Teaching Practices for Enactment of Socio-scientific Issues Oriented Teaching:

An Instrumental Case Study of an Exemplary Teacher

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Introduction

Socio-scientific issues (SSI) are contentious social issues that have conceptual ties to science but are unable to be resolved through an understanding of science alone. SSI are wicked problems in that they are complex and not well defined and involve multiple perspectives (Zeidler, 2014). Though several possible courses of action exist, none of them is likely to benefit all stakeholders equally. An SSI approach to instruction values the knowledge and scientific ways of thinking that have traditionally defined science literacy. It also positions science learning as a means for enabling students to practice making informed decisions about real world issues to prepare them for citizenship in a democratic society (Roberts & Bybee, 2014). It is for this reason- the requirement of both societal and scientific knowledge to solve real-world problems- that SSI serve as a viable pedagogical approach for enhancing scientific literacy among all learners.

Extensive literature has emerged that supports a variety of positive outcomes in terms of student thinking and learning in the context of SSI. For example, several studies have found that students can make significant gains in understanding science content through SSI curricula (Sadler, Romine & Topcu, 2016). SSI have also served as effective contexts for students’ development of nature of science understandings (Khishfe & Lederman, 2006), reflective judgement (Zeidler, Sadler, Applebaum & Callahan, 2009), discourse and argumentation practices (Zohar & Nemet, 2002), as well as the development of character and propensity toward active citizenship (Lee et al., 2013). Thus, SSI approaches have been shown to facilitate student learning and thinking consistent with many important goals for science education.

The research noted above supports the SSI approach as a practical means by which teachers can contextualize the content and practices of science in a manner that students can relate to
while developing scientific literacy. However, we know relatively little about how SSI approaches are carried out in classrooms - particularly the things that teachers do to facilitate learning in the context of issues-oriented instruction. Our interest is in better understanding how a teacher enacts SSI curricula with a focus on teacher practice. The following research question guided our work: *What practices does an experienced teacher employ for successful enactment of SSI-oriented teaching?*

**Frameworks Guiding the Research**

We draw on several lines of thinking and research for conceptualizing dimensions of our work. First, we view the instruction that takes place in any learning environment as a dynamic interaction between teachers and the curricula they employ to guide instruction. Curricular tools “both shape and are shaped by human action through their affordances and constraints” (Remillard, 2005, p. 221). Throughout this interactive process, the interpretation, adaptation, and employment of curricular materials are affected by the teacher’s pedagogical background and the culture of the school in which he or she teaches (e.g., Remillard, 1992). Guided by this perspective, we recognize our inability to neatly separate teacher from curriculum; however, our focus in this study is on the teacher and her enactment of SSI instruction.

Teachers play an important role in student learning (van Driel, Berry, & Meirink, 2014), and teacher knowledge structures, such as pedagogical content knowledge, have been an important focus for educational research (Bausmith & Barry, 2011). A line of recent scholarship, however, has directed increasing attention toward teacher practices - what actually happens in the classroom (Ball & Forzani, 2009). While we certainly acknowledge the value of teacher knowledge, we recognize the practices in which teachers engage during their enactment of instruction have the biggest influence on student learning (Remillard & Heck, 2014; Rockoff,
Our perspective is grounded in the SSI Framework for Teaching and Learning (Sadler, Foulk & Friedrichsen, 2017). Using this framework, students are first introduced to a focal issue before exploring connections between the issue and those science ideas and societal concerns integral to its negotiation. Once students have explored the issue, they begin to engage in understanding it by way of its societal and scientific underpinnings through iterative cycles of experience with the science ideas and practices that define the issue while reasoning about the societal influences that make the issue complex and difficult to resolve (Sadler, Barab, & Scott, 2007). Finally, a culminating activity requiring students to synthesize the key science ideas and practices with social and ethical concerns enables students to apply their learning experiences to advance a position or direct policy recommendations concerning the resolution of that issue. The SSI teaching and learning framework described above influenced our work with the teacher in this study was used in designing the curriculum, and aided our interpretation of results.

**Literature Review**

**Teacher Practices**

Ambitious teaching refers to the enactment of practices in classrooms such that all students achieve important learning outcomes (Ball & Forzani, 2009). Lampert and Graziani (2009) argue that ambitious teaching must involve “stable and learnable practices” (p. 492) that can be articulated and shared for the improvement of the teaching profession. Researchers and teacher educators have recognized that teaching practice drawing on “shared professional knowledge, values, and skills” (Ball & Forzani, 2009, p. 499) likely serves as a better predictor of student achievement than teacher characteristics, such as teaching experience or attainment of a master’s degree (Rockoff, 2004). Yet, even experienced teachers struggle to enact ambitious teaching
practices that yield productive student learning outcomes (Kennedy, 2005); however, improving teacher practice may well be the most effective way to enhance student engagement, learning, and achievement (Grossman & McDonald, 2008).

**Science Teacher Practices**

Recognizing the substantial impact that high-leverage, domain-specific teacher practices can have on student learning, science education researchers have sought to identify a repertoire of exemplary science teaching practices that might serve to guide novice and veteran teachers alike. Windschitl, Thompson, Braaten, and Stroupe (2012) defined “ambitious science teaching” practices as those “routine activities teachers engage in devoted to planning, enactment, or reflection that are intended to support student learning” (p. 882). They proposed four core high-leverage practices that could be used frequently and across science topics. The first was a planning practice in which teachers construct a “big idea” (Windschitl et al., 2012, p. 888) – a puzzling scientific phenomenon to be used as a context through which science can be learned and practiced. After introducing students to the big idea and developing an initial explanatory model, the teacher then engages in three enactment practices: 1) eliciting students’ prior conceptions and adapting instruction in real time by using the students’ own language to shape classroom conversations; 2) facilitating students’ sense-making and reasoning about unobservable features of the big idea, providing feedback on students’ initial models, and normalizing common language of practice; and 3) assisting students’ enhancement of their explanatory models. Together, these practices of planning and enacting instruction in the context of a big idea are considered by some to represent ambitious science teaching.

Extending the work of Windschitl and colleagues (2012), Kloser argued that the provision of a core set of teaching practices on which to focus teacher professional development could
aid the quality of instruction immensely. Using Delphi methodology, he proposed 10 science teaching practices that make up the core of science instruction. The Delphi panel reasoned that adept practitioners built classroom learning communities defined by investigation and rich discourse while remaining perceptive of student thinking so as to provide timely guidance, encouragement for participation, and constructive criticism by way of feedback and varied formative and summative assessments. These teachers would have to be sufficiently organized to manage curricula and laboratory equipment around which their instructional routine would be based, but most importantly, and along with the students who would also hold membership in the community of learners, embark on a search for understanding science ideas by way of engagement in science practices. The community of learners, as a whole, would be charged with linking those ideas with phenomena, identifying connections that may transcend traditional subject boundaries, and using models to explain these phenomena and make predictions about future events. In doing so, the community of learners would build norms around applying science knowledge and practice to guide the actions in which they engaged in everyday, thereby contributing to their own science literacy.

**Science Teacher Practices in the Context of SSI**

Researchers have devoted limited attention to science teacher practices necessary for the successful enactment of SSI teaching. However, it seems likely that many of the teacher practices identified by the likes of Ball, Grossman, and Kloser would be important for SSI teaching. In presenting a framework for SSI teaching, Presley and colleagues (2013) argue that building safe classroom communities of learning around participation and mutual respect are critical. In a case study of SSI enactment, Simon and Amos (2011) observed one teacher struggle to elicit stu-
dent thinking to drive instruction and facilitate argumentative discourse in the context of the issue. Unfortunately, even experienced science teachers struggle to generate student input for use “as a social resource for learning” (Windschitl et al., 2012, p. 886) – a problem that is compounded for teachers attempting to venture outside of teaching established scientific knowledge to include discussion about an issue perceived to be controversial (Hodson, 2003). Another teacher enacting SSI instruction about reproductive technology had difficulty making clear her own ethical viewpoint while encouraging students to consider all ethical aspects (Dawson, 2011). Zeidler, Applebaum, & Sadler (2011) observed a teacher who struggled to shift his position from purveying information to mediating a community of learners’ engagement in science practice and moral reasoning – a stance not easily adapted by a teacher used to taking an authoritative stance in a classroom of students expecting the same.

Having recognized that teachers’ enactment of instruction truly impacts learning outcomes, science education researchers have begun to focus on ambitious teaching practices. Similarly, emerging lines of research support SSI as a viable context through which to facilitate science learning and the development of scientific literacy. However, though potential connections between core science practices and SSI instruction exist, it is not clear what science teaching practices look like in classrooms that are engaged in learning through SSI. This study is the first to focus specifically on the practices an experienced teacher employs as she successfully enacts SSI-oriented teaching.
Methods

Case Study

This qualitative investigation was an instrumental case study (Stake, 1995). The case was bounded by one teacher’s enactment of a unit of SSI-oriented instruction about antibiotic resistance in a single section of Honors Biology (taught over the course of nine 90-minute class periods) during the 2014-2015 school year. The case was further bounded in that it was the teacher’s second year of implementing the unit. As this investigation was a contemporary study concerned with the particularities and complexities of a single case (Stake, 1995), and sources of evidence included direct observation and interview of the teacher understudy, case study methodology was appropriate (Yin, 2014).

Context

The case study was conducted in a large high school (~2,000 students) located in a mid-sized Midwestern city in the US. The teacher, Ms. Jackson (pseudonym), had twelve years of high school biology teaching experience. She was a recognized teacher leader within the school and district, received a state-level teaching award, and regularly served as a mentor for pre-service and early career teachers. For 18 months prior to this study, we worked with Ms. Jackson to collaboratively design an SSI unit focused on the emergence of antibiotic resistant bacteria, such as methicillin-resistant *Staphylococcus aureus* (MRSA), to teach natural selection (Friedrichsen, Sadler, Graham, & Brown, 2016). The unit emphasized the Next Generation Science Standards’ practice of scientific modeling. Ms. Jackson had implemented the full antibiotic resistance (ABR) unit once prior to the initiation of the case study reported herein.
The antibiotic resistance unit, as well as the teacher’s instruction of it, were shown to be effective during the first year of implementation. Pre/post assessment analyses indicated that students showed statistically significant gains (with large effect sizes) in their understandings of natural selection and statistically significant decreases in natural selection-related misconceptions (Sadler et al., 2015). Students’ modeling competencies also demonstrated substantial growth over the course of the unit (Peel, Zangori, Friedrichsen, Hayes, & Sadler, 2018). Furthermore, we noted anecdotal evidence indicating that students enjoyed the SSI unit and were motivated to learn science through the exploration of this issue. Based on this evidence of student impacts, we concluded that the ABR unit and Ms. Jackson’s enactment of it could be considered a successful example of science teaching and learning. In the second year of our partnership, we directed our research attention to the case study reported here; that is, an exploration of the teaching practices Ms. Jackson employed as she enacted the ABR unit.

**Data Collection**

Researchers were present for each of the nine class periods that composed the ABR unit, and each lesson was video recorded. The recordings focused on Ms. Jackson’s teaching, including episodes of whole-class instruction, her interaction with individual students, and engagement with small groups during learning activities. When students were working in groups or carrying out laboratory investigations, the researchers captured video of group interactions. Where appropriate, student artifacts, including course products such as lab reports and a culminating policy proposal, were used to supplement the analysis.
Data Analysis

We used an inductive approach to analyze the data by identifying individual video segments that captured science teaching practices or instances of student engagement that contributed to SSI instruction. Segments were recorded into an Excel datasheet. Each entry contained a video identification number, the date and lesson number, the start and end time for that segment of video, a brief description of the segment, the context of instruction in which the segment of interest occurred, teacher and student dialogue that defined the segment, and rationale for why that segment was identified as important for this case study. In the second round of analysis, similar codes were grouped thematically (Creswell, 2013). The characterization of the codes was influenced by language used in previous studies of teacher practices and SSI-oriented instruction (e.g., Kloser, 2014; Presley et al., 2013; Sadler et al., 2017; Windschitl et al., 2014). The trustworthiness of the findings was enhanced by way of researcher triangulation (Denzin, 1978; Erzerberger & Prein, 1997).

Results

A diversity of teaching practices contributed to Ms. Jackson’s successful enactment of SSI instruction, spanning the range of those previously deemed to be core and ambitious (Kloser, 2014; Windschitl et al., 2012). We sought to focus on those practices that were particularly important for successful SSI instruction, as well as SSI-specific teaching practices not previously identified in the teaching practices literature. In the first section of the results, teaching practices unique to SSI instruction are reported. The second section addresses core science teaching practices of particular importance to the enactment of this ABR unit.
Science Teaching Practices Unique to SSI Instruction

Teaching practices in which Ms. Jackson engaged to help her students in the application of science through SSI included contextualizing teaching and learning in the issue, challenging students to analyze the issue from multiple perspectives, urging students to employ skepticism when analyzing potentially biased information regarding the issue, promoting the critique of idea, and positioning the teacher as learner.

**Contextualizing teaching and learning in the issue.** Akin to the big ideas and phenomena aforementioned by Kloser and Windschitl, natural selection and bacteria’s development of antibiotic resistance served as the focal point of instruction. However, SSI include societal dimensions and demand resolution – elements of instruction that are unaccounted for in contemporary literature concerning teacher practices. Ms. Jackson’s SSI-oriented instruction positioned natural selection as a means through which students could understand the sticky issue of bacteria’s development of ABR, including societal factors that influence its resolution, and develop the ability to reason through a promising resolution. In this case, Ms. Jackson was still responsible for fomenting student understanding of the concepts underlying natural selection and linking it to the phenomena of bacteria’s development of ABR through science practice, but her role was expanded to include helping students make sense of ABR as a societal issue and work towards its resolution it by addressing concerns of science and society, thus contributing to their development of functional scientific literacy. Ms. Jackson contextualized teaching and learning in the issue by connecting the issue to personal experiences and making ongoing connections to SSI.

**Connecting to personal experiences.** Ms. Jackson was intentional in making personal connections between health issues and the decisions that students were making, or might have make, in their everyday experiences. For example, after her class watched an introductory video
about a girl who contracted MRSA, Ms. Jackson opened the floor to students to share their thoughts about the video, which elicited students’ surprise at the ease of the spread of MRSA, even with things like touching a doorknob. Ms. Jackson’s consistent focus on the personal nature of health issues raised by ABR and her facilitation of collaborative group work made space for students’ discussion of their own interactions with ABR to develop organically, such as one girl’s admission that she had a staph infection, which her parent’s hid from her for fear of how she might react. Students’ personal connections to ABR were used to highlight the issue and were synthesized with the understanding of natural selection and ABR being developed in class.

**Making ongoing connections to SSI.** Ms. Jackson seamlessly adjusted her standard suite of tools and materials to feature the issue when enacting the ABR unit. For example, Ms. Jackson framed the guiding questions to require consideration of the ABR issue and often redirected students’ thinking toward them: “The purpose of this lab was to learn how ABR occurs using harmless bacteria *Bacillus megaterium*. In this assignment, you will describe and analyze your findings using what you know about *Bacillus*, streptomycin, and natural selection . . . Describe how these results fit into the bigger things… Bring this back to the bigger picture of what we've been talking about. 'What is MRSA? Why is it a problem? What is ABR? Why do they become useless? How does this happen?’ How [did] what you learned today fit with what you saw on your plates and ABR?” Across all of her instruction, Ms. Jackson tasked students with using their notebooks to reflect on personal perspectives on the issue and brainstorm possible solutions to ABR policy by requiring them to capture notes, record laboratory activity, and complete writing assignments in a science journal: “I would like you to write a couple of these things down in your notebook, because this is a resource for you as you’re thinking about your [ABR policy] proposals.”
Ms. Jackson also made adjustments to the focal assignments that normally anchored each unit to ensure that students used science ideas and practices to create new products that connected the knowledge developed in class with the ABR issue. For example, Ms. Jackson extended the customary lab report concerning natural selection by requiring students to extrapolate bacteria’s development of ABR on agar plates containing antibiotics to factors that contribute to the development of ABR in humans, such as individuals not completing a round of antibiotics. Similarly, at the conclusion of the ABR unit, Ms. Jackson expanded her usual unit-ending project to include a culminating activity that tasked students with developing a policy recommendation toward the resolution of the ABR issue. This necessarily required students to incorporate the understanding they had gained from engaging in science practices and ideas with different social, cultural, and economic perspectives held by the stakeholders involved in the resolution of the issue. This process enabled students to experience a town hall-like setting, where multiple perspectives are shared and understood in light of a scientific understanding to provide direction for policy.

**Challenging students to analyze SSI from multiple perspectives.** In constructing the ABR unit, an emphasis was placed on students’ understanding and respecting the many perspectives that pertain to an inclusive resolution of an issue - particularly important when employing an SSI approach. Ms. Jackson encouraged the sharing of perspectives and constructive criticism during modeling, as well as in ascertaining the outcomes of the class’ laboratory activities. For examples, when having students describe their models of cell organelles, productive discussion ensued: ST1: "I just added the ribosome part, cause I didn’t think about that when I did the individual part"….ST2: "I'm adding the molecular genetic part to mine because I did not have that and her drawing really helps me understand it.” This normalization of students’ valuing of peers’
perspectives when developing a scientific understanding served Ms. Jackson well when having her class negotiate possible solutions for the ABR issue - solutions that necessarily involve a variety of stakeholders. Ms. Jackson positioned her own students as policy makers who should employ “thinking . . . informed by what you know about the science behind this issue, but … also . . . by the social aspects of the issue.” To do so, Ms. Jackson arranged students in groups to share the various perspectives each student had researched, including what “the stakeholders . . . [would] recommend in terms of policy for ABR,” while taking into account the quality of those sources of information. The resulting discussions were rich and elucidated the complexity of SSI and the importance of social and cultural influences on the formation of policy outside of the application of scientific knowledge.

**Urging students to employ skepticism when analyzing potentially biased information regarding SSI.** While it is important to view all scientific reports with a critical eye toward methodology, it is particularly important for students to exhibit skepticism when dealing with potentially biased sources of information. Though not a focus of the ABR unit, Ms. Jackson attempted to aid students in recognizing the importance of being skeptical of inherent bias likely present in different stakeholders’ perspectives on an issue by providing a *Know Your Sources of Information* worksheet [Appendix A] and urging them to use it when accessing information about ABR. At least one student heeded her warning: “My article is about government intervention in health care, and it was a blogger, ‘unbiased’ so called ‘politically neutral coalition’ [does finger quotes and laughs], and then there was another one that was a new article reporting the findings of an American survey. Both seemed reliable, but the first one seemed a little more quality because it was actually written by a medical professional.”
Promoting the critique of ideas. In developing a community of learners, Ms. Jackson normalized the critique of peers’ ideas - central to the advancement of science and to the resolution of the SSI. For example, Ms. Jackson had no problem providing formative feedback on students’ work. "Last class period…we asked you to redraw your models including natural selection . . . I’m just going to say it outright, that a lot of you…missed the time element…[and] didn’t show a change over time.” After calling out deficiencies herself, Ms. Jackson hosted a critique session by projecting images of both satisfactory and unsatisfactory models of natural selection and inviting student critique of their peers’ products, including suggestions for improvement. By role modeling evaluation and initiating a safe space for students to practice it with supervision, Ms. Jackson normalized the critique of ideas in the classroom and valued the results that came from it – in this case, enhanced models and conceptions of natural selection. Ms. Jackson went on to formalize the process of critique, giving students complete ownership over the critique of their peers’ products in groups. In doing so, Ms. Jackson assigned value to peer feedback and expected that peer critique would enable students to enhance their ability to resolve SSI by taking into account the perspectives of others and critiquing the policy proposals they developed.

Positioning the teacher as learner and welcoming uncertainty in the learning environment. Inquiry is a hallmark of the scientific enterprise, characterized by the pursuit of understanding and a struggle with uncertainty (Colburn, 2000). In fact, welcoming uncertainty in the learning process is requisite if one is to move from delivering authoritative, declarative information in its final form to providing students to engage in inquiry learning where uncertainty is celebrated and par for the course, Ms. Jackson negotiated this well on several levels. First, she positioned herself as a lifelong learner - important to remaining informed concerning SSI that are dynamic and require ongoing inquiry into scientific and societal developments that are constantly
in flux. Ms. Jackson exemplified this when, upon reading and grading her students’ work, told them “I always love reading these because I learn things by reading what you’re learning.” With this statement and others like it, Ms. Jackson valued her students’ ideas and supported their confidence in sharing ideas in the future while indicating that she, too, was still learning. While this comment may seem contrived, it set her up well for a moment of uncertainty that followed the faulty analysis of unexpected bacterial growth on agar plates containing streptomycin. After initially calling it contamination, Ms. Jackson admitted that she was mistaken - the bacteria had actually mutated. She aptly turned the error into a learning opportunity: “What’s a genetic mutation? When DNA replication occurs, a mistake happens…So once that mistake is made, is it going to go back? No…it’s a permanent change that happens randomly.” Ms. Jackson could have certainly taken an authoritative stance and declaratively informed her students as to how bacteria growth would be affected by the inclusion of antibiotic in the medium. Instead, Ms. Jackson engaged her students in an investigation, the results of which were not certain and in this case, were unexpected. However, Ms. Jackson’s ownership of the error, and recognition of uncertainty as in a science classroom, served to exemplify her role as a learner in the classroom while demonstrating the means used by scientists to reform models of understanding when new information becomes available. Considering that socio-scientific reasoning requires ongoing investigation to have the most informed position, it stands to reason that the teacher, as well as the student, would need to be in a position of continued learning.

**Science Teaching Practices of Particular Importance to the Enactment of the ABR Unit**

While all of the science teaching practices previously identified as core and ambitious in the literature are important for quality instruction, some appeared to be particularly important for the successful enactment of SSI instruction. For example, building a classroom community
where active participation is expected and critical feedback concerning policies proposed to solve SSI serve to model the expectations of citizenship in functional democracy. Additionally, focusing on core ideas and practices by linking science concepts to phenomena, eliciting student thinking about core ideas and practices to guide instruction, and supporting students’ modeling competencies enables a better understanding of the natural world, which should enhance their ability to make informed decisions in the future. The manner in which Ms. Jackson was able to carry out these practices is described in detail below.

**Fostering classroom community.** If the purpose of instruction through SSI is to prepare students to engage in dialogue about science and societal aspects of issues and use the understanding that results to inform their decision-making about them in their everyday lives, then teachers would be well served to foster classroom communities that reflected this reality. Ms. Jackson fostered such a classroom community by setting clear expectations for student participation and performance and facilitating classroom discourse. Support for these themes follows.

**Setting clear expectations for student participation.** Civic engagement requires active participation in the democratic processes, if a democracy is to remain functional. Ms. Jackson made her expectations for students’ participation clear from the outset, often using proximity and general expectation sharing by working her way around the room and broadcasting general remarks, such as “I should hear lots of talking” when engaging students in discourse with their peers. At other times, Ms. Jackson assigned specific roles to students to enhance participation and ensure that each student practiced a diversity of tasks, including becoming informed as to different stakeholders’ positions concerning the ABR issue and explicating those positions to their peers. These were generally accompanied by explicit directions and expectations for both in-class and take-home assignments, including the provision of rubrics to increase the ability for
students to meet her expectations. Ms. Jackson’s explication of clear expectations for participation and performance demonstrated to the students that they were responsible for the actions and products to be carried out and accomplished. Ms. Jackson’s expectation that her students actively participate certainly serves as a best teaching practice in any context; however, it is particularly important in the context of SSI-oriented instruction.

*Facilitating classroom discourse.* Perhaps the ultimate goal of establishing clear expectations for participation and performance was to maximize the quality of student-centered, collaborative learning experiences, which represented a majority of the time in Ms. Jackson’s class. Ms. Jackson often formalized collaboration by grouping students and tasking them with developing models or brainstorming ideas for upcoming projects. She also used impromptu sharing sessions to ensure students’ understanding of concepts, often ending segments of instruction with think-pair-share activities by having students “share three things you’ve learned today with your shoulder partner.” Ms. Jackson used informal sharing in a variety of ways: as a tool for students to discuss what they knew about an upcoming topic, to compare and contrast student products, to summarize knowledge into precise answers to focal questions, or to review previously learned science ideas or competencies by discussing them with peers. She also used collaborative learning experiences as a forum for students to share the multiple perspectives of stakeholders that they had researched and incorporate their understanding of the science undergirding with these societal aspects to brainstorm a course of action that might successfully resolve the ABR issue. In this manner, collaboration and classroom discourse were employed as tools for promoting the communication of science ideas and societal aspects of the ABR issue with the end goal of resolving it.
**Focusing on core ideas and practices.** Ms. Jackson maintained a focus on core science ideas and practices by linking science concepts to phenomena, eliciting student thinking about core ideas and practices to guide instruction, and supporting students’ modeling competencies. Support for these themes follows. For example, after Ms. Jackson engaged her students in an investigation concerning the growth of bacteria on agar plates with and without a streptomycin antibiotic, she tasked students with describing “how these results fit into the bigger things, things to include are natural selection, antibiotic resistance, the MRSA problem. Bring this back to the bigger picture of what we’ve been talking about, right? We started this whole thing by saying 'what is MRSA? Why is it a problem? What is antibiotic resistance? Why do they become useless? How does this happen? . . . Bring into it what you learned today fit with what you saw on your plats and antibiotic resistance." In this manner, the ideas and practices in which students engaged were not left as isolated events. Rather, students were able to use those learning experiences to construct an understanding about the phenomena under study – ABR.

**Linking science concepts to phenomena.** Ms. Jackson made sure to ensure that students were making connections between the science ideas and practices in which they engaged and the phenomenon under study – natural selection and bacteria’s development of antibiotic resistance.

**Eliciting, assessing, and using student ideas.** Teachers might demonstrate the elicitation, assessment, and use of student ideas by probing students’ conceptions of natural selection and directing instruction accordingly. Ms. Jackson accomplished this by asking questions that sought further explanation and elaboration, interpretation and prediction, and synthesis of ideas, as well as anticipating and responding to students’ alternative conceptions, and summarize key points. These are briefly addressed below.
Asking questions. Ms. Jackson used questions in a variety of ways to solicit student understanding and encourage deep processing. For example, Ms. Jackson used pointed questions to solicit student explanation and elaboration of concepts to ensure that they had made the connection between the variability resulting from mutations concerning rabbit ear length and the recognition that long ears became more frequent in the population over time due to their being better suited for thermoregulation in desert environments. She also used probing questions that required students to evaluate prior knowledge alongside current information to make informed predictions concerning future events, such as the extent to which bacteria would be expected to row on agar plates with and without streptomycin. Similar questioning strategies were employed to promote students’ synthesizing of information, such as the results of laboratory experiments and computer-based modeling simulations (in NetLogo), to enhance their models of natural selection. In this manner, Ms. Jackson’s questioning helped to ensure that the learning that had occurred over a number of days did not remain as disparate events, and students were able to elaborate on and extend the ideas they encountered over the course of the unit.

Anticipating and responding to students’ alternative conceptions. Ms. Jackson also used responsive teaching to bolster understanding, often in response to students’ vocalization of alternative conceptions or in anticipation of them. For instance, one student aired a misconception by asking whether individuals of a species could control their adaptation, which Ms. Jackson used as an opportunity to clarify that natural selection occurs at the population level and thus, dispelled the misconception. Ms. Jackson also made it a point to address potential misconceptions before they arose, such as her assertion that the existence of variation in a population prior to an environmental change was crucial to natural selection as it enabled some individuals of a species to survive once the change occurred. Additionally, Ms. Jackson used whole class discussion to
elicit students’ perceptions of what had been learned on a given day before summarizing their ideas in a manner that tied the content that was covered to experiments the students had previously conducted. In doing so, Ms. Jackson was able to reinforce the concepts she had intended for students to grasp while serving to formatively assessing their understanding of them.

**Supporting students’ modeling competencies.** One of the main objectives of the ABR unit was for students to gain competence in the development, evaluation, and revision of models in order to explain and predict phenomena – in this case, natural selection through bacteria’s development of ABR. Ms. Jackson nurtured students’ development of modeling competencies by tasking students with representing phenomena using models, explaining their models to peers, evaluating and revising their models before using them to make predictions (Windschitl et al., 2012). Recognizing the value of modeling as an essential science practice, Ms. Jackson nurtured students’ development of modeling competencies by tasking students with representing phenomena using models, explaining their models to peers, evaluating and revising their models before using them to make predictions (Windschitl et al., 2012). She accomplished this by positioning students as valuable resources for one another when developing modeling competency and enabling those students to recognize that enhanced models result from the peer review process.

**Discussion**

Identifying, understanding, and improving effective, subject-specific teacher practices should enhance learning outcomes for all students (Ball & Forzani, 2009; Kennedy, 2005). Windschitl (2012), Kloser (2014) and others have begun to identify high-leverage teaching practices that are expected to enhance learning and achievement in the sciences specifically. With this study, we sought to further these efforts by building a better understanding of the practices an experienced teacher employs when enacting SSI-oriented instruction. Ms. Jackson engaged in
the science teaching practices deemed high-leverage in previous studies, as well as some that appear to be unique to the enactment of SSI-oriented instruction and have not yet been noted in the literature. In the discussion that follows, we seek to situate in the literature those science teaching practices that were essential to this enactment of SSI-oriented instruction. We conclude with a discussion of implications for implementing SSI instruction and directions for future research.

Core and Ambitious Science Practices Surface During SSI-oriented Instruction

Ms. Jackson’s successful enactment of SSI was facilitated by employing a number of science teaching practices previously deemed high-leverage in the literature. For example, Ms. Jackson built a safe, participatory classroom community - another science teaching practice that is essential to successful instruction in all learning contexts (Kloser, 2014). Yet, the nature of SSI instruction contributes to the complex, open-ended, and uncertain nature of discussion around issues that need to be resolved, which necessarily requires individuals be able to listen to one another’s potentially opposing perspectives and find some common ground of understanding (Owens, Sadler, & Zeidler, in press). Because SSI-oriented instruction necessitates active participation, collaboration, and discussion of contentious issues about which students are likely to disagree, the importance of this teaching practice to successful SSI instruction is magnified.

Additionally, Ms. Jackson continuously directed students’ understanding of natural selection and the underlying causal mechanism toward the phenomena surrounding bacteria’s development of resistance to antibiotics. This contextualization served as the substantive and engaging “big idea” around which learning was developed and “without which ambitious teaching could not be initiated” (Windshitl et al., 2012). Ms. Jackson maintained focus on this big idea by engaging students in constructing, interpreting, and refining models of natural selection, which she supported with investigations of bacterial development of ABR. The planning, enactment, and
analysis of these investigations provided Ms. Jackson with a number of opportunities to elicit her students’ thinking, assess it in the moment, and adapt her instruction to best suit their needs. It also often served as fodder for classroom discourse and reflection, which served to iteratively enhance the qualities of the students’ models of natural selection. As a result, we can say with confidence that an SSI approach includes and, in fact, requires the full gamut of science teaching practices that improve learning outcomes (Kloser, 2014; Windschitl et al, 2012; Wilson, Taylor, Kowalski, & Carlson, 2010).

Science Teaching Practices Unique to SSI-Oriented Instruction

Some of Ms. Jackson’s high-leverage teaching practices seemed especially essential given her engagement in SSI-oriented instruction. The science teaching practices described in the section below mirror essential practices previously described in the literature. However, successful SSI-oriented instruction requires an extension of those practices. Concerning the enactment of SSI-oriented instruction under study, natural selection and its explanatory model together served as the big idea through which Ms. Jackson engaged in ambitious science teaching (Windschitl et al., 2012). However, Ms. Jackson’s SSI-oriented instruction positioned natural selection as a means through which students could understand the sticky issue of bacteria’s development of ABR and develop the ability to reason through a promising resolution. In this case, Ms. Jackson was still responsible for fomenting student understanding of the concepts underlying natural selection, but her role was expanded to include helping students make sense of ABR as an issue and resolve it by addressing concerns of science and society, thus contributing to their development of functional scientific literacy.
Ms. Jackson’s contribution to the development of the community of learning by ensuring opportunities for students to receive both teacher and peer critique on their ideas is a practice known to enhance students’ engagement, attitude, and achievement and essential to any science-learning environment (Kloser, 2014). However, effectively communicating constructive criticism is especially important during the negotiation of SSI. In fact, the ability to communicate criticism of others’ positions regarding SSI in a way that is both respectful and constructive is requisite to informed participation in a democratic society.

Finally, Ms. Jackson made adjustments to the focal assignments that normally anchored each unit to ensure that students used science ideas and practices to create new products that connected the knowledge developed in class with the ABR issue (e.g., policy recommendations). Specifically, students were required to link the science concepts they were learning to their application – considered a core science teaching practice (Kloser, 2014). However, this practice is especially important when seeking to help students appropriately resolve SSI by synthesizing their understanding of science ideas and practices with a multiplicity of stakeholder perspectives. By ensuring that course products linked science ideas and practices with societal components of the issue, students are constantly involved in applying science concept knowledge and socio-scientific reasoning, toward the resolution of the SSI.

**Implications for Implementation**

Science teachers need to engage in high-leverage science teaching practices if student-learning outcomes are to be achieved (Grossman & McDonald, 2008). These results suggest that successful enactment of SSI instruction requires the core practices of ambitious science teaching, but necessarily includes additional practices that serve to enhance students’ ability to connect
science learning to contentious issues about which they must make informed decisions. SSI instruction extends the invitation for participation in civil discourse and democracy by contextualizing the science being learned not just in phenomena, but also in the current issues to which an understanding of those phenomena contributes and about which students are already likely to have an opinion. In doing so, SSI-oriented instruction aids students in their development of skills, such as employing skepticism and understanding issues from multiple perspectives – skills that contribute to their participation in the scientific enterprise and informed and active citizenship.

While the core and ambitious science teacher practices identified by Kloser, Windschitl, and others are certainly reflective of good science instruction, they do not include all of the practices necessary for good SSI teaching. For example, even great practitioners often present science as unproblematic and prefer to dispense established and secure knowledge while avoiding the controversial or ethical topics that are requisite to the preparation of a new generation of informed citizens while remaining hesitant to reveal their own values or ethical perspectives (Cross & Price, 1996; Hodson, 2003). Yet, by excluding the controversial and ethical aspects of SSI from their instruction in the safety of their classroom communities, teachers leave students to their own devices to integrate their value-free understanding of science into the negotiation of value-laden issues (Allchin, 1999). Moving forward, research directed at better understanding how ‘ideal’ SSI instruction can be achieved and identifying the teacher practices requisite to doing so is certainly warranted. We remain focused on better understanding how teachers can best balance science and society in the classroom so as to manage safe, effective learning environments where touchy subjects are touched on.
References


APPENDIX A

Know Your Sources of Information

Consider your sources as you collect information regarding any difficult issues, especially issues that involve science.

With modern technologies, it is possible to find information on virtually any topic, but the quality and usefulness of the information to which you have access will vary. It is critical that you pay attention to where information is coming from, who is behind the information (their credibility, expertise, biases, etc.), and what you can and/or should do with that information. There is no single method for documenting the credibility and reliability of information and information sources, but here are some suggested questions to explore in your analysis of any information source. Keep in mind that not all of these questions will be pertinent for all information sources.

1. Who is (or what organization or company) presenting the information?

2. What is the purpose of the publication?

3. What expertise and/or relevant experience does the author (or organization or company) have?

4. What biases does the author (or organization or company) have and how might those biases affect the presentation of information?

5. Does the information presented seem to be accurately reported? Are the claims made in the presentation supported? Do any facts or analyses seem to be distorted?

6. Does the presentation leave important information out? Does the presentation offer information that is unnecessary (particularly if the extra information distorts the message)?