific practices such as analyzing and interpreting data, using evidence to participate in argumentation, and collecting, evaluating and communicating information (NRC, 2012). Socio-scientific issues (SSI), open-ended social problems with substantive connections to science (e.g., climate change, gene therapy, and nuclear power), represent the kinds of situations in which many individuals will be challenged to exercise their scientific literacy. Therefore, using these issues in formal science education provides an ideal approach for promoting vision II scientific literacy.

By providing SSI as a context in which students learn science, they can gain an awareness of the interrelationship between social, political and scientific perspectives as they learn important science content and practices such as argumentation, reasoning and decision-making (e.g., Hodson, 2003; Zohar & Nemet, 2002; Sadler, 2005; Driver, Newton & Osborne, 2000). In the recently published book, *Socio-scientific Issues in the Classroom: Teaching, Learning, and Research* (Sadler, 2011), science education researchers from around the world present examples of classroom-based SSI research with special attention to the nature of SSI interventions and implications for teaching and learning of SSI. The nine research studies featured in the volume varied in several ways including classroom contexts (elementary, middle, secondary, and college classrooms), types of SSI (including climate change, environmental issues, and biological determinism), length of intervention (from short units to year-long projects), and analytic approaches to the research (including pre/post-tests, case studies, mixed methods, and discourse analysis). Together, these studies represent a large range of SSI-based instruction in K-16 settings. By examining the instruction and research findings that emerged across these empirically based studies, we developed a framework for SSI-based instruction. This framework identifies key features of teaching and learning in the context of SSI. The framework we advance is not a fixed model that provides a simple list of procedures to follow; but rather, it offers flexible guidelines for use by practitioners, curriculum designers, administrators and researchers to conceptualize the essential elements and complexities of successful SSI teaching and learning. The purpose of this article is to present and describe this SSI instructional framework and to discuss significant considerations for the implementation of SSI-based instruction. In the following section, we present the framework, the necessary features, as well as the sub-components of each of the features. Figure 1 outlines the essential and recommended components of the framework and throughout the paper we cite literature that supports the use of these components.

Framework

The framework for SSI-based instruction is composed of three core aspects - *Design Elements*, *Learner Experiences*, and *Teacher Attributes* which together are shaped by various contexts such as the *Classroom,* the *School/District,* the *Community,* and *State/National Policy*

Keywords: instructional framework, science practices, scientific literacy, socio-scientific issues

Figure 1

I. Core aspects
  a) Design elements
    i) Required design elements
      (1) Building instruction around a compelling issue.
      (2) Presenting the issue first.
      (3) Providing scaffolding for higher-order practices.
      (4) Providing a culminating experience.
    ii) Recommended design elements
      (1) Using media to connect classroom activities to the "real world."
      (2) Using technology to facilitate student learning experiences
  b) Learner experiences
    i) Required learner experiences
      (1) Engaging in higher-order practices.
      (2) Confronting scientific ideas and theories related to the issue.
      (3) Collecting and/or analyzing scientific data related to the issue.
      (4) Negotiating social dimension of the issue.
    ii) Recommended learner experiences
      (1) Confronting the ethical dimensions of the issue.
      (2) Considering nature of science themes associated with the issue.
  c) Teacher attributes
    i) Familiarity with the issue being considered.
      (1) Knowledgeable about the science content related to the issue.
      (2) Aware of the social considerations associated with the issue.
    ii) Teachers as learners.
      (1) Honest about knowledge limitations.
      (2) Willing to position self as a knowledge contributor rather than sole authority.

II. Classroom environment
  a. High expectations for student participation.
  b. Collaborative and interactive environment.
  c. Students and teachers demonstrate respect for one another.
  d. Students and teachers feel safe within the environment.

III. Peripheral influences
  a. Support and encouragement for teachers implementing SSI-based instruction.
  b. Access to SSI-based materials.
  c. Flexibility of curriculum that allows teachers to adapt SSI-based instruction.
  d. Existence and awareness of local community issues to prompt SSI-based lessons.
  e. Strategies for negotiating community patrons' concerns or disapproval of SSI-based lessons.
  f. Connections between SSI-based curricula and state- or national-level curriculum objectives.

Figure 1: Organizational outline of a SSI based framework.

This framework is graphically depicted in Figure 2. The three core aspects (*Design Elements*, *Learner Experiences*, and *Teacher Attributes*) are situated centrally to depict them as fundamental components of the framework. The *Classroom Environment* is represented as a concentric circle around the core aspects to highlight the immediate influence this environment has on the core aspects. A slightly larger circle, labeled *Peripheral Influences,* encapsulates the classroom environment and represents a series of important factors that shape SSI-based education including the school and community, state context, and national policy. Each of these components is discussed in detail below.

Design Elements

The first core aspect of the SSI-based framework, *Design Elements*, contains four essential features:

1. Building instruction around a compelling issue.
2. Presenting the issue first.
3. Providing scaffolding for higher-order practices (e.g. argumentation, reasoning, and decision making).
4. Providing a culminating experience.

SSI-based instruction should be related to a compelling social issue with strong connections to science (*first required design element*). If a socio-scientific issue is not central to the curriculum, then it simply is not SSI-based instruction. Not only should a compelling issue be the curricular focus, but the issue should also be presented at the beginning of instruction (*second required design element*). By introducing the issue initially, it can serve as a true context for learning. Textbooks often provide many examples of how the content is related to a real-world issue at the end of a section such as when the issue of genetic engineering is presented at the end of a chapter on genetics. However, mentioning relatable issues *after* the instruction occurs misses the point of SSI-based instruction. SSI-based instruction is grounded in providing real-world contexts to allow students to navigate the social dimensions of scientific issues. By providing an authentic experience, students will gain a deeper understanding of the content and develop skills that will be applicable outside of the school environment (Sadler, 2011).

The third essential design element recommends that scaffolds need to be provided for student engagement in higher-order practices. A defining element of SSI-based instruction is to provide opportunities for students to engage in practices such as argumentation, reasoning and decision-making. The key point that the framework highlights in this respect is the need to provide appropriate scaffolding for these higher-order practices. Engaging in sophisticated forms of higher-order thinking is challenging, and educators should not expect these skills to be fully developed. Scaffolding can help develop these skills and can come in many forms (Quintana, 2004). For example, technological tools can help students connect evidence to claims as they work toward more sophisticated forms of argumentation (Tal, Kali, Magid, & Madhok, 2011). Scaffolds could also be structured activities that support learner analysis of multiple perspectives as they work toward identifying their own position on a controversial issue (Eastwood, Schlegel, & Cook, 2011). These are only two of many

Figure 2

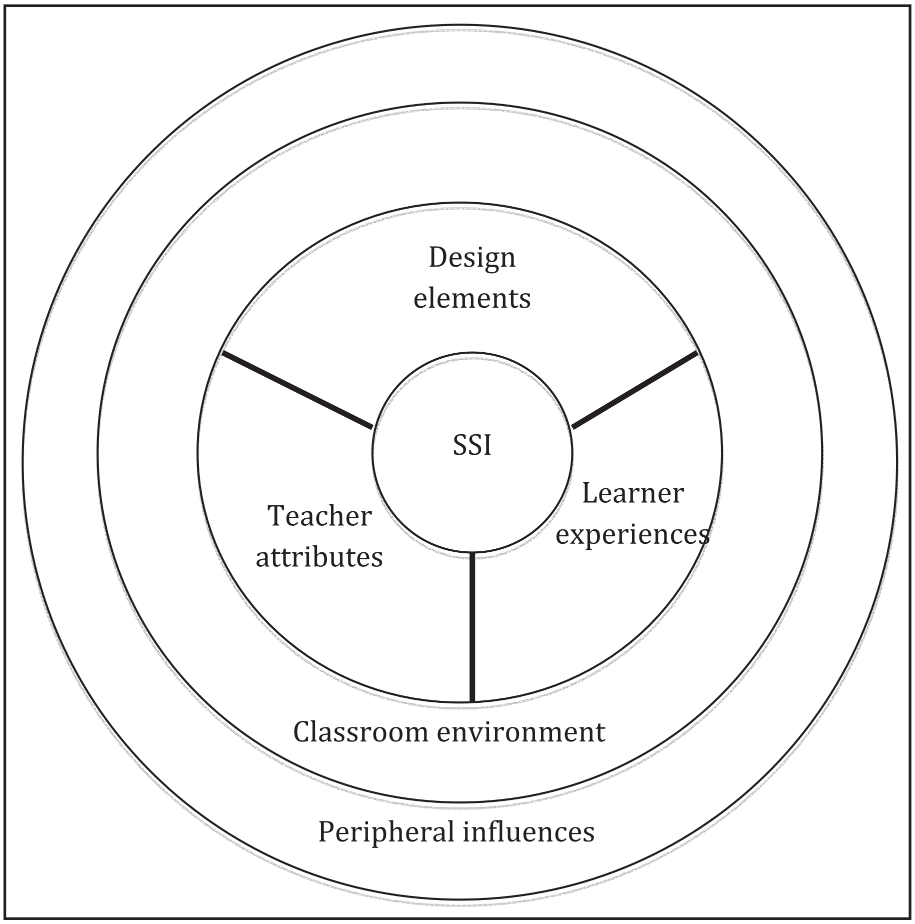

Figure 2: Graphical representation of SSI based framework.

possible scaffolds for higher order practices. The framework does not prescribe a particular type of scaffolding but points to the need for these kinds of supports to advance student thinking and practice.

The final essential design element is the inclusion of a culminating experience that provides learners with opportunities to integrate what they have learned with their prior knowledge and to allow them to relate this knowledge to the issue. These culminating experiences may take multiple forms, including role-play, debate, and service learning projects. Regardless of the format, the key to successful culminating activities is that they should provide opportunities for learners to reflect on their experience and to use higher-order practices (Eastwood, Sadler, Sherwood, & Schlegel, 2012).

In addition to the essential design elements described above, the SSI framework offers two recommended design elements. Whereas the essential design elements are offered as necessary components of successful SSI-based instruction, the recommended design elements are suggested but not necessarily essential. These recommendations include:

1. Using media to connect classroom activities to the "real world."
2. Using technology to facilitate student learning experiences.

Incorporation of media resources provides instructors with a greater diversity of sources and can aid learners in connecting what they are learning in class with what is happening in the world (Klosterman, Sadler, & Brown, 2012). For instance, when an instructor is using SSI-based curriculum related to a compelling social issue, teachers as well as students could use newspaper articles or television reports to access recent information about the issue. The other element involves utilizing technology to support student learning. Technology can be used in a variety of ways to enhance SSI-based instruction and has the potential to be a powerful tool for providing access to relevant social issues (Evagorou, 2011). Additionally, technology can be used for networking with either other students or experts in different locations (Chen, Seow, So, Toh, & Looi, 2010). Of course, students and teachers can use technology to access many forms of media as well.

Learner Experiences

Along with essential design elements, there are essential experiences that learners need to engage in during SSI-based learning. The second core aspect in the SSI framework describes necessary learner experiences and opportunities, which include:

1. Engaging in higher-order practices (e.g., reasoning, argumentation, decision making and/or position taking).
2. Confronting scientific ideas and theories related to the issue being considered.
3. Collecting and/or analyzing scientific data related to the issue being considered.
4. Negotiating social (e.g., political and economic) dimensions of the issue being considered.

To experience effective SSI-based instruction, all learners need to have opportunities to engage in activities that promote one or more of the higher-order practices of reasoning, argumentation, decision making, and position taking (*first essential learner experience*) (Walker & Zeidler, 2007). For example, when students are learning about climate change, they could be assigned to groups that view climate change differently. Students could then research the evidence backing their perspective and present that evidence to the other group. Students could engage in argumentation by using evidence to back their claims and offer rebuttals against the evidence presented by the opposing group. After evidence has been presented for both sides, students should have the opportunity to choose a side based on the arguments. As students conduct research and hear opposing arguments, they will also learn scientific content (*second essential learner experience)* (Klosterman & Sadler, 2010). In the case of climate change, students may be exposed to the carbon cycle, the water cycle or the greenhouse effect. To help develop their arguments, students can conduct individual investigations or analyze existing data sources (*third essential learner experience)*. For example, students could collect their own data from greenhouse models or they could analyze atmospheric data available through publicly accessible databases (e.g., http://www.ncde.noaa.gov/oa/ncde.html). The final learner experience involves negotiation of the social dimensions of the SSI under investigation. In the case of climate change, students can examine economic and political aspects of the issues and policies designed to address the issue. The goal is not necessarily to make all students experts in economics and politics, but rather, to help students better understand the economic and political contexts that significantly shape the issue and interact with science (or interpretation of the science) underlying the issue.

The SSI framework also recommends additional learning experiences. As with the first core aspect (design elements), we differentiate between the set of four required learner experiences (described above) and experiences that are recommended but not absolutely essential. The recommended learner experiences are:

1. Confronting the ethical dimensions of the issue.
2. Considering nature of science (NOS) themes associated with the issue.

Understanding the ethical dimensions and the NOS themes associated with an SSI are recommended learner experiences because these two aspects may not be present for all SSI-based instruction. Furthermore, tensions could arise when discussing an ethical issue. However in the case of climate change, it may be appropriate to discuss the ethical and NOS pieces of the issue. For example, in explorations of climate change, students may discuss the extent to which humans have a moral obligation to care for the earth. While conducting research on the climate change issue, students will inevitably confront the subjectivity and tentativeness of science along with sociocultural influences on science. These could provide ideal opportunities for educators to encourage learners to think about NOS themes.

Teacher Attributes

Along with design elements of the instruction and experiences the learners should engage in, the teacher should have certain characteristics in order to successfully facilitate SSI-based instruction in the classroom. The third core aspect in the framework describes these essential *teacher attributes* for supporting SSI-based instruction which include:

1. Familiarity with the issue being considered.
   a. Knowledgeable about the science content related to the issue.
   b. Aware of the social considerations associated with the issue.
2. Teachers as learners.
   a. Honest about knowledge limitations.
   b. Willing to position self as a knowledge contributor rather than sole authority.
3. Willingness to deal with uncertainties in the classroom.

One essential teacher attribute is teachers' familiarity with the science content and the social issues of the SSI around which they organize instruction. In order to teach science in the context of an issue, teachers need to understand the underlying content knowledge (Lee & Witz, 2009). For example, to teach an SSI-based lesson on tropical deforestation, the teacher needs to understand the scientific concepts of solar radiation and the greenhouse effect to explore relationships between deforestation and climate change. Yet, successful SSI instruction also depends on teacher awareness of the social considerations associated with the issue (Barrett & Nieswandt, 2010). To help students arrive at decisions regarding deforestation, understandings of the economic impacts of removing or not removing forests need to be considered. It is important to note that while we are calling for a level of science content expertise, we are not suggesting comparable expertise related to all of the social aspects of a given SSI. In order to successfully implement SSI-based instruction, it is important for teachers to be aware of potential political, economic, and ethical challenges associated with the issue, but obtaining the same level of expertise with the social dimensions of the issues is not feasible (Sadler, 2011).

Because SSI often involve cutting-edge science and always incorporate elements of uncertainty, SSI-based instruction requires teachers to become learners alongside their students (*second essential teacher attribute)*. The teacher should have enough knowledge and awareness of the issue to help guide students to resources that will lead to new information and understandings, but teachers should not be expected to know everything surrounding a particular issue. Teachers certainly contribute to the ideas and knowledge constructed in the classroom (as do students), but successful SSI teachers do not position themselves as the sole authority in the classroom (Dolan, Nichols, & Zeidler, 2009).

SSI-based instruction is built around inherently open-ended problems, and therefore, it is difficult to predict exactly what directions classroom discourse associated with SSI will take. This makes classrooms that incorporate SSI necessarily more uncertain than more traditional classrooms. In order to be successful with SSI based teaching and learning, teachers have to develop a degree of comfort with uncertainty (*third essential teacher attribute)*. This can be challenging for teachers accustomed to well-rehearsed teaching sequences and easily predicted student response patterns (Zeidler, Applebaum, & Sadler, 2011). Effective SSI-based instructors take advantage of the uncertainties and transform them into powerful and engaging learning experiences for students. Successful teachers of SSI-based instruction provide opportunities for students to become experts in understanding the scientific and social aspects of a particular issue, and encourage them to share their knowledge, consider alternative viewpoints, and develop coherent arguments.

Classroom Environment

The *Classroom Environment* makes up the second layer of the SSI framework; this aspect represents factors that significantly influence the central, core aspects (i.e., design elements, learning experiences, and teacher attributes). The classroom environment subsumes the norms and expectations necessary for successful implementation of SSI in local learning contexts. The essential features of the classroom environment for supporting and shaping SSI-based instruction include:

1. High expectations for student participation.
2. Collaborative and interactive environment.
3. Students and teachers demonstrate respect for one another.
4. Students and teachers feel safe within the environment.

Setting high expectations for all students is the first essential feature for a classroom environment to be conducive for SSI-based instruction. Teachers should create an environment that encourages students to feel comfortable. This environment can be created via assigning different roles to each student and facilitating interactive activities. Providing collaborative activities that encourage participation and accountability among students is the second essential feature. Allowing students to engage in group discussions, presentations, and argumentation are likely to foster more meaningful participation and accountability to one another (Aufschnaiter, Erduran, Osborne, & Simon, 2008; Van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). The first two classroom features are dependent on the final two: shared respect and feelings of safety. In SSI-based instruction, students often need to discuss controversial issues, such as genetically modified organisms, genetic testing, and cloning. In order to have potentially difficult dialogue that may accompany controversial SSI, all participants, teachers and students, need to respect one another and feel safe. Developing a classroom environment in which there are high expectations, collaboration, and feelings of respect and safety takes time. It requires a concerted effort on the part of the teacher and significant buy-in on the part of students (Zeidler, Applebaum, & Sadler, 2011). However, these investments are essential for the classroom to support SSI-based instruction.

More Peripheral Influences

Other *Peripheral Influences* make up the third and outer layer of the SSI framework; this aspect represents factors that significantly influence the core aspects (design elements, learning experiences, and teacher attributes) and the classroom environment (the second layer). Influences from the school, the community, as well as state and national policies can affect SSI-based instruction. The essential features of this aspect include:

1. Support and encouragement for teachers implementing SSI-based instruction.
2. Access to SSI-based materials.
3. Flexibility of curriculum that allows teachers to adapt SSI-based instruction.
4. Existence and awareness of local community issues to prompt SSI-based lessons.
5. Strategies for negotiating community patrons' concerns or disapproval of SSI-based instruction.
6. Connections between SSI-based curricula and state- or national-level curriculum objectives.

The school and the district can have significant impacts on the implementation of SSI-based curriculum. Teachers are generally suspicious of implementing unfamiliar instructional strategies, and therefore encouragement and support at the school and district level is essential for their success (*first essential feature of peripheral influences)* (Johnson, 2006; Khourney-Bowers, Dinko, & Hart, 2005). In order for teachers to implement SSI based education, they require access to good curricula and supporting materials. Many teachers have neither the time nor expertise to create curricular materials (Beyer & Davis, 2012; Fogleman, McNeill, & Krajcik, 2011) so ensuring access to high quality SSI materials is important. High quality curricula consistent with the SSI approach such as *BSCS Biology: A Human Approach* (BSCS, 2012) and *Science Education for Public Understanding Program* (Lawrence Hall of Science, 2012) are two of many examples currently available. Specific SSI activities and units are also available (e.g., Dolan, Nichols, & Zeidler, 2009; Sadler & Klosterman, 2009) (*second essential feature of peripheral influences)*. Although most teachers may not be in an ideal position to create SSI materials from scratch, they do bring a great deal of expertise related to the specific needs, concerns, and talents of their students. Therefore, ensuring that curricula are flexible enough for teachers to make modifications to suite their teaching environments is important (*third essential feature of peripheral influences)*.

The local community in which SSI education takes place provides additional influences. Teachers, students, and administrators will need to become familiar with local issues, and seek out information about them (*fourth essential feature of peripheral influences)*. In addition, if community patrons deem a local issue or SSI topic controversial, they could place pressure on teachers or administrators to discourage SSI-based instruction (Hughes, 2000). Teachers and school personnel will therefore need to develop strategies for negotiating these concerns. For instance, teachers and school personnel (specifically administrators) can arrange a meeting with parents and/or community patrons to inform them and explain why students need to learn the issue (*fifth essential feature of peripheral influences)*.

All science education reforms exist within state and national policy contexts. The general movement toward student evaluation, teacher accountability and standardized curriculum on the international scale will likely impact SSI-based instruction. Teachers may be reluctant to develop or teach SSI-based lessons if they perceive the lesson content to be too far removed from curriculum objectives that form the basis for their evaluation (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006). Therefore, curriculum developers and teachers will need to consider how SSI-based lessons connect to state- or national-level objectives to support their implementation in the classroom (*sixth essential feature of peripheral influences)*.

Conclusion

In order to effectively implement SSI-based instruction in the classroom, several aspects must be taken into consideration. The curriculum itself must be centered on a socio-scientific issue and should provide students with scaffolds to engage in higher-order thinking processes. The curriculum should also allow students to use what they have learned in new situations in order to help them reflect on what they have learned. Successful implementation of SSI also relies on several characteristics of the teacher and classroom environment. Learners should have opportunities to engage in experiences such as argumentation and teachers may have to re-think their roles in the classroom (such as shifting from the sole-authority of the classroom to a facilitator). The classroom environment needs to be supportive, collaborative and respectful. Additionally, peripheral influences including the school climate, district and community expectations as well as state standards and national policy will significantly affect how teachers and students can confront controversial issues in their classrooms.

The new framework for K-12 science education and the Next Generation Science Standards emphasize the importance of students developing scientific literacy and understanding scientific practices (NRC, 2012). To make these goals a reality, students must have the opportunity to engage in scientific investigations, analyze and explain data, use evidence to support claims and participate in discussions about scientific issues. In order for teachers to authentically incorporate these processes in their classroom, they must be embedded within a context. SSI provide ideal contexts for this work. The research-based framework we have presented is not meant to be a step-by-step guide for classroom teachers; rather, it is a model that represents the necessary elements for SSI-based instruction. Practitioners can use this model to incorporate the essential features into their instruction when using SSI. This framework can be used by curriculum designers in order to effectively incorporate social issues with science content. Professional developers and administrators can use this framework to assist teachers implement SSI-based instruction. Finally, researchers could use this framework when conceptualizing and conducting investigations on features of SSI-based instruction. The framework we have presented with its essential features, as derived from current research, can be used by a variety of stakeholders in order to facilitate implementation of SSI-based instruction in the classroom and help students develop scientific literacy and engage in scientific practices.

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