A Teacher-Researcher Collaboration
For SSI-Based Teaching and Learning

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By the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their own lives, and to continue to learn about science throughout their lives” (Schweingruber, Keller, & Quinn, 2012, p. 9)

This vision for K-12 science education is set forth in A Framework for K-12 Science Education (Schweingruber et al., 2012). The Next Generation Science Standards (NGSS) articulates this vision in the form of student performance expectations (Next Generation Science Standards: For States, By States, 2013). NGSS represents major conceptual shifts from earlier science reform documents (e.g., National Science Education Standards); those shifts include a “focus on deeper understanding of content as well as application of content” (p. 2) and “to prepare students for college, careers, and citizenship” (p. 3).

The science education community has much to learn about how to reform teaching and assessment such that the vision of NGSS can be realized. One point that is immediately evident from an examination of the new standards is that students will require rich learning contexts that afford opportunities for building deep understandings of important science ideas and for engaging in a range of sophisticated science practices (Quinn, Lee, & Valdés, 2012). Issues that emerge from the intersections of science and society, that is socio-scientific issues (SSI), can provide exactly the kinds of rich contexts that challenge learners to make sense of complex phenomena, collect and/or analyze scientific data, exercise scientific practices, and connect experiences from school science to their lived experiences (Zeidler, 2014). While the SSI approach to teaching science has potential for promoting NGSS-aligned learning, unanswered questions remain concerning how to support widespread implementation of SSI-based education.

Hofstein, Eilks, and Bybee (2011) highlight some of these questions in their call for science educators to “more thoroughly consider societal desiderata in science education which are (a) to develop curricula and teaching materials that focus the learning about dealing with societal issues related to science and technology, (b) to develop appropriate assessments to appraise students’ attainment of the objectives of these approaches, (c) to better educate teachers in a way that enable them to implement these materials and assessments effectively, and (d) to find ways of providing rewards for teachers and students who are successful in attaining the goals of socio-scientific issues-based science education” (p. 1478). This case study addresses the call by examining a teacher-researcher collaboration in which we designed and implemented an SSI-based curriculum unit using the issue of antibiotic resistance (ABR) to address the NGSS evolution standards.

**Conceptual Framework**

The conceptual framework underlying our work is based on an emergent framework for SSI-based education. In the book, Socio-scientific issues in the classroom: Teaching, learning, and research, Sadler (2011a) analyzed a collection of nine SSI studies, and inductively derived a framework for designing and implementing SSI-based instruction (Sadler, 2011b). The initial
A TEACHER-RESEARCHER COLLABORATION

The framework consisted of four primary aspects: design elements, learner experiences, classroom environment, and teacher attributes. In the initial version of the framework, the design elements and learner elements are located in the center of the framework, denoting their position as fundamental, core dimensions of SSI-based instruction. Design elements are elements that need to be included in a SSI-based unit and are divided into essential and recommended elements of curriculum design. The essential design elements are: “1) Build instruction around a compelling issue; 2) Present the issue first; 3) Provide scaffolding for higher-order practices (e.g., argumentation, reasoning and decision-making; and 4) Provide a culminating experience (Sadler, 2011b, p. 363). The recommended design elements include: “5) Use media to connect classroom activities to the ‘real world; and 6) Use technology to facilitate student learning experience” (p. 363).

The learner experiences include higher-order practices such as reasoning, argumentation, decision making or position taking. Learning experiences are sub-divided into essential and recommended experiences. The essential learning experiences include:

1. Engage in reasoning, argumentation, decision-making and/or position taking.
2. Confront the scientific ideas and theories related to the issue being considered.
3. Collect and/or analyze scientific data related to the issue being considered.
4. Negotiate the social dimensions of the issue being considered. (p. 365)

The recommended learning experiences include: “5) Confront the ethical dimensions of the issue being considered; and 6) Consider nature of science themes associated with the issue” (p. 365).

The remaining two elements of the framework, classroom environment and teacher attributes are located in the outer circle of the framework, denoting their role in supporting SSI-based instruction. The essential classroom environment features are: “1) High expectations for student participation. 2) Collaborative and interactive. 3) Students and teachers demonstrate respect for one another, and 4) Students and teachers feel safe within the environment” (p. 366).

Four essential teacher attributes are identified in the framework:

1. Familiar with issues being considered.
   a. Knowledgeable about science content related to the issue.
   b. Aware of the social considerations associated with the issue.
2. Honest about knowledge limitations.
3. Willing to deal with uncertainties in the classroom.
4. Willing to position self as a knowledge contributor rather than the sole authority. (p. 367)

Sadler and colleagues revised the emergent instructional framework, making two substantial changes (Presley et al., 2013). The first change is that Teacher Attributes is moved from its initial supporting, peripheral role to become one of three core aspects of the SSI-based instructional framework. In the revised model, Teacher Attributes, Design Elements, and Learner Experiences comprise the central core of the framework, indicating fundamental components of SSI-based instruction (See Figure 1). The Teacher Attributes features remain the same, with some re-grouping: “honest about knowledge limitations” and “willingness to position self as a knowledge contributor rather than sole authority” are re-grouped under “Teacher as Learner” (Presley et al., 2013, p. 29). The individual features of the Design Elements and Learner Experiences remain consistent in both versions of the model. The Classroom Environment is retained as an element surrounding the central core, and its four elements remain the same. The Classroom Environment is positioned in the framework to indicate that it significantly influences
the three core aspects of the framework. The second change is the addition of an outer ring, *Peripheral Influences*, indicating factors that significantly influence the *Classroom Environment*, as well as the core aspects of *Design Elements*, *Learning Experiences*, and *Teacher Attributes*. The *Peripheral Influences* includes six essential features:

1. Support and encouragement for teachers implementing SSI-based instruction.
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. (Presley et al., 2013, p. 30)

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   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.
   c. Willing to deal with uncertainties in the classroom.

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 instruction.
   f. Connections between SSI-based curricula and state- and national-level curriculum objectives.

Figure 1. Framework for SSI-Based Instruction.

Sadler (2011b) and Presley et al. (2013) call for research exploring the use of the emergent SSI-based instructional framework. In this study, we use the framework to analyze a successful university-school partnership in which we collaborated with a high school teacher to design and teach an SSI-based unit. In this study, we describe how we addressed the core design elements of the framework in our curriculum unit, a tension we encountered during the planning process, and the peripheral influences that supported our work.

Literature Review

In the first section, we review the literature on selecting an issue in SSI-based instruction. In the second section, we review the specific issue of ABR and studies related to teaching ABR to high school students.

Selecting an Issue

One feature of SSI instruction is that it provides “a relevant and meaningful context for probing students’ moral and ethical beliefs on controversial issues while guiding them to become tolerant and open to conflicting opinions and perspectives” (Zeidler & Kahn, 2014, p. 4) Selecting a compelling issue for the context is a critical component of the SSI teaching model framework and is generally considered the starting point for designing SSI instruction; however, little has been written about challenges associated with selecting a compelling issue.

Eilks (2002) described a secondary chemistry unit on biodiesel, and discussed the need for the issue to be personally relevant to the students. Sadler (2004) stated, “the most fruitful
interventions would be those which encourage personal connections between students and the issues discussed, . . .” (p. 523). Zeidler and Kahn (2014) advise teachers that the issue needs to be relevant and interesting to students and the curriculum. Sadler (2011b) elaborates on selecting a SSI: (1) the issue must be relevant and interesting to students, (2) the issue must have connections to science, and (3) it is helpful if students can explore ethical tensions within the SSI.

Marks and Eilks (2009), using a sociocritical and problem-based approach to teaching chemistry, offer more specific criteria to teachers for selecting issues: authenticity, relevance, socio-scientific uncertainty or controversy, allows for open discussion, and deals with questions from science and technology. Authenticity is judged by whether or not the selected issue is present in contemporary media sources. “Only issues allowing authentic differences in opinion which have been expressed in public debate by different stakeholders or pressure groups are chosen” (p. 234). Although relevance of the issue is critical to the success of an SSI unit, Hofstein et al. (2011) caution that relevance is a subjective judgment. Teachers may view an issue as relevant to students, but students may not see the same relevance. Van Aalsvoort (2004) identified four different uses of the term relevance in the chemistry education literature: personal relevance, professional relevance, social relevance, and personal/social relevance. Personal relevance refers to making a connection to students’ lives, while professional relevance refers to possible science-related career choices. Social relevance refers to the goal of “clarifying chemistry’s purpose in human and social issues” (p. 1152), while personal/social relevance refers to helping students develop into responsible citizens.

In summary, building instruction around a compelling issue is the first required design element of SSI-based instruction (Presley et al., 2013). General guidelines have been offered in the literature. The issue should be relevant to students, authentic, open to multiple perspectives, allow for open discussion, and align with concepts in the science curriculum. However, researchers have not problematized the inherent challenges association with issue selection including examining of where tensions exist for teachers in selecting a compelling issue to teach specific science content.

**Antibiotic Resistance**

ABR is becoming a pandemic public health issue due to regular use and misuse of antibiotics, with an estimated 23,000 deaths per 2 million infections in the United States annually (Centers for Disease Control and Prevention, 2013). A representative example of ABR is MRSA (methicillin-resistant *Staphylococcus aureus*, a common source of severe infections in the community and in hospitals), where people infected are estimated to be 64% more likely to die than those with a non-resistant form of the infection (World Health Organization, 2014). Beyond the public health concern, there is tremendous economic cost associated with ABR. In the United States, it is responsible for $20 billion in excess health care, $35 billion in societal costs, and 8 million additional hospital days per year (Bush et al., 2011).

Bacteria can develop antibiotic resistance through mutations and they can also acquire resistance by lateral gene transfer. There are three mechanisms of lateral gene transfer: transformation, conjugation, and transduction. Transformation involves the uptake of short pieces of naked DNA. In conjugation, bacteria make contact and exchange DNA via sexual pilus. In transduction, bacteriophages transfer DNA from one bacterium to another (http://amrls.cvm.msu.edu). Transduction is an important mechanism of microbial antibiotic
resistance. The spread of Methicillin-resistant *Staphylococcus aureus* (MRSA) has been attributed to transduction (Barlow, 2009).

Educators have responded to this pandemic through the design of ABR curriculum. In 2006, the European Commission funded the initial development of a large-scale project, e-Bug: “the aim of e-Bug is to increase young people’s understanding, through enjoyable activities, of why is so important to use antibiotics correctly in order to control ABR, and to have good hand and respiratory hygiene to help reduce the spread of infection” (McNulty et al., 2011, p. v3). The project is now led by Public Health England’s Primary Care Unit, and involves a consortium of 28 international partner countries (http://e-bug.eu/partners/index.html). Evaluation studies have shown the lessons are effective in teaching students about the spread of infections on farm visits (Hawking, Lecky, Verlander, & McNulty, 2013), the effectiveness of web games in teaching about microbes and antibiotics (Farrell et al., 2011), and the implementation of the curricular materials in various countries, e.g., Denmark (Holt & Jensen, 2011). However, e-Bug focuses on the message of overuse of antibiotics and was not designed to teach the concept of natural selection.

In another project, Fonseca, Santos, Costa, Lencastre, and Tavares (2012) described a one-week, hands-on summer program, *Microbiology recipes: antibiotics á la carte*, taught to 15-17 year olds. The students self-selected to enroll in the program, and had completed a high school biology course prior to enrollment. They reported significant pre-/post-test differences for every question in the questionnaire ($p<0.05$), although there were no questions specifically related to natural selection. The authors reported that the program was successful as a summer enrichment program for high school students who had completed a year of biology, but stated the need to implement the unit in a high school classroom setting. They did note, at the end of the program, some confusion remained among the students regarding differences between horizontal and vertical gene transfer. Wassmer, Kipe-Nolt, and Chayko (2006) described a hands-on simulation for demonstrating the spread of ABR in four different treatment regimes, but do not make connections to natural selection in the lesson. In our review of the literature, we found examples of ABR curricula, although none of the curricula was designed to specifically teach natural selection. In this study, we explore ABR as an issue to teach natural selection to high school biology students.

**Purpose**

In this descriptive case study, we examine our collaborative efforts to design and implement a SSI-based curriculum unit using the issue of ABR to meet the NGSS evolution standards. In the first research question, we examine the design of our curriculum unit and how we addressed the design elements called for in the SSI instructional framework. In this study, we apply the framework in a practice setting (i.e., a 10th grade Honors Biology classroom) and examine the ways in which we were able to address the design elements proposed in the framework. The second research question examines tensions encountered during the design process, while the third research question explores peripheral influences foundational to the implementation of the curriculum unit. The SSI instructional framework offers a list of peripheral influences; in this study, we inductively explore peripheral influences specific to our school context that supported our implementation of the curriculum unit. This research question offers an opportunity to expand the list of potential peripheral influences and explore the nuances of identified influences. The research questions are:
1) In designing an antibiotic resistance curriculum unit, in what ways did we address the design elements of the SSI-based instructional framework?
2) What tensions were encountered during the design process?
3) What peripheral influences supported implementation of the SSI-based curriculum unit?

**Methods**

Yin (1994) describes a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p 13). In this descriptive case study, we studied the phenomenon of planning and implementing an SSI-based curriculum unit in the real-life context of a school in the process of implementing NGSS. The case (or unit of analysis) is defined as a yearlong collaboration between two university researchers and a secondary biology teacher as they planned and implemented an SSI-based curriculum unit aligned with NGSS. The planning process began in the fall of 2013 and the unit was taught in the spring of 2014. Trustworthiness of the case study was addressed through multiple data sources, confirming findings across these data sources, extended time in the field, and member checking.

**Participants**

The participants included two university researchers and an experienced secondary biology teacher. The first author, Pat, researches teacher learning and evolution education, and the second author, Troy, researches SSI-based approaches to teaching science. The experienced teacher, Kerri, has received numerous teaching awards, She is recognized as a leader in her school building, and has served on the school’s Executive Council, an elected position. The first author had worked previously with Kerri in our university’s teacher education program, as Kerri frequently served as a mentor teacher for pre-service teachers. (The fourth author is a pre-service teacher who supported data analysis processes.) In addition to the participants described above, we collaborated with a microbiologist who designed an ABR lab for the curriculum unit.

During the 2013 – 2014 school year, the high school’s Biology Professional Learning Community (PLC) was in the process of redesigning their curriculum to meet NGSS. In the fall of 2013, Pat and Troy invited Kerri to collaborate on the planning and teaching of an SSI unit aligned with NGSS. The unit was designed during the fall and winter of 2013-2014. While Kerri was teaching the unit in the spring of 2014, Pat and Troy were primarily participant observers in her classroom; although, they assisted during the lab exercise and Pat led the class one day when Kerri was absent.

**Data Sources**

From August 2014 – March 2015, the team met approximately every two weeks for 1-hour planning meetings. These meetings were audiotaped and transcribed verbatim. The transcripts of the planning meetings were the primary data source for this study. Secondary data sources included researchers’ journals, emails, the curriculum unit, classroom artifacts associated with the unit, and classroom video of the unit being taught.

**Data Analysis**

The first and fourth authors coded the interview transcripts using NVivo 10.2 for Mac. The first round of coding used deductive codes from the SSI instruction framework (Presley et al., 2013) which aligned with our research questions. Initial codes included: design elements; compelling issue; higher order practices and scaffolds: argumentation and explanation, and modeling; and peripheral influences. In the second round of coding, an inductive content analysis
was employed with codes emerging from the data. For example, in the original code, compelling issue, the following inductive codes emerged: exploring other issues, high student interest, implementation in the unit, need to follow-up in the unit, and problems with ABR. For peripheral influences, the following codes were created: meeting NGSS, nature of collaboration, and the PLC.

School Context

The study took place in a public high school located in a Midwestern city with a population of approximately 100,000. During the 2013-14 school year the student population was approximately 2000 students in grades 9-12, with 17% qualifying for free or reduced lunch. The student population was 75% Caucasians, 11% African Americans, 6% Asian, 5% Multiple, 3% Hispanics, and less than 1% Native Americans. The school’s average ACT composite score was 24.4 in comparison to the state average of 22.4. The four-year graduation rate was 95% with 75% of the graduating seniors stating their intention to go to a 4-year college.

Findings

The findings are organized around the three research questions. The first section addresses how we attended to the required design elements, while the second section explores a tension that arose in designing and teaching the ABR unit. The final section explores peripheral influences that supported the implementation of the unit.

Required Design Elements: The Antibiotic Resistance Unit

The SSI instructional framework identifies four required design elements: building instruction around a compelling issue, presenting the issue first, providing scaffolding for higher-order practices, and providing a culminating experience. In this section, we describe how we addressed each of these required design elements.

Building a unit around a compelling issue: selecting the issue. In the first planning session with Kerri, we explored potential topics for the new curriculum unit. The Honors Biology PLC had not yet revised their last two units of the school year, evolution and ecology. Pat was involved in co-teaching a new undergraduate evolution course, and was dissatisfied that the course had not included the contemporary issue of ABR. Based on the team’s content expertise and interest, we decided to design a curriculum unit to address the NGSS evolution standards and Pat suggested ABR as the compelling issue. The team briefly explored the possibility of other issues, including extinction and herbicide resistance. In an earlier planning meeting, Pat explored an extinction-related issue:

Then the issue really being, ‘Should we invest all of these resources to save the black footed ferret and should, if we have mammoth DNA, should we being trying to construct [mammoths]?’ So for me, I got to thinking, ‘Okay that's a really interesting SSI for me because there isn't a clear answer for me about should we being doing these things or not.’ (Planning Meeting (PM) 9-19-2014)

The current Honors Biology curriculum did not have a strong emphasis on macro-evolution. Kerri stated, “When it [macro-evolution] is touched on, I don't feel like it's taught well to connect it, then to me it's just like looking at history and finding the trends in history and ‘What does this in a predictive way, what does this mean for us?’” (PM 1-19-2014). Using extinction as an issue required that the unit be expanded beyond the concept of natural selection. Based on Kerri’s preference and past curriculum, we decided to divide micro- and macro-evolution into two smaller units, focusing our work on micro-evolution and the mechanism of natural selection. For
our first collaboration we wanted to keep the curriculum unit manageable in scope, so the idea of exploring extinction-related issues was quickly discarded.

The team also explored the issue of herbicide resistance but expressed concerns about that issue generating widespread student interest. Kerri stated, “I'll have three students that are ag-based that would, you know, I had one student yesterday that was like ‘Yes! It's raining!’ And everybody else was like ‘No!’ and she said, ‘No, my dad needs rain, he's a farmer. This is a good thing.’ But that was one student of my seventy-five kids that day” (PM 1-19-2014). Based on the suburban nature of the student population, the team discarded the idea of using herbicide resistance as an organizing issue for the unit.

The team quickly settled on the issue of ABR for several reasons. First, ABR was seen as relevant and interesting to students. In the first planning meeting, Troy stated:

Everyone's been sick. The idea of probably everyone in your class has taken antibiotics. I mean the idea that there's this disease that was curable back when you were a baby and yet now, even in your lifetime, we're really scared that we're not going to be able to control that. I think that has the potential to really grab some attention and interest in ways that might be more powerful than the farm situation. (PM 1-19-2014)

The issue was also seen as being open enough in regard to societal concerns. Troy stated, “I do think . . . there could potentially be some interesting conversations about kind of individual rights and choices and healthcare decisions relative to kind of large scale calculations of societal good. And so, for me, that's where there could be some of that kind of interesting SSI stuff” (PM 9/19/2014). This issue would also limit the scope of the evolution unit, focusing on micro-evolution and the mechanism of natural selection. The specific example of MRSA emerged as we designed the first lesson of the unit.

Presenting the issue first. We used the beginning of the Front Line video, “Hunting the Nightmare Bacteria,” to introduce the MRSA issue (http://www.pbs.org/wgbh/pages/frontline/health-science-technology/hunting-the-nightmare-bacteria/meet-the-nightmare-bacteria/) (See Table 1 of the Unit Overview). The first segment of the program introduces the problem of ABR and shows the story of an 11-year old girl, Addie, who contracts community-associated MRSA and dies from the infection. Addie’s mother is a nurse and chronicles Addie’s illness. The students were interested in the video, particularly Addie’s story and asked questions after the video (PF Field notes, 3-05-14). The next day Kerri asked students to share their reactions to the video; one student stated, “It’s frightening that it passes along to people so easily just by touching people or touching the same doorknob” (Class Video Day 2 HDV_0114 2:00-3:18).

After the video, students explored a set of web resources to learn more about MRSA (see Appendix A). The instructional resources included two personal accounts of MRSA, a popular media account, and a medical website with pictures and descriptions of MRSA. We used this media-rich context to teach about MRSA, and in doing so, we addressed the recommended design element of “using media to connect classroom activities to the ‘real world’” (Presley et al., 2013, p. 30). When Kerri asked the student to summarize some things they learned from the resources, one student stated, “I was just going to say it’s like funny because the preventative measures you can take is basically good hygiene. Wash your hands thoroughly with soap and water” (Class Video, Day 2 HDV_0119 1:36-2:05).

Providing scaffolding for higher-order practices. In the curriculum unit, we chose to focus on the following high-order practices of modeling. (see Table 1 for specific student
learning goals related to each practice). We designed several scaffolds to support each practice; however, in this paper we limit the discussion to two scaffolds to support the modeling practice.

We introduced students to the idea of varying biological levels of organization (population, organismal, and molecular levels). This “Levels of Organization” scaffold was designed to help students model the phenomenon they were observing in the ABR laboratory investigation and to think about how mechanisms were connected across population, cellular and molecular levels (see Appendix B). In the lab, students grew *Bacillus megaterium* on two Luria Broth (LB) plates, one with the antibiotic streptomycin and one without. In the first set of plates, there was little ABR in the bacterial population. After the lab, the students drew an initial model (see Figure 1). This sample of student work illustrates that while the students observed the phenomenon of bacteria growing on the control plate (LB) and no or little growth on the streptomycin (strep) plate, they didn’t understand what was happening at the population, individual and molecular level. In Figure 1, the student draws a smaller bacterium on the strep plate and a larger individual bacterium on the LB plate. After viewing the students’ initial models, we explained how bacteria reproduce and helped students distinguish between individual bacteria and colonies.

The bacterial culture was sub-cultured and grew several days before the students inoculated a second set of plates (LB and LB/Strep). In the LB/Strep plate, the number of colonies increased in comparison to the first set of plates. To help students understand what was happening on the cellular level, we gave a brief explanation of different mechanisms of ABR, focusing on efflux pumps and a mutation that changes the ribosomal shape so that streptomycin cannot attach to its target. The students revised their models to incorporate this additional information. The student model presented in Figure 2 demonstrates an understanding of what is happening on the population and individual level, with an understanding of some of the ABR mechanisms at the cellular level. However, at this stage of the modeling, students tended to leave the molecular level blank and did not identify the source of variation in the population.

Based on version 2 of the students’ models, we gave a short explanation of how new mutations can arise in individuals. The students had already completed units on protein synthesis and genetics, so the information on mutations was a review for them. For this part of the explanation, we restricted our discussion to vertical gene transfer with surviving bacteria reproducing and passing on their mutation to the next generation. Figure 3 shows the third version of a student’s model. In this version, the student demonstrates an understanding of all three levels of the phenomenon of ABR: the population, individual and molecular.

Our second scaffold was developed to help students use a NetLogo model to further develop their understandings of natural selection. After the students experienced the phenomenon of ABR in the bacteria lab, they used the NetLogo model, Bacteria Food Hunt (Novak & Wilensky, 2013). The NetLogo model does not demonstrate ABR; however, we chose this particular NetLogo model because it used the same type of organism, bacteria, to teach the concepts of natural selection and trade-offs (see Figure 4). In the model, individual bacteria varied in the number of flagella, ranging from 1-6 flagella. Students could vary the amount and distribution of the food and watch how frequencies of bacterial flagella number shifted over time. (See Appendix C for the NetLogo Bacteria Food Hunt Worksheet.)
In the worksheet, we highlighted aspects of natural selection. We had students observe the initial variation in the population; next, we asked students to use the trace path feature to observe movement of the bacteria. From this observation, students were able to see the connection between the number of flagella and the speed of a bacterium. Students were asked to set up different conditions in which they changed environmental pressures (i.e., food amount and distribution) and observed the effect on the bacteria population over time. The worksheet also provided information about asexual bacteria reproduction so that they could infer heritability of the flagella number. In addition, students were given an optional challenge of developing their own question and collecting data. While the students were working with the NetLogo model, one male student said to his friend, “That was awfully fun. I don’t now if anyone ever had this much fun playing with virtual bacteria” (PF Field notes 3/17/2014). Through the use of the NetLogo Model and class discussions, the teacher helped students develop an understanding of natural selection including variation in a population, environmental pressures, differential survival and reproduction, and resulting shifts in the frequency of alleles in the population.

Providing a culminating experience. For the culminating experience, the students wrote individual papers in which they made a specific policy recommendation to address the issue of ABR. Students designated if the policy would be applied at the local, state, national or international level. (See Appendix D for the Culminating Project Student Assignment Sheet.) As part of the paper, students analyzed the potential benefits and disadvantages of their policy. They also identified who would likely support their proposed policy and who would likely oppose it. Students needed to use scientific evidence to support their proposed policy, and explain why their proposal had not been implemented in the past. In small groups of four, the students shared their papers and engaged in peer review. The students were given the opportunity to revise their papers based on peer feedback.
Design Tension: Compelling Issue Versus Teaching Natural Selection

After we selected the issue of ABR to teach natural selection, we began to experience tension between two required design elements in the SSI instructional framework —using a compelling issue and having students confront scientific ideas and theories related to the issue. We describe this tension in the following phases: (1) complexity of the biology becomes problematic, (2) negotiation of the tension among collaborators, and (3) resolution of the tension.

Complexity of the biology becomes problematic. As we explored the complexity of the biology of ABR, we struggled to select a specific case of ABR to highlight in the unit:

Troy: Yeah, the challenge is, I mean when you get into the specifics of any real case-
Kerri: It's so complex.
Troy: The complexities multiply.
Kerri: Exactly. . .
Pat: For the mechanisms to be simple enough. . . . Looking at a really common example. Looking at a simple example. I'm trying to think about what my criteria is going to be for choosing [a specific antibiotic resistant bacteria].
Troy: I mean it seems to me that the mechanism, a relatively simple mechanism, but one that we can help the kids explore enough that it's not a total black box that we can actually connect it to some biological processes that they can make sense of.
Pat: And I think it has to be a fairly common example. . . . not some obscure thing that no one's ever heard about. (PM 10/02/2013)

As we explored the biology of ABR, we wanted to select a specific example that was fairly common in the media, yet had a simple mechanism of ABR that the students could understand. Because the students had some background cell knowledge, we wanted to show how antibiotics worked on the cellular level. Kerri stated, “I think it would be doing them a disservice if we didn't go into how do some of these antibiotics kill the bacteria” (PM 9/26/2013).

We also struggled with whether or not we should include lateral gene transfer, which makes the spread of ABR much greater than what would happen with natural selection alone. In team planning meetings, we discussed whether or not to include lateral gene transfer as part of the unit.

Pat: We haven't talked about lateral gene transfer. Are we going to?
Kerri: Yeah. A question for me was to whether we were going to introduce some of those ideas to help explain why they evolve even quicker besides the fact that they reproduce fast. And I think this is probably why people don't use antibiotic resistance. But I think it's so cool. I think-
Pat: And I don't think it's a hard idea that you could transfer that mutation to another bacterium.
Kerri: Mmm
Pat: And that would spread within the population.
Kerri: So I do have and traditionally we've done bacterial transformation showing a plasmid and doing transformation in that way. I've never gone into the ideas of conjugation and transduction with my sophomores. But yet I don't know if we're doing it in the context of this, it might be appropriate to do that. I don't know. It might be just really confusing the issue. (PM 9/26/2013)
As a team, we continued to struggle with the complexity of ABR and how much of the science content we should include in the unit. The following week, we continued our discussions:

Pat: But that's [mutations] an explanation for a very small percent of, if you're looking at how does this happen right now and it's lateral-

Kerri: Lateral gene transfer

Pat: It's giving these mutated genes from other bacteria in it and so how do like-

Troy: And it's all lateral gene transfer.

Pat: Okay so . . . conjugation taking up other plasmids with the resistant gene

Kerri: Mmhmm.

Pat: Taking up naked DNA that has a mutation, viruses transferring that to them and then just conjugation.

Kerri: That one's a hard concept.

Pat: So it's not clear to me, I don't have a recommendation for how deep we go . . . So part of me thinks that we're not telling, if we say that mutations . . . that doesn't really explain why this is such a big problem. And so introducing this idea of once we get a successful mutation product in a bacteria, they are really successful at transferring that among themselves. (PM 10/2/2013)

Troy and Pat viewed lateral gene transfer as an important part of the real story of ABR, but including it in the curriculum unit complicated the natural selection story.

Troy and Pat met with the microbiologist who was helping with the ABR laboratory investigation in our unit. When we discussed wanting to avoid introducing lateral gene transfer, the microbiologist suggested using a historical case of ABR in which plasmids were not involved. During a planning meeting with Kerry, Troy reflected on the earlier meeting with the microbiologist:

Troy: And you know she [microbiologist] has some really good ideas but the more we talk about the labs that we could use and the specific bacterial examples and things like that we would have to use a historic case unless we were just making up stuff [to avoid discussing plasmids and lateral gene transfer].

Kerri: Right, right.

Troy: Which doesn't make much sense in a science class. We really would have to go to a historic case to do some of this which kind of -

Pat: And a very specific bacterium that doesn't have plasmids.

Troy: Right, which challenged the whole underpinning notion of the SSI thing, trying to and I'm not saying that a case-based approach is not -

Kerri: Mmhmm

Troy: A historical case-based approach could work.

Kerri: Right, exactly

Troy: But that wasn't what we were really trying to do and then it kind of calls into question the whole piece that we were talking about in terms of the culminating activity and the contemporary stuff because the contemporary stuff is really not based on the parts of the natural selection stuff, the ideas that we want to motivate.

Kerri: Right.

Pat: To me it's [ABR] a really great elaboration [referring to 5E model].

Troy: Yeah, once the kids really have a good understanding of natural selection.
Troy was dissatisfied with the idea of using a historical case study of ABR in which the ABR gene was located on the bacterial chromosome, but recognized the challenges of using ABR as a vehicle for teaching natural selection.

**Negotiation of the tension among collaborators.** Troy and Pat discussed abandoning ABR and the SSI approach for a simpler example of natural selection. When we met with Kerri, Troy reflected on the meeting with the microbiologist, “It just, we just got to a place where we said, ‘You know we don't think this really makes sense and this is probably not in the best interest of the students and if that's the case we need to recalibrate that. That just doesn't make sense [to use a historical case]’” (PM 11/07/2014). If we didn’t use a contemporary example of antibiotic ABR, Troy did not want to use ABR as the compelling issue. He began to question whether ABR was an appropriate issue to teach natural selection.

When Troy and Pat talked to Kerri about giving up the idea of using ABR as the issue which would mean abandoning the SSI approach. However, Kerri us to continue planning the unit around this issue. Kerri explained her position:

I think here's the thing, why I was really excited about it [ABR unit]. . . I look at the way we do school right now and don’t really love how we're doing school right now. Just as a whole. Right? And so walking down the hallways last year as a mentor, seeing kids sitting in their desks drooling as they're watching. There's got to be a better way to do it. And some of this [SSI]. . . [is] trying to find things that light kids up so that they love learning. And so I don't have all the answers for it, nobody does, right? But how can we do this? And so that’s where I feel like the SSI was like a small nugget of how can we make this a societal something that and it wouldn’t interest all of my kids, right? Because some are going to get more jazzed than others but how can we make something that at least a good handful of them will go, ‘Ooh, this means something to me. I can see the immediate effects of something like this. I can see.’ And then to have them think about it with themselves but then to extend beyond themselves in the ‘What does this mean for us in society?’ And so that's what was exciting to me about it, I see all of these possibilities and I am very much a ‘let's go, let's try, let's do’ type of person. . . And so I've been looking and this was a great vehicle for me to do this little bit of a nugget of ‘Oh, what could this look like?’ in a scientific classroom? And so that is what really excited me about that. (PM 11/14/2-14)

Kerri focused on the positive aspects of using ABR as a compelling issue for our unit. She was dissatisfied with current schooling practices. She wanted school to be more relevant to her students. She saw ABR as an issue that would be relevant to her students and excite them about learning. Once Kerri expressed that her motivation for collaborating with us was because she saw the issue of ABR as a way to make school more relevant to her students, we decided to continue planning the unit around ABR.

As part of the negotiation process, we decided that we would need to spend time talking about lateral gene transfer and some of the mechanisms of ABR.

Troy: Is it okay that the replacement unit focuses on natural selection but also focuses on some other things that might ultimately be at the expense of some elements of natural selection frankly? Because it requires us to spend some time for the students to spend precious time thinking about some elements of biotechnology

Kerri: Mmhmm.
Troy: And some elements of cellular biology and microbiology. In ways that we take that time; whereas, if we were just dealing with you know finches then we wouldn’t have to do that. (PM 11/14/2013)

Kerri did not see it as a problem that we would need additional class time to include information about mechanisms of ABR and lateral gene transfer. Once we made a decision to continue with the issue of ABR, we moved to a resolution phase.

**Resolution.** We decided to resolve the tension by telling the ABR story in two parts. For the majority of the unit, we would develop only the natural selection story. In the bacterial lab, we would focus on the idea that, over the course of several days, some of the bacteria in the culture tube mutated. The bacteria with favorable mutations that made them resistant to streptomycin would survive on the LB/streptomycin plate. The resistant bacteria would reproduce, resulting in visible colonies the students could see growing on the LP/streptomycin plate. Pat summarizes the negotiated plan:

So I wasn't ready to throw away antibiotic resistance after talking with [the microbiologist]. But I realized that it would be a modification of it. So here's MRSA, let's learn about how [natural] selection works using bacteria that doesn’t have a plasmid and they [the students] get the natural selection part and then can we come back in and layer, it actually spreads even faster than that because of lateral gene transfer. (PM 11/14/2014)

After the bacteria lab, we continued to focus on the natural selection story as the students used the NetLogo Model, Bacteria Food Hunt. After the students completed both the bacteria lab and the NetLogo Model, we reviewed Darwin’s postulates for natural selection.

At the very end of the unit, Kerri used a few PPT slides to give a short explanation of lateral gene transfer. Kerri was in favor of waiting to tell the second part of the story (i.e., lateral gene transfer) until the very end of the unit. She explained her position:

Kerri: They're [her students] used to me lying to them.

Troy: No, I didn't mean that.

Kerri: No, no, I do. I mean they get to be seniors [in AP Biology] and I'm like ‘I lied to you here when you were sophomores, sort of.’

Pat: Oh you don’t even tell them the year that you lied?

Kerri: No, well I do sometimes, like sometimes certain ones I'm like, ‘I lied to you here and I lied to you here. Get used to it.’ And then when there are other little pieces I'm like, ‘You just weren't ready to handle the truth and so now I'm telling you the full truth. I showed you the partial truth the first time around.’ (PM 9_26_2014)

Because Kerri was comfortable with this approach, we resolved the tension by revealing the story in two parts. During the unit, we focused on the natural selection aspect of ABR. At the end of the unit, Kerri gave a short presentation on lateral gene transfer to explain how ABR can spread within a population in the same generation.

**Peripheral Influences**

In this section, we describe peripheral influences that supported the implementation of the SSI-based curriculum unit. These peripheral influences were foundational in supporting our collaboration; they included: a supportive professional learning community, curriculum revision to meet NGSS, and the Biology PLC’s history of focusing on skills and content.

**Supportive professional learning community.** Teachers in the high school in which Kerri worked participated in PLCs that aligned with courses taught. Kerri was the leader of the Honors Biology PLC and also participated in the Biology PLC, at the request of the teachers in
this second PLC despite the fact that she was not teaching general biology at the time. Within these two PLCs, she provided leadership in curriculum revision to implement NGSS. When we first met with Kerri to discuss the possibility of collaborating, Pat suggested that we limit curriculum implementation to Kerri’s classroom, using her classroom to pilot the curriculum before the other teachers in the Honors Biology PLC adopted it. From her first year of teaching, Kerri had always planned with a PLC, and she felt a strong commitment to her Honors Biology PLC. When we suggested that Kerri plan and teach a unit separate from her PLC, this would have been an anomaly for her. During our initial meeting, Kerri indicated she wanted to talk to the other Honors Biology teachers before she agreed to our collaboration. In a follow-up email, Kerri wrote:

Angie [pseudonym], Karen [pseudonym], and I finally were able to discuss our involvement in developing an evolution or ecology unit with you. Both of them are very excited about this opportunity. We decided that I will meet with you for the initial meetings, to alleviate the logistics of finding a common meeting time for all 6 of us, and report back to them / get their feedback. As we continue through the planning process, then, they’ll want to increase their involvement—as it’s easier for them to teach if they’ve done some of the thinking. :-) (Email, 9-01-2013)

From the beginning of the collaboration with Kerri, the other two Honors Biology PLC teachers agreed to teach the newly designed unit. They also offered to allow us to collect data in their classes, although we did not pursue this offer (Email 9-01-2013). Due to the logistics of scheduling meeting times, we only met with Kerri to plan the unit; the other two teachers were not involved in the planning process. However, they wanted to teach the same lessons as Kerri was teaching, so Kerri met separately with Angie and Karen to explain the lesson plans. During the first year of the collaboration, Troy and Pat did not meet with the other teachers in the Honors Biology PLC, and Pat only briefly interacted with them during the implementation, i.e., a few minutes before school or between classes to discuss the lab results. Based on Kerri’s leadership and experience, the other two Honors Biology teachers felt comfortable implementing the SSI lessons in their own classes. Although Kerri may have considered collaborating with us separately from her PLC, the support of her PLC made the collaboration feasible without adding another course preparation.

**NGSS curriculum revision.** When we sent the initial email to Kerri in August, 2013, inviting her to collaborate on an SSI unit, she responded, “What a fun opportunity in a year when we are changing EVERYTHING. I would love to visit with you and Troy” (Email, 8-22-2013). Although the state had not adopted NGSS, the school district science coordinator charged the district’s science teachers with implementing NGSS beginning in the fall of 2013. To begin the curriculum revision process, the biology teachers met during the summer to create a new curriculum map. During the school year, the Biology and Honors Biology PLCs met weekly to revise their curriculum units to meet the NGSS standards. It was not a minor revision. For each unit, the teachers bundled NGSS Performance Expectations (PEs) and designed new units to meet the PEs.

When we approached Kerri about collaborating, the Honors Biology and Biology PLCs were in the process of re-designing their curriculum. Kerri described the year as being in a state of flux. “It’s not like we’re chugging along doing our same old thing, like our whole year is just tipped over on its side” (PM 9/19/2013). During one of the planning meetings, Kerri reflected on the reason she accepted our invitation to collaborate:
Honestly, the reason I took this on though, is it feeds into what I’m trying to do. When you came to me it was, it fits with what my vision of where I want to go and so it wasn't an add-on. It was support for something else that I was going to be working with. You know and trying to make more relevant for my kids or build in this argumentation, build in skills for my kids. So, it was something that I was going to do in some way or the other, so having support to do it is, to me, a blessing. So, it hasn't been more work. Yes, we've met, but it's allowed me to think about things and like I said I don't feel like I'm alone in thinking through this process. (PM 11/14/2013).

Because the Biology and Honors Biology PLCs were in the midst of a major curriculum revision to implement NGSS, Kerri viewed the collaboration as an opportunity to receive additional help in re-designing curriculum.

**PLC’s history of focusing on skills and content.** The Honors Biology PLC had a history of focusing on developing skills and well as content knowledge. Kerri explained:

Before I even started teaching Honors Biology [12+ years ago], the course focused on both skills and content. The focus was as follows:

1. Each unit focused on content and the scientific practices of designing, performing, and analyzing controlled experiments.
2. We did quarterly projects in addition to our units. These projects focused on the skills of analysis and evaluation. The kids read scientific literature and then wrote essays that practiced the skills. We started with analysis and built our way to evaluation. The analytical essays were not argumentative. Instead they focused on comparing/contrasting, categorizing, drawing inferences, etc. Once they got to evaluation second semester, the essays became argumentative. (Email 3/28/2015)

The biology teachers were explicit with their students about the focus on skills. At the beginning of the school year, the students received the “Honors Biology Skills” handout (Appendix E). The skills were divided into reading/writing skills, modeling, scientific investigation, research skills and study skills. Within the category of Reading/Writing Skills, they focused on analysis/synthesis, evaluation, and communication.

In Honors Biology, the students’ final assessment was to give a TED talk related to stem cells. Kerri explained the rationale for the TED talk assignment:

*We're really working on communication skills a lot. Description, analysis and communication are in biology what we're working on. Like, ‘Can you describe things? Can you analyze and can you communicate them both on paper and orally?’ So this is our goal to start to get to that oral communication with it, so that's the skill. The analysis of all this information and then we’ll get a good idea of their basic understandings of differentiation through whatever they say with this stem cell stuff.* (PM 10/15/2014)

The grading scheme also reflected the emphasis on both skills and content. In Honors Biology, the students’ course grade was based on: 30% quizzes, 5% homework, 45% skills which includes papers and lab reports, 15% final exam and 5% state assessment (PF Field Notes, 3/30/2015).

Kerri reflected on their implementation of NGSS, “We’re asking our kids to read more and write more and analyze more” (PM 1/19/2014). In recent years, the Biology and Honors Biology PLCs collaborated with the World Studies PLC to develop a common rubric to analyze students’ papers. Kerri modified this common rubric for the culminating project in the SSI curriculum unit.
In summary, there were school contextual factors that supported our collaboration to design and implement a SSI curriculum unit aligned with NGSS. First, the support of the Honors Biology teachers was critical to Kerri’s involvement in the collaboration. Second, the biology teachers were already engaged in revising their curriculum to align with NGSS. Third, the biology teachers had a history of focusing on developing skills and content.

Discussion

In the first section, we discuss the use of the SSI-based instructional framework. In the next section, we discuss the tension we encountered between two elements of the framework. In the final section we discuss critical peripheral influences that supported the design and implementation of the ABR unit.

SSI-based Instructional Framework

In this study, the author of the SSI-based instructional framework was one of the collaborators. The other authors were experienced curriculum designers, but did not have experience designing SSI-based curriculum. In the early stages of planning, Troy made references to the framework to guide our curriculum design. The other authors found the framework to be a useful tool in helping us understand SSI-based instruction. During the design process, we were able to easily address all the required and recommended design elements without having to “force fit” any elements. For example, once we decided on the issue of ABR as our compelling issue, we found a plethora of resources available online. In the unit, we used a media account of MRSA to introduce ABR and had students explore additional online resources. After we identified the required learners’ higher order practices (modeling and socio-scientific reasoning), we returned to the required design elements to identify scaffolds students would need.

In this paper, we described two scaffolds: the “Levels of Organization” worksheet and the NetLogo worksheet. Because the students lacked experience with microbiology, they were unfamiliar with growing bacteria in cultures and on LB plates. Students completed three versions of ABR models using the “Levels of Organization” worksheet. This scaffold helped us identify student difficulties during the lab. Initially, students did not understand what the colonies were, which prompted a short teacher-led explanation of individual bacteria vs. colonies vs. populations. The third version of the student models illustrated a deeper understanding of what was happening on the population vs individual level, with an understanding of ABR mechanisms on the cellular level.

While the “Levels of Organization” worksheet supported the students in understanding the ABR lab, the students needed additional scaffolds to develop a more explicit understanding of natural selection. After the ABR lab, we engaged students in a NetLogo model using the same organism, bacteria, but a different trait (varying number of flagella) to further develop their understanding of natural selection. The NetLogo worksheet specifically focused on aspects on natural selection that may have been missing in the students’ earlier models of the ABR lab: initial variation, heritability of traits, environmental pressure, and differential survival and reproduction.

As we reflect on the SSI instructional framework, it’s important to return to the fact that the first three authors were experienced biology teachers and curriculum designers. Because of our previous experiences, we used the backwards design process to develop the ABR curriculum unit. We started by identifying NGSS performance expectations, selecting a compelling issue,
and designing our final assessment, the culminating product, before we developed the lesson sequence and scaffolds. The SSI instructional framework identifies required design elements and student learning experiences, but it doesn’t illuminate the process of designing an SSI-based unit using these elements. Experienced curriculum developers will automatically impose a backwards design process as they interpret the framework; however, novice curriculum designers would benefit if the framework were revised to illustrate a suggested sequence of addressing the elements of the framework.

**Tension: Compelling Issue Versus Teaching Natural Selection**

Throughout the six-month planning process, we experienced tension between two required elements of the SSI framework: building instruction around a compelling issue and confronting scientific ideas and theories related to the issue.

We found no other published studies in which ABR was used as a context to teach natural selection. Other published ABR education studies had a similar focus, for example, connecting ABR to failure to finish a full dose of antibiotics (Wassmer et al., 2006), without connecting ABR to natural selection. During the design process, we came to question whether ABR was a good context for teaching natural selection.

We saw ABR as a compelling issue that students would see as relevant to their lives. It provides a context that immediately immerses students in a contemporary evolution example. According to a recent Pew Report, 33% of Americans reject evolution (Pew Research Center, 2013). In the school context where we implemented the ABR unit, the biology teachers had a long history of teaching evolution. Kerri noted, in general, the community was supportive, although she typically had a few students who voiced opposition. In teaching this unit, no students voiced opposition to evolution. The students had experience with ABR, either firsthand or they knew someone who had an ABR infection. Relevancy is an important criterion for selecting an issue in SSI instruction (Marks & Eilks, 2009; Sadler, 2011b; Van Aalsvoort, 2004). As a SSI, ABR met the criterion of relevancy, being both personally and social relevant (Aalsvoort, 2004).

Although ABR was a compelling issue, the complexity of the biology created challenges. First, the model organism, bacteria, is an unfamiliar, microscopic organism. Students couldn’t see individual bacteria or see the population in the culture tubes. What they could see, dots (colonies) on the LB plates, they didn’t fully understand. The “Levels of Organization” scaffold and short teacher explanation helped address the student difficulty in distinguishing between individuals, colonies and populations. This issue is an important one due to the many misconceptions related to natural selection.

To understand evolution, students must be able to reason across multiple levels of organization, individual and population levels. A common misconception is that individual organisms change, rather than individuals die or survive and reproduce, resulting in the frequency of a trait in a population shifting over time (Bishop & Anderson, 1990). Related to this misconception, Gregory (2009) discusses the problem of students viewing evolution as an event rather than a process which can lead students to believe adaptive changes occur in the entire population simultaneously. By introducing natural selection through 5-day ABR lab, we may have re-enforced the misconception that evolution is an event. Another common misconception is that mutations occur as a need-based adaptive process, occurring in response to environmental pressures (Bishop & Anderson, 1990; Garvin-Doxas & Klymkowsky, 2008). In
the first set of plates in the ABR lab, there was little growth on the LB/streptomycin plates. The students inoculated a second set of plates with a 3-day old culture and observed more colonies growing on the LB/streptomycin plates. In reviewing some of the students’ models and lab reports, we questioned if a few students had the persistent misconception that bacteria knew in the second set of LB/streptomycin plates that they needed to mutate to be able to survive. In choosing ABR as an issue, we may have had more fertile ground to re-enforce misconceptions.

And finally, and most problematic for the first two authors, was the confounding concept of lateral gene transfer. Our students needed to develop an understanding of natural selection with bacteria as a model organism, which was challenging in itself. However, ABR is not just a natural selection story, bacteria can acquire resistance genes from other neighboring contemporary bacteria through transduction or conjugation, or by uptaking small pieces of naked DNA (http://amrls.cvm.msu.edu). Fonseca et al. (2012), in their ABR project, noted that high school students confused vertical and lateral gene transfer, and these students had already completed a high school biology course. We addressed the lateral gene transfer part of the story by telling the story in two parts. We focused only on vertical gene transfer for the majority of the unit. At the end of the unit, we explained that ABR can spread within a population much quicker because of lateral gene transfer; we highlighted conjugation as an example. ABR is a not a simple example of natural selection; from a teaching stance, Darwin’s finches are less problematic.

Throughout the planning of the ABR unit, the first two authors struggled with including the whole story (the actual biology) versus telling part of the story (school science/biology). For Kerri, this was less problematic; ABR as a compelling issue easily outweighed challenges associated with the complexity of the biology. She offered a simple solution—delay and de-emphasize the rest of the story until the end of the unit. We share the tension we experienced in designing a SSI-based unit because selecting a compelling issue has not been problematized in the literature.

Peripheral Influences

We examined peripheral influences that were critical in the planning and implementation of the SSI-based unit. We set aside the list of peripheral influences identified in the SSI-based Instructional Framework and coded our data inductively. The support of the Honors Biology PLC was critical to Kerri’s willingness to collaborate with us. Although the other members of the PLC were not able to meet with us because of scheduling issues, they willingly agreed to be silent collaborators. The biology department at this school has a 15-year history of working together in PLCs. Kerri needed more than what the framework identified as “support and encouragement for teachers implementing SSI-based instruction.” She needed the teachers in her PLC to agree to teach the unit we designed, even though they were not able to give any input on the design. Without their support, our collaboration would have created an additional course preparation for Kerri. Because Kerri was the senior teacher in her PLC and the teachers had a long history of collaborating together, the PLC was supportive. This study contributes to the literature by identifying the important role of PLCs in implementing SSI-based instruction.

The second peripheral influence critical to our collaboration related to the timing and implement of NGSS. The SSI-based Instructional Framework identifies peripheral supports: “flexibility of curriculum that allows teachers to adapt SSI-based instruction, and connections between SSI-based curricula and state- or national-level curriculum objectives.” The biology department was in the process of a major curriculum revision to implement NGSS. We
approached Kerri about collaborating at the beginning of their revision process, and we selected a unit that still needed to be revised. Kerri viewed our collaboration designing a new unit as work she would be doing anyway. She viewed the collaboration as helpful, and not as an additional thing she agreed to do. So, in this case, the timing of the collaboration was critical to its success. If we had approached Kerri after the PLC had re-designed their entire curriculum, the invitation to collaborate would not have been as attractive. Related to timing is a third peripheral support inherent in our collaboration; we shared common goals: making the curriculum more relevant and implementing NGSS. When we approached Kerri, we emphasized that we wanted to explore using an SSI-based approach to implement NGSS. In this case, we didn’t use the approach of making connections to NGSS, rather we used an SSI approach to re-design curriculum to meet NGSS. This study contributes to the literature by illustrating that SSI can be an avenue for implementing NGSS.

The final peripheral influence is related to the Honors Biology PLC’s historical focus on developing skills as well as students’ content knowledge. The teachers valued developing students’ descriptive and analytic writing skills. The Honor Biology students were assigned four major writing assignments in the course. The teachers had engaged in a long-term collaboration with the World Studies teachers to develop a common rubric for assessing students’ papers. Because the biology teachers valued developing students’ writing skills, and had experience assessing students’ writing, they embraced the culminating project in the unit. This case illustrates how prior emphasis on developing higher-level skills can act as a support for implementing SSI-based instruction.

In summary, in this case, we identified the following peripheral influences: the PLC teachers’ willingness to teach the SSI-based curriculum unit, the timing of the collaboration in that the teachers were engaged in a major curriculum revision, sharing of common goals of making the curriculum more relevant and implementing NGSS, as well as the biology teachers’ long history of focusing on higher-level skills. Peripheral influences in the SSI-based Instructional Framework are an important addition to the model. Peripheral influences will vary with the school context. For example, “strategies for negotiating community patrons’ concerns or disapproval of SSI-based lessons” was a non-issue in our collaboration. However, we found that there were peripheral influences that were critical to the implementation of the SSI-based unit. As researchers and professional developers, we need to pay close attention to the peripheral influences outside the classroom that influence what can and does happen in the classroom.

**Implications**

In this section, we make recommendations for future research and practice based on our experience collaborating with a biology teacher to design and teach an SSI-based unit to meet the NGSS standards for natural selection. More research is needed using the SSI-based instructional framework in professional development settings with teachers, particularly with varying degrees of experience in curriculum design. In what ways does the framework support teachers in designing SSI-based curriculum? What is missing from the framework? How do the teachers interpret the framework and what scaffolds are needed to help teachers understand the framework? In regard to the required design element of using a compelling issue, more criteria needs to be developed to aid teachers in selecting a compelling issue. Research is also needed on how teachers negotiate the complexity of the science concepts underlying the compelling issue to align with state- and national-level objectives. This study showed the importance of supporting
peripheral influences. More research is needed examining how peripheral influences hinder or support SSI-based instruction implementation in school settings.

References


Table 1. Antibiotic Resistance (ABR) Unit Description

**Antibiotic Resistance (ABR) Unit Description**

**Class:** High School Honors Biology (10th grade)

**Focal points of the unit:**
- Developing and using a conceptual model of biological evolution.
- Exploring the scientific and social dimensions of an evolution-related socio-scientific issue (SSI).

**Student learning objectives:**
As a result of learning experiences in the unit, students will be able to:

1. Develop and explain a conceptual model of natural selection that accounts for a) genetic variation associated with particular traits, b) selective pressure that leads to differential reproductive success linked to these traits, and c) changes in trait frequencies within the population.

2. Use the model (1) as a basis for reasoning about novel problem situations.

3. Create and describe a representation of a cellular mechanism that confers bacterial resistance to antibiotics. (Elements of this representation should include targets of antibiotic activity and ways in which bacteria disrupt that activity.)

4. Demonstrate socio-scientific reasoning in response to complex SSI.
   a. Identify and discuss sources of issue complexity.
   b. Identify areas of uncertainty and ask related questions.
   c. Analyze the issue from multiple perspectives.
   d. Identify and discuss ways in which scientific evidence can inform issue resolution as well as limits on the use of scientific evidence.

**Instructional Sequence:**

<table>
<thead>
<tr>
<th>Day*</th>
<th>Instructional focus</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Elicit student ideas.</td>
<td>Administer pre-tests for Natural selection (NS) and socio-scientific reasoning (SSR).</td>
</tr>
<tr>
<td>1</td>
<td>Introduce ABR as significant issue. Review bacterial structure.</td>
<td>Video from a news magazine. Small group exploration of MRSA cases from multiple media sources. Students complete “Bacteria study guide.”</td>
</tr>
<tr>
<td>2</td>
<td>Student exploration of bacterial evolution. Introduce AB mechanisms.</td>
<td>Lab: set-up bacterial cultures (w/wo AB in the agar) and make predictions. Lecture with references to the “Bacteria study guide.”</td>
</tr>
<tr>
<td>3</td>
<td>Introduce modeling.</td>
<td>Students use modeling across biological levels of organization tool to predict lab results.</td>
</tr>
<tr>
<td>Day</td>
<td>Student Exploration</td>
<td>Lab Notes</td>
</tr>
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<tr>
<td>4</td>
<td>Student exploration of bacterial evolution. Explain mechanisms for antibiotic resistance. Use models to account for lab results.</td>
<td>Lab: Document changes in bacterial growth. Lab: Examine second set of plates; record class data. Lecture. Students use modeling across biological levels of organization tool to explain lab results.</td>
</tr>
<tr>
<td>5</td>
<td>Explore NS as a model for change in populations. Relate NS to lab results.</td>
<td>Students manipulate Netlogo models of NS. Students write lab conclusions with a NS perspective.</td>
</tr>
<tr>
<td>6</td>
<td>Review NS. Decision-making that links science to social challenges.</td>
<td>Class questions/discussion. Culminating activity (CA): Review epidemiological data on ABR; jigsaw activity-students explore various social perspectives.</td>
</tr>
<tr>
<td>7</td>
<td>Decision-making that links science to social challenges.</td>
<td>CA: jigsaw activity-share various social perspectives; brainstorm policy options.</td>
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<tr>
<td>8</td>
<td>Decision-making that links science to social challenges. Apply NS model.</td>
<td>CA: Present and peer evaluate policy proposals. Read, interpret and make predictions of a case of herbicide resistance.</td>
</tr>
<tr>
<td>9</td>
<td>Elicit student ideas. Explain lateral gene transfer.</td>
<td>Administer pre-tests for NS and SSR. Lecture/discussion</td>
</tr>
</tbody>
</table>

* A “day” represents a class period. Most class periods were 85 minutes; although, there were many exceptions to this because of the school calendar.

Assessments:

- Pre/post-testing of NS understandings; multiple choice (CINS) plus open-ended item (Opfer, Nehm & Ha, 2012) – *summative*
- Pre/post-testing of SSR; open-ended survey (Sadler, Klosterman & Topcu, 2011) – *summative*
- Models of cellular mechanisms and related changes in bacterial populations (multiple time points) – *formative*
- Models of natural selection in the context of the laboratory investigation – *formative*
- Application of NS model to a novel case – *formative & summative*
- Application of SSR in the context of a policy recommendation - *formative & summative*
Figure 1. Student example of first version of “Levels of Organization” scaffold
Figure 2. Student example of second version of “Levels of Organization” scaffold
Figure 3. Student example of third version of “Levels of Organization” scaffold
Appendix A
Introductory Lesson

Exploring Cases- MRSA
You will work in small groups (about 4 people) to explore multiple resources related to people struggling with MRSA. Each student is responsible for exploring one resource and completing the questions listed below. However, no single resource has all the answers for all the questions. After each group member explores her/his resource, the group should work together to complete the questions. Keep in mind that some of the questions have multiple answers provided by the various sources. As you consider the information in your resource, it is very important to consider the source and quality of information (refer to the “Know Your Sources of Information” for some helpful tips).

Resources
A. Personal account of dealing with MRSA, Personal Blog:
   http://tutusandtantrums.blogspot.com/2012/02/my-experience-with-mrsa.html
B. Personal account of dealing with MRSA, Daily Strength Support Group:
   http://www.dailystrength.org/c/Methicillin_Resistant_Staphylococcus_Aureus/forum/7578667-my-experience-ca-mrsa
C. Popular media account with an embedded case, USA Today article:
D. Medical website pictures and descriptions, MedicineNet slideshow:
   http://www.medicinenet.com/mrsa_picture_slideshow/article.htm

Collaborative Questions
1. MRSA is an acronym for methicillin-resistant Staphylococcus aureus. What does it mean for these bacteria to be “resistant”?
2. How many people are affected by MRSA infections in the US on an annual basis? How many people die because of MRSA on an annual basis?
3. Who is at a high risk for contracting MRSA?
4. Why is MRSA often referred to as a “super bug”?
5. How do people catch MRSA?
6. What percentage of the US population carries staph infections? According to the Centers for Disease Control, what percentage of the US population carries MRSA?
7. What are symptoms associated with a MRSA infection?
8. Keep a list of the various medicines (particularly antibiotics) that patients featured in the cases are prescribed.
9. What strategies can be used to control the spread of staph infections?

10. Why do you think doctors prescribe multiple medicines for MRSA infected patients?
### Model of Phenomena across Biological Levels of Organization

<table>
<thead>
<tr>
<th>Population</th>
<th>Individual</th>
<th>Molecular / Genetic</th>
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Appendix C  
NetLogo Bacteria Food Hunt Worksheet

HONORS Biology  
Name_______________________________________

NetLogo Bacteria Modeling

Scientists often use models and simulations to help develop explanations for phenomena. Models allow you to make predictions and test possible explanations. We will be using NetLogo to model bacterial populations.

NetLogo Model Assumptions: All models have assumptions built into them. The NetLogo Model we are using is built on the following assumptions:

- Bacteria are heterotrophs, need to hunt for food
- Bacterial movement is determined by an algorithm
- Bacteria feed, when they are “full” they divide into two
- Bacteria die when they don’t have enough food
- Rates of energy use are fixed and directly relate to # of flagella
- Food regenerates in the same place

Exploring: Play with the NetLogo model and change as many variables as possible.

1) What two variables can you change in the bacterial population? (Ignore visualize-variation.)

2) What two variables can you change in the environment?

Initial Bacteria Population Variation:

Set the following: , then click

3) Describe the variation in the initial bacteria population.

Now turn on a new feature: . Click on and . Let the simulation run for a few seconds.

4) Summarize what you observed. What is the relationship between flagella number and speed?
Reproduction and Inheritance: Bacteria reproduce asexually by a process called binary fission. A single cell copies its genetic material, grows to twice its size and then splits into two. The result is two identical daughter cells. The bacteria we are using in lab, *Bacillus megaterium*, which can divide every 25 minutes. See diagram below for binary fission: (Image Source: http://en.wikipedia.org/wiki/Fission_(biology)

![Binary fission in a prokaryote.](image)

1. The bacterium before binary fission is when the DNA tightly coiled.
2. The DNA of the bacterium has replicated.
3. The DNA is pulled to the separate poles of the bacterium as it increases size to prepare for splitting.
4. The growth of a new cell wall begins to separate the bacterium.
5. The new cell wall fully develops, resulting in the complete split of the bacterium.
6. The new daughter cells have tightly coiled DNA, ribosomes, and plasmids.

5) If a bacterium has 5 flagella, after reproducing, how many flagella will each of the daughter cells have?

6) Explain your reasoning.

In the NetLogo model, one assumption is that the number of flagella is an inherited trait.

Over-Reproduction and Limited Resources: In a population, more offspring are produced than can survive due to limited resources, such as food.

MODEL 1: Set the following parameters so the bacteria have limited food resources, and then click on Setup. BEFORE you click on GO, make a prediction below.
7) Prediction: Which bacteria are more likely to survive?

8) Explain your reasoning for your prediction.

Click on Go, and let the simulation run until the population appears to stabilize. Run the simulations multiple times until you think you see a trend.

Survival & Reproduction:

9) Which bacteria survived?

10) Give a possible reason to explain your results.

Adaptations: An adaptation is a heritable trait that gives an individual an advantage in a particular environment. An adaptation increases an individual’s fitness – the ability to survive and reproduce.

11) What adaptation allowed some individuals to survive and reproduce in Model 1, in which the food was somewhat scare and randomly distributed?

Cost and Benefits: Adaptations have both benefits and costs to the individual.

12) What is the benefit of having more flagella?

There is a cost to the bacterium for each flagellum. It requires more energy to move when a bacterium has more flagella. Let’s explore this cost.

Model 2: This model will be more realistic in that we will add a cost to the organism for each flagellum. Set the parameters to the following. We will keep all the parameters the same as in Model 1, with the exception of the energy-cost-per-flagella. BEFORE you click on GO, make a prediction.

ENERGY
13) Model 2 Prediction: Which bacteria are more likely to survive?

14) Explain your reason.

Run Model 2 several times until you see a trend in the results.

15) Which bacteria survived and reproduced?

16) Explain why the surviving population in Model 2 was different from the surviving population in Model 1, even though the environment stayed the same.

**Changing Environment Pressure:**

For Model 3, we will change the environmental pressure. In the left region, the food will be concentrated around a central point, while in the right region, the food will be randomly distributed anywhere. We are also reducing the energy-cost/flagella to 0.25

Set the following parameters:

17) Model 3 Prediction:

a) Which bacteria are more likely to survive in the left region where the food is concentrated around a central point?

   Explain your reasoning.

b) Which bacteria are more likely to survive in the right region where the food is randomly distributed?

   Explain your reasoning.

Run Model 3 several times:

18) Which bacteria survived in the left region?

19) Which bacteria survived in the right region?
20) Give a possible explanation for why different adaptations were selected for in each of the two environments.

**AT THIS POINT, STOP FOR WHOLE CLASS DISCUSSION.**

21) **If you are waiting for your classmates to finish**, run the simulation with different variables to determine under which conditions the purple bacteria (1 flagella) have the highest fitness? (Fitness refers to surviving and reproducing)

Conditions:

22. **REVIEW:** Darwin’s Four Postulates of Natural Selection:

a) 

b) 

c) 

d) 

23. What would happen to the bacterial population if there were no variation?

24. In a population of bacteria, what is the original source of variation?

**DESIGN YOUR OWN EXPERIMENT:**

Use NetLogo to explore your own question related to bacteria and natural selection.

Question:
Prediction:

Run the model multiple times. State your findings as a claim supported with evidence from the model.

Claim:

Evidence:

Each group will share their experiment with the class.
Appendix D
Culminating Project

Policy Development & Analysis

Assignment Overview
Throughout the rest of the Antibiotic Resistance unit, you will be asked to think about making a specific policy recommendation related to bacterial diseases and antibiotic resistance. A policy recommendation is a suggested course of action that could be implemented at one of several levels of government. For example, recommendations could be made for a state (like the state of Missouri) or a country (like the US). International policy can be implemented through an organization like the United Nations.

The purpose of this exercise is to get you thinking about what should be done (or not done) to deal with the problem of antibiotic resistance. This thinking should be informed by what you know about the science behind this issue, but your thinking may also be influenced by the social aspects of the issue. For this project, you will collaborate with classmates in small groups but you will be responsible for making your own policy recommendation and analysis of that recommendation.

As you review information about the issue and various perspectives on the issue, remember the importance of evaluating your sources of information. The “Know Your Sources of Information” handout provides helpful questions to ask when looking at websites or other information resources.

Process and Products
1. Students are assigned to groups of ~4.
2. Everyone in the group should review resources that highlight epidemiological data related to antibiotic resistant bacteria. Then individual students will review a couple resources that present information and perspectives about a particular aspect of the AB-resistance issue:
   a. Parental and doctor concerns
   b. Use of antibiotics in international settings
   c. Government intervention in healthcare issues (like AB-resistance)
   d. Drug company perspectives on new antibiotics.
3. Each group member is responsible for reviewing information pertinent to her/his assigned perspective AND for sharing the basic ideas about this perspective with her/his group. Each student should be prepared to share information corresponding to the discussion question (shown in #4).
4. Group discussion. Students should present the information they find relative to each aspect.
   a. What sources did you access? What is the quality of these sources?
   b. Describe the aspect on AB-resistance you explored.
   c. Who is involved with this aspect? What are their likely interests?
d. What would the stakeholders represented in your readings recommend in terms of policy for AB-resistance?

After presenting information about the various aspects, the groups should brainstorm possible courses of action that could serve as the basis for a policy recommendation. Examples include doing nothing, regulating doctors’ activities, regulating patient access to AB, incentivizing corporate investment in AB development, launching an educational campaign.

5. Individual students select a governmental level for policy enactment and create a policy recommendation.
   a. Policy Statement
      i. Identify the target level for policy (state, national, international)
      ii. Describe the policy you are proposing and provide a sound rationale for implementation of that policy.
   b. In addition to creating the policy, students must provide a written analysis of the policy guided by the following questions.
      i. What are the potential benefits of the enactment of this policy?
      ii. What are the potential disadvantages of the enactment of this policy?
      iii. Who would likely support this policy? Why?
      iv. Who would likely oppose this policy? Why?
      v. If this is a good solution to the problem of AB-resistance, why has it not already been implemented?
      vi. What scientific evidence or scientific models can be used to strengthen the case to be made to support your recommendation?

Schedule
March 7: Introduce the activity; Groups review epidemiological data
   **HW:** Read assigned aspect; answer questions on aspect, prepare description of this aspect for group (DUE: March 13)

March 13: Submit written description of aspect and associated information.

March 17: Groups discuss various perspectives and brainstorm possible courses of action.
   **HW:** Policy proposal and analyses (DUE: March 21)

March 19: Work on proposal analyses in class.

March 21: Submit written policy proposal and analyses.
Honors Biology Skills Handout

Reading/Writing:

Analysis/Synthesis
1. Use analysis and synthesis to better understand scientific texts and other informational sources.
2. Apply the skills of analysis and synthesis to write conclusions for experimental investigations and scientific studies.

Evaluation
3. Appraise and critique evidence, arguments, or solutions to current scientific issues.
4. Use evidence and research to propose solutions to current scientific issues.

Communication
5. Communicate your analysis, synthesis and evaluation of scientific texts, informational sources, and experimental investigations both in oral and written forms.

Modeling
1. Create a model (physical, visual, analogies, verbal, demonstrations, etc.) to illustrate your understanding of specific scientific concepts.

Scientific Investigation
1. Demonstrate the ability to ask questions to further learning (OWL- Observe, Wonder, Learn).
2. Design and conduct investigations to provide evidence for scientific questions or solve a problem.
3. Analyze and represent data using appropriate mathematical techniques.
4. Identify and describe patterns in collected data.
5. Explain the results of an experiment or scientific study using appropriate rationale.

Research Skills
1. Gather relevant and reliable information from multiple authoritative sources.
2. Demonstrate appropriate in-text citations, and create a list of references.

Study Skills (Not Directly Assessed)
1. Practice different methods of note-taking—guided notes, outlined notes, notes from reading/research, notes from listening.
2. Use different study strategies to learn class content.
<table>
<thead>
<tr>
<th>Category</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
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<tbody>
<tr>
<td><strong>Policy Statement</strong></td>
<td>Policy statement clearly &amp; effectively addresses the issue, identifies the appropriate target level, and provides a controlled and thoughtful rationale for the policy.</td>
<td>Policy statement fully addresses the issue, identifies the target audience, and provides a logical rationale for the policy.</td>
<td>Policy statement addresses the issue and provides a rationale that may be too narrow, superficial, and/or vague.</td>
<td>Policy statement responds partially to the prompt with a rationale that is vague, incomplete, or lacks reasoning.</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>Smoothly and thoroughly integrates specific, relevant, and accurate scientific &amp; social evidence, creating a strong foundation for the policy.</td>
<td>Integrates specific, relevant, and accurate scientific &amp; social evidence, creating a foundation for the argument.</td>
<td>Integrates limited and/or general evidence; may lack relevance and/or accuracy; creating a weak foundation for the argument.</td>
<td>Attempts to integrate evidence, but is insufficient in creating a foundation for the argument.</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>Clearly and efficiently breaks down and elaborates thoughtfully on meaning and significance of each piece of evidence. All analysis questions are thoughtfully addressed.</td>
<td>Clearly and efficiently breaks down and elaborates on meaning and significance of each piece of evidence. All analysis questions are addressed.</td>
<td>Breaks down and elaborates on meaning and significance of each piece of evidence. Does not fully address all of the analysis questions.</td>
<td>Breaks down evidence but provides limited meaning and significance. Does not address many of the analysis questions.</td>
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<tr>
<td><strong>Communication</strong></td>
<td>My command of language skills is superior. I am professional, fluent, and engaging to the audience.</td>
<td>My command of language skills is above average. I demonstrate above average professionalism and fluency, and I am engaging to the audience.</td>
<td>My command of language skills is inconsistent. I attempt to be professional and fluent, but I may not consistently engage the audience.</td>
<td>My command of language skills is lacking. I demonstrate a deficiency in being professional and fluent, and I am largely disengaging to the audience.</td>
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<td><strong>Research</strong></td>
<td>Multiple creditable sources utilized throughout the piece. Correct MLA format is observed.</td>
<td>Multiple creditable sources utilized; however, strong reliance on one source throughout the piece. Mostly correct MLA format is observed.</td>
<td>Few sources are referenced, but they are not creditable or utilized throughout the piece. Incorrect MLA format is observed.</td>
<td>Sources utilized throughout the piece are not referenced or are not creditable, and poor MLA format is observed.</td>
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<tr>
<td><strong>Evaluation</strong></td>
<td>I make a reasoned judgment based upon a thorough examination of all sides, which leads to a thoughtful proposal.</td>
<td>I make a clear judgment based upon an examination of most sides, which leads to a logical proposal.</td>
<td>I make a judgment based upon a weak examination of some or most sides, which leads to a superficial proposal.</td>
<td>I make a judgment based upon an incomplete examination of both sides, which leads to a weak proposal or none at all.</td>
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