

Rigorous Investigations of Relevant Issues: A Professional Development Program for Supporting Teacher Design of Socio-Scientific Issue Units

by [Amanda Peel](#), University of Missouri; Troy D. Sadler, University of Missouri; Patricia Friedrichsen, University of Missouri; Andrew Kinslow, University of Missouri; & Jaimie Foulk, University of Missouri

Abstract

Socio-scientific issues (SSI) are complex problems with unclear solutions that have ties to science concepts and societal ideas. These complexities make SSI ideal contexts for meaningful science teaching and learning. Although the student benefits of SSI in the classroom have been established, there is a literature gap pertaining to teacher preparation and support for SSI teaching and learning, and the design of SSI units. In order for successful and meaningful SSI incorporation in science classrooms, teachers need professional development (PD) experiences that scaffold their understanding of the complexities associated with SSI teaching and learning. As such, our team designed and implemented a PD program with explicit examples and design tools to support teachers as they engaged in learning about SSI teaching and learning. Additionally, our PD program supported teachers as they designed their own SSI units for classroom implementation. We describe our PD process for supporting in-service secondary biology, chemistry, and environmental science teachers as they learned about SSI instruction and co-designed their SSI units.

Before our work with this group of teachers began, our research team designed and implemented SSI units, and these results informed development of the SSI-TL framework. The SSI-TL framework has been helpful as we continue to design and structure new SSI units, so we made it a central aspect of the PD to guide what SSI teaching should entail. This framework and other tools were used to support teachers as they designed their own SSI units. The PD was successful in that all groups designed SSI units, and many were able to implement in their classes. The teachers indicated the PD was effective from their perspective and they learned about issues and practices. Specific feedback around scaffolding tools we provided indicated the tools helped teachers navigate the design process.

Introduction

Socio-scientific issues (SSI) are complex problems with unclear solutions that have ties to science concepts and societal ideas (Sadler 2004). These complexities make SSI ideal contexts for meaningful science teaching and learning. The benefits of SSI instruction have

been widely documented in science education literature and include gains in the understanding of science content (Klosterman and Sadler, 2010), scientific argumentation (Dawson and Venville, 2008; 2010), and epistemological beliefs about science (Eastwood, Sadler, Zeidler, Lewis, Amiri & Applebaum, 2012). Although the student benefits of SSI in the classroom have been established, there is a literature gap pertaining to teacher preparation and support for SSI teaching and learning, and the design of SSI units.

A few studies have characterized some challenges associated with SSI teaching in classroom contexts. When teachers included SSI in their classrooms, they used SSI as a way to get students interested in and motivated to learn a science topic, but they tended not to include ethical concerns or biases about the issue or the science, resulting in a lack of awareness of the interdependence between society and science (Ekborg, Ottander, Silfver, and Simon, 2012). Teachers also struggled to incorporate evidence and critical evaluation of evidence through media literacy and skepticism in their teaching about SSI and informed decision-making (Levinson, 2006). Even after a targeted intervention focusing on the social, moral, and ethical dimensions of issues, teachers struggled with effectively incorporating these dimensions in their classrooms (Gray and Bryce, 2006).

In order for successful and meaningful SSI incorporation in science classrooms, teachers need professional development (PD) experiences that scaffold their understanding of the complexities associated with SSI teaching and learning (Zeidler, 2014). Additionally, teachers need explicit examples of SSI teaching and learning to support their adoption of instructional techniques for incorporating new ideas in science classrooms, such as media literacy, informed decision-making, and highlighting social connections to an issue (Klosterman, Sadler, & Brown, 2012). As such, our team designed and implemented a PD program with explicit examples and design tools centered around our SSI Teaching and Learning framework. To support teacher learning about SSI teaching and learning, we engaged teachers in 1) SSI unit examples and experiences as learners; 2) explicit discussion and unpacking of the approach; and 3) designing in teams with active support from the research team. Our PD program supported teachers as they designed their own SSI units for classroom implementation with various tools developed by our team, including the SSI-TL framework, a framework enactment guide, the planning heuristic, an issue selection guide, and unit and lesson design templates. We describe our PD process for supporting in-service secondary biology, chemistry, and environmental science teachers as they learned about SSI instruction and co-designed their SSI units.

PD Audience & Goals

To ensure effective teacher participation in the PD program, we identified and invited 30 science teachers from diverse geographic locations throughout the state who met the following criteria:

1. Currently teaching secondary biology, chemistry, or environmental science.

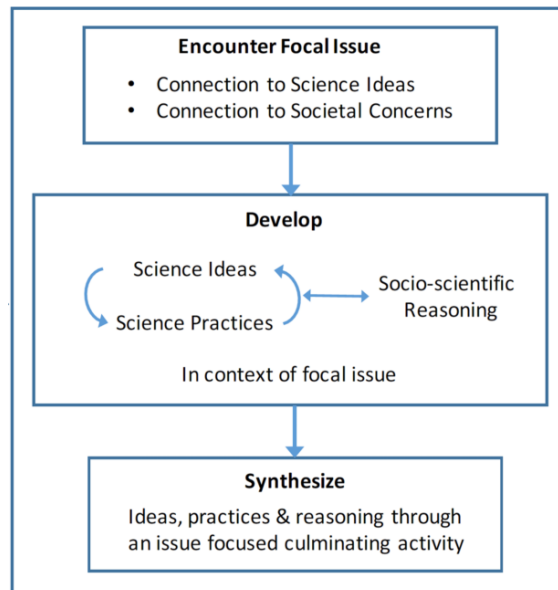
2. Receptive to learning about socio-scientific issue instruction and curriculum design.
3. Commitment to teacher learning and professional growth.

Eighteen teachers accepted our invitation to participate in the workshop. Participant teaching experience ranged from 1 to 32 years. Seven (39%) were early-career teachers with 1-5 years teaching experience. Five (28%) mid-career participants had taught for 6-10 years. The remaining six (33%) participants were veteran teachers with 10 or more years of teaching experience. Over half of the participants (55%) taught at schools within urban clusters as defined by the U.S. Census Bureau, with populations of 2,500-50,000 people. Just over one fourth (28%) of participants taught in urbanized schools within cities of 50,000 or more people, and 17% of the teachers worked in rural districts.

Socio-scientific Issue Teaching and Learning Framework

Our research group has developed a framework for SSI teaching and learning (SSI-TL) for the purpose of designing SSI based science units (Figure 1). An overarching goal of SSI-TL is to provide students with a context for developing scientific literacy through engaging in informed and productive negotiation of complex societal and scientific issues. The SSI-TL framework is composed of three sections, the first of which is Encounter the Focal Issue. In this section, students encounter the SSI and make connections to the science ideas and societal concerns. In the second section of the model, where a majority of classroom activities take place, students Develop science ideas and practices and engage in socio-scientific reasoning (SSR; Sadler, Barabe, & Scott, 2007; Romine, Sadler, & Kinslow, 2017) in the context of the SSI. Learning activities in this section focus on science content embedded within opportunities to engage in science and engineering practices. In terms of focal practices, our group emphasizes modeling, argumentation, and computational thinking because of the potential for these practices to promote sense-making. To facilitate socio-scientific reasoning, we emphasize opportunities for learners to consider the issue from multiple stakeholder perspectives and to consider consequences of potential decisions and actions from a range of vantage points (e.g., economic, political, ethical, etc.). The last section of the SSI-TL framework calls for student Synthesis of ideas and practices and reasoning about the SSI through engaging in a culminating activity.

Figure 1 (Click on image to enlarge). Socio-scientific issue teaching and learning (SSI-TL) framework.



The SSI-TL framework aligns with various essential learning outcomes, which include awareness and understanding of the focal issue, understanding of science ideas, competencies for science and engineering practices, and competencies for socio-scientific reasoning. As teachers utilize this model, they may choose to focus on various discretionary learning outcomes, such as competencies in media literacy, understanding of epistemology of science, competencies for engineering design, and interest in science and careers in STEM. We leveraged this SSI-TL framework during a series of PD sessions to support teachers as they designed SSI units for their classrooms.

The PD Process

An initial meeting of the teachers and our research group took place in December, 2015. At this brief meeting, the participating teachers and the research group members introduced themselves and discuss their interests and experiences regarding SSI teaching. We provided a brief overview of the PD program and our expectations for the participating teachers. The teachers were also given a brief overview of SSI teaching and learning to introduce them to examples of issues they would be choosing in their design teams.

A second full group meeting took place over two days in March, and a third meeting occurred over three days in June. These in-person meetings were used to engage teachers in SSI teaching and learning and to provide structured planning and design time with the help of the PD team. Initially, teachers were grouped by content and assigned a mentor from our research group to aid in SSI learning and the design process. Teachers then chose design partners from their content groups and worked in groups of two to three to design SSI units for their classrooms during and in between the formally organized meetings. To maintain communication between meetings, we used an online community to share content readings and exchange ideas. Teachers read two articles and responded to prompts by commenting

on each post (Figure 2; Presley, Sickel, Muslu, Merle-Johnson, Witzig, Izci, and Sadler, 2013; Duncan, and Cavera, 2015). More reading resources can be accessed at <http://ri2.missouri.edu/going-further/related-reading>.

Figure 2 (Click on image to enlarge). Reading response prompts.

In the Stoker-Duncan & Cavera article (attached below), the authors describe the "three dimensions of the NGSS" in three ways: Disciplinary Core Ideas: "a conceptual toolkit that students can use to reason about and explain phenomena" (p. 86) Science and Engineering Practices: "these activities and norms that are at the core of science," and that are "inherently social and based in a community of practice" (p. 75) Crosscutting Concepts: "a set of lenses that can be used to explore and explain phenomena" (p. 76) - What are your thoughts about these descriptions? - In what ways might they might influence the planning and carrying out of science instruction? - In what ways would a focus on 3-D science learning make your teaching different from what it has been? Link	After reading the Presley et al. article: 1. What stands out as "different" about the approach described in this article? That is, in what ways does it represent a different approach to using issues, as compared to ways in which you have used issues in your classroom (or seen them used in other science classrooms)? 2. In what ways could this framework for using issues in the classroom interact with what we read last week about NGSS? 3. What questions do you have about issues based teaching? Notice the article uses the term "ISS-based teaching," which we consider to be interchangeable with "issues based teaching." Please respond here by the end of the day Saturday, 3/27. As always, your ideas will help us better prepare for the workshop, and we appreciate your willingness to share them with the group!
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Experiencing SSI & Examples

To familiarize teachers with SSI learning, we engaged them as learners in a portion of a fully developed SSI unit. The unit explored the issue of the emergence of antibiotic resistant bacteria with a focus on natural selection as science content and the practice of scientific modeling. The unit was developed for high school biology classes and had been implemented in several classrooms (Friedrichsen, Sadler, Graham & Brown, 2016). The learning experience was led by one of our teacher partners who had used the unit prior to the workshop. She introduced the issue as she did in class by having participants watch a selection from a video about a young girl who contracts methicillin-resistant *Staphylococcus aureus* (MRSA). After being introduced to the issue, teachers engaged in a jigsaw activity in which each group was given a different source with information about MRSA to begin the discussion of credibility of different sources and the ways in which scientific information is used by different stakeholders interested in an issue. The groups read over their source and presented to the whole group. Sources included blog posts, a USA Today article, and Centers for Disease Control fact sheets. This activity was followed with a discussion of the different sources and their varying levels of credibility. After these learning activities, the teachers were given an overview of the full unit and shown student work samples, including student models of antibiotic resistance and natural selection, and synthesis projects which called for students to develop and advocate for a policy recommendation to stem the spread of antibiotic resistant bacteria. The full antibiotic resistance SSI unit (Superbugs) can be accessed at <http://ri2.missouri.edu/ri2modules/Superbugs/intro>.

During the June meeting, teachers were provided with an overview of an SSI unit related to water quality that had been developed and implemented in a high school environmental science class. This unit focused on a local water resource issue with conceptual links to ecological interactions, nutrient cycling, and water systems. The scientific practices emphasized in the unit were modeling and argumentation. One of our team members who was the lead designer and teacher implementer of this unit led a presentation of an overview and key aspects of the unit. The full water quality unit (the Karst Connection) can be accessed at <http://ri2.missouri.edu/ri2modules/The%20Karst%20Connection/intro>.

Including SSI in science classrooms can be challenging because science teachers are often unfamiliar with or uncomfortable addressing the social connections to the issue. To help scaffold this addition to science curricula, we engaged the teachers as learners in an activity highlighting social and historical trends from an SSI unit related to nutrition and taxation of unhealthful foods (a so called “fat tax”). In this activity, groups of teachers were assigned different historical events that had to do with nutrition and nutrition guidelines. Each group investigated their event and wrote the key ideas on a sheet of paper. These papers were placed along a timeline at the front of the room (Figure 3). Each group shared out to the full group about their event, and as each group presented, they drew connections between historical events and nutrition guidelines of the time. For example, one event was a butter shortage, which resulted in the nutrition guidelines urging people to exclude butter from their diet. This activity allowed teachers to see and experience an example of making social connections to an issue while exploring how the social and science concepts impacted each other over time. The full description of this learning exercise can be accessed at <http://ri2.missouri.edu/ri2modules/Fat%20Tax/intro>.

Figure 3 (Click on image to enlarge). Nutrition timeline activity.



Unpacking the SSI Approach

After experiencing SSI as learners in our March meetings, we introduced the teachers to the SSI-TL framework (Figure 1) with emphasis on the three main dimensions of the framework: Encounter the focal issue; Develop ideas, practices, and reasoning; and Synthesize. Using the antibiotic resistance unit as an example prior to introducing the framework allowed us to make connections between the framework and what they experienced as learners. Along with the framework, we introduced a framework enactment table, which depicts student and teacher roles and learning outcomes associated with each dimension of the framework. The enactment table allowed teachers to develop a more in-depth understanding of what each section of the framework entails. The framework enactment table can be accessed at <http://ri2.missouri.edu/content/RI%C2%B2-Framework-Enactment>.

Focus on NGSS Practices. At the time of the PD program, our state had recently adopted new science standards that are closely aligned with the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). Like NGSS, the new state standards prioritize 3-dimensional (3D) science learning, which calls for integration of disciplinary core ideas (DCI), crosscutting concepts (CCC), and science and engineering practices. Due to the interwoven nature of the two, our team has chosen to combine CCCs and DCIs into a single construct of “science ideas”, as seen in the SSI-TL framework (Figure 1). There are eight science and engineering practices outlined in the NGSS, but our team has chosen to focus on a subset of practices: modeling, argumentation, and computational thinking. We chose these practices because they are high leverage practices, meaning that in order to engage in these practices at a deep level, the other practices, such as asking questions or constructing explanations, are being leveraged as well. For example, we posit that in order to create a detailed model, students engage in constructing explanations and analyzing and interpreting data. Our SSI-TL framework calls for 3D learning by engaging students in science ideas and high leverage science practices in the context of an SSI.

Because 3D science learning and practices were new to all of the teachers in the PD, our team offered breakout sessions focusing on a specific scientific practice: modeling, argumentation, or computational thinking. Teachers chose which of the three sessions to attend based on their interests and the practices they planned to feature in their own units. In each session, teachers were engaged in the practice as learners, and then were shown examples of student work pertaining to each practice. Examples were from prior unit implementations and depicted 3D learning through the incorporation of the science practice with science ideas. For example, in the computational thinking session, teachers were shown student generated algorithms of the process of translation, which incorporated computational thinking with the science ideas of protein synthesis. These practice-specific sessions allowed teachers to get an in-depth look at modeling, argumentation, and computational thinking in order to support the incorporation of high leverage practices into their SSI units.

Socio-scientific Reasoning & Culminating Activity. Socio-scientific reasoning (SSR) is a theoretical construct consisting of four competencies that are central to SSI negotiation and decision-making:

1. Recognizing the inherent complexity of SSI.
2. Examining issues from multiple perspectives.
3. Appreciating that SSI are subject to ongoing inquiry.
4. Exhibiting skepticism when presented potentially biased information (Sadler, Barab, and Scott, 2007).

SSR competencies are key to the SSI teaching and learning approach; therefore, we highlighted them in a demonstration and discussion during the PD. Teachers were introduced to the four SSR competencies, and they explored examples of activities designed to strengthen student SSR competencies. For example, engaging students in a jigsaw activity

where they explore an issue from the perspectives of different stakeholders encourages students to engage in SSR because they deal with the complexity of the issue, bring up questions that remain unanswered, analyze information with skepticism about biases, and recognize the limitations of science pertaining to the issue. This session supported teachers in their understanding of SSR and provided them with multiple examples of how this construct can be used in the classroom within SSI contexts.

The culminating activity called for as a part of the Synthesis section of the SSI-TL framework was challenging for the teachers to conceptualize after the first PD session. To support teachers in their understanding of the culminating activity, we presented sample activities and student work from the units we previously developed and implemented. The goal of the culminating activity is to give students a final task where they can synthesize and reason through their ideas about the science behind the issue, the social connections to the issue, and the science practices employed in the unit. This session presented teachers with specific examples and ideas for culminating activities to be used in their SSI units. Teachers engaged in a jigsaw activity and each group examined a different culminating activity example and shared out to the whole group. Teachers discussed how they could alter activities for their classrooms and their units to support the inclusion of culminating projects in their SSI units. An example culminating activity can be accessed in “Lesson 6” at <http://ri2.missouri.edu/ri2modules/The%20Vanishing%20Prairie/sequences>.

In order to further support teachers as they designed their SSI units, we held a panel discussion where various members of our team (SSI unit designers and implementers) shared information about their units and experiences. In particular, panelists discussed the issue they chose and why they chose it, the science practices featured, and their culminating activities. After each panelist shared, the teachers asked questions about the units and experiences; they were particularly interested in hearing more details about ways in which SSR was incorporated in the units and the culminating activities. They also posed several questions about assessment generally and the scoring/grading of culminating activities more specifically. To further address these questions, we provided the teachers with samples of student work and a rubric that was used in one of our implementations for assessing the culminating activity. Through the various sessions and panel discussions, teachers were supported in their understanding of the overall SSI teaching and learning approach.

Teacher Work & Tools

As the teacher design teams worked through the PD program, the goal for each team was to develop a complete SSI unit ready for implementation in their classrooms. By the end of the June PD session, the expectation was for teams to have completed a unit outline and two lesson plans. The full units were due by the end of the summer. Teachers were responsible for choosing an issue, science ideas, and science practices for their units. In order to support

teachers as they designed their unit overviews and lesson plans, we scaffolded their design process with various group techniques and planning tools as described in the following sections.

Group Work & Processes. Initially, teachers worked individually to brainstorm ideas for their units, including possible issues, science ideas, and relevant science practices. Teachers then presented their ideas within their content groups (i.e, biology, chemistry, and environmental science) in order to find shared interests. Based on these discussions, teachers formed design teams, which consisted of two or three teachers who worked together on the design of a unit for the upcoming school year. The composition of design teams ranged from groups with teachers from the same building to groups made up of teachers from different parts of the state.

Planning Heuristic. To scaffold the design process, our team introduced a Planning Heuristic: a table outlining a simplified process for beginning the design of an SSI unit. It describes design steps, products associated with each step, and examples of products from one of the units our team designed. For example, the first step of the heuristic is: explore possible issues, big ideas in science, and target practice(s). The products from this step are a large-scale issue, science themes and focal practices. Examples of these from one of our sample units are climate change as the issue, ecology as the science theme, and modeling as the focal practice. Teachers were encouraged to use the planning heuristic to aid them in their design process. The full Planning Heuristic can be accessed at <http://ri2.missouri.edu/planning-heuristic>.

Issue Selection Guide. Choosing an issue to center a unit around can be a daunting task. To support teachers in their issue selection, our team designed an Issue Selection Guide. Each design team worked through the guide resulting in narrowing their ideas about possible issues, and ultimately deciding on an issue. The guide poses several reflective questions about the issue to help teachers decide on the appropriateness of that issue. Prompting questions fall under three main questions: 1) Is the issue an SSI? 2) Is the issue a productive SSI for the intended audience? and 3) What instructional moves should be considered in presenting the issue? The Issue Selection Guide can be accessed at <http://ri2.missouri.edu/issue-selection-guide>.

Design Templates. To align teacher units with our example units for ease of planning and designing their units, we provided teachers with unit design templates. We provided teachers with a Unit Plan Template, which was used to outline the unit and the key ideas within the unit, such as science ideas, science practices, and the issue. We provided teachers with a Lesson Plan Template that presented a basic structure for each lesson, including time the lesson will take, goals for the lesson, lesson assessments, resources needed for the lesson, and an instructional sequence. These templates can be accessed at <http://ri2.missouri.edu/templates>.

Teacher Reactions & Feedback

The goal of producing SSI units was met because every design team was able to select an issue and complete design of a unit. Table 1 depicts the teams, the issue they selected, whether or not they completed their unit, and whether or not they implemented their unit in their classrooms the following year. Although implementing their units was not a requirement of the PD program, 12 out of 18 teachers implemented the units they designed in their respective classrooms. Six teachers did not implement their units for various reasons. The food additives, made of up a first and second year teacher, did not feel that their unit was far enough along in its development so they decided to wait until the following year to try it. A few of the other teachers experienced changes in their teaching assignments, which made implementation of their units difficult.

Table 1 (Click on image to enlarge)

Design Team Products and Unit Details

Teacher Group	Class Content	Issue Selected	Completed Unit	Implemented Unit
1	Chemistry	Food Preservatives	Yes	No
2	Biology	Invasive Species	Yes	Yes
3	Anatomy and Physiology	Performance Enhancing Drugs	Yes	2 (of 3) Partners
4	Biology	Fat Tax and Energy	Yes	Yes
5	Biology	Mars Habitation	Yes	1 (of 2) Partner
6	Chemistry	Clean Water	Yes	Yes
7	Environmental Science	Flooding and Water Diversion	Yes	Yes
8	Environmental Science	Nuclear Power	Yes	No

Issue Selection Challenges

Interviews were conducted with all of the teachers after the final PD session in June. During these interviews, teachers were asked a series of questions about what they learned and the extent to which the developed tools helped them. Teachers identified the Issue Selection Guide as one of the most useful tools because it helped them narrow down their ideas about issues and allowed them to determine if it was appropriate for their unit. Multiple teachers said that selecting an issue was the most challenging aspect of designing their units:

“[We] had a real issue finding an issue, and [it] was difficult... I had a lot of ideas” (T2, June Interview).

“I had no idea what could be a social and science issue... I used the topic selection paper, that chart thing that you guys made to help work up to picking an issue after – I had a whole bunch of ideas storming around, and it helped me narrow it down and select one that would work for this unit.” (T3, June Interview).

The Issue Selection Guide was useful to the teachers who were struggling with selecting an issue because it helped them narrow their issue ideas and choose an issue that would fit the instructional needs of their classes.

The Value of Examples

When asked what the most valuable part of the PD was, teachers identified the SSI unit examples and experiences as the most helpful:

“Seeing the variety of lesson topics and ideas, working through some of the lessons.”

“The sample SSI units were very helpful in seeing [SSI] in action.”

“The parts of model lessons where we participated in the student portion of the lesson” (Teacher Responses, Anonymous Post Survey, June 2016).

Teachers found the explicit examples of SSI-TL implementation to be the most helpful when learning about SSI and designing their units, indicating that the PD design supported teacher engagement in SSI teaching and learning.

Lesson Planning Challenges

In addition to selecting an issue, teachers identified writing lesson plans as a challenge in their design process:

“I never actually had to sit down, and write a lesson plan before... so going through and planning something start to finish, is not something that I have had to do... that was a challenge for me” (T1, June Interview).

“[The] process of putting it [unit plan] together is a challenge. Because most of the time I just sort of do it internally, I don’t really write it down” (T4, June Interview).

Most of the teachers were experienced teachers, so they didn’t need to write out every lesson because they felt comfortable with what they were teaching and how they were going to teach it. Because the SSI teaching and learning approach was new to the teachers, we were explicit in the structure of these units. The provided unit plan and lesson templates helped the teachers work through a planning and documentation process that was more formal than most of the participants were used to, and it resulted in materials that could be shared with other teachers.

Increases in Comfort with SSI and Science Practices

Teachers also responded to a Likert scale survey before and after the PD with questions about their comfort in teaching SSI, designing SSI units, and utilizing science practices. Ten survey items yielded statistically significant increases from before the PD to after the PD (Table 2). The first two items deal with teachers’ abilities to teach SSI in the classrooms. After the PD more teachers agreed they knew enough about SSIs in their area to design instruction using them, indicating teachers felt more comfortable with SSI design after the PD. More teachers also agreed they were able to negotiate the use of SSIs in their classrooms when talking to community members and parents with concerns, indicating an

increase in comfort level with using SSI in their classrooms. The remaining items related to the teachers' comfort level with scientific practices. Teachers increased in their comfort with the scientific practices of modeling, explanations, argumentation, and evaluating information.

Table 2 (Click on image to enlarge)

Survey Items with Statistically Significant Increases from Pre to Post PD

Survey Item	p value
I know enough about controversial issues related to my science discipline to build instruction around them.	.014
I am able to negotiate community members' and parents' concerns about using potentially controversial social issues to teach science concepts in my classroom.	.025
I feel confident in my ability to construct, revise, and use models to explain relationships between systems and their components.	.035
I feel confident in my ability to construct and revise explanations based on evidence.	.014
I feel confident in my ability to base causal explanations on valid and reliable empirical evidence from multiple sources.	.025
I feel confident in my ability to criticize and evaluate arguments in light of evidence.	.007
I feel confident in my ability to evaluate the merits of competing arguments.	.003
I feel confident in my ability to distinguish between claims, evidence and reasoning within scientific arguments.	.011
I feel confident in my ability to construct a counterargument that is based in evidence and that challenges another proposed argument.	.005
I feel confident in my ability to critically read scientific reports prepared for public audiences.	.025

Conclusion

Teachers are important agents of change, and, given proper supports, they can successfully facilitate SSI learning experiences for their students. Before our work with this group of teachers began, our research team designed and implemented SSI units, and these results informed development of the SSI-TL framework. The SSI-TL framework has been helpful as we continue to design and structure new SSI units, so we made it a central aspect of the PD to guide what SSI teaching should entail. This framework and other tools were used to support teachers as they designed their own SSI units.

The PD employed a blended model of face-to-face meetings and communications with an online networking tool. During the PD we alternated among three sets of activities to support teachers: 1) SSI unit examples and experiences as learners; 2) explicit discussion and unpacking of the approach; and 3) design teams working together with active support from the research team. Throughout the PD we provided design supports with various tools developed by our team, including the SSI-TL framework, the framework enactment guide, the planning heuristic, the issue selection guide, and unit and lesson design templates. The PD was successful in that all groups designed SSI units, and many were able to implement in their classes. The teachers indicated the PD was effective from their perspective and they learned about issues and practices. Specific feedback around scaffolding tools we provided indicated the tools helped teachers navigate the design process.

As we consider ways of advancing this work, we are interested in exploring ways to work with school-based teacher professional learning communities (PLCs). Bringing together teachers from across widely varying school contexts and facilitating their work together was a challenge. We think that supporting communities of teachers familiar with the same local affordances and constraints may be a more effective way to bring about more lasting

incorporation of SSI teaching into science classrooms. We are also interested in extending our investigations to learn more about the ways in which teachers implement their units. In the current project, we were able to elucidate some of the challenges teachers faced in designing SSI units (like selecting issues) and presented tools to help teachers navigate these challenges (e.g., the issue selection guide). We think that it would be a productive step for the SSI-TL agenda to do this same kind of work (understanding challenges and designing tools to address them) for implementation.

Supplemental Files

[Supplemental-1-Design-Heuristic.pdf](#)

[Supplemental-2-Selecting-An-Issue-Worksheet.pdf](#)

[Supplemental-3-Unit-Plan-Template.pdf](#)

[Supplemental-4-Lesson-Plan-Template.pdf](#)

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