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ARTICLE

Conexiones: Fostering Socioscientific Inquiry in Graduate Teacher Preparation

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Socioscientific Inquiry (SSI) represents one approach designed to target interest and knowledge in science. In this context, students consider scientific issues that have social implications and require a range of trade-offs, concepts, and considerations in order to arrive at informed conclusions (Sadler, 2004). However, inquiry tasks in general and SSI projects in particular are not widely adopted in K–12 settings, despite strong beliefs among teachers that these types of activities are valuable (Marshall, Horton, Igo, & Switzer, 2009). We suggest Collaborative Action Research may provide an important platform for enabling teachers to experience success through systematic investigations of their practice supported by peer interaction and collaboration (Capobianco & Feldman, 2006).

In our investigation, we sought to understand the learning experiences of teachers within redesigned graduate-level courses aimed at preparing teachers to implement SSI approaches in the classroom. Data were collected from course participants to capture changes in scientific content knowledge, perceptions of SSI instruction, and strengths as well as recommendations of the experience. Results suggest that teachers can gain both content knowledge and pedagogical capacity in SSI methods.

Keywords: science, inquiry, socioscientific inquiry, SSI, teacher change, science knowledge

Introduction

The use of socioscientific issues (SSI) has been advocated for at least the past decade in order to foster the development of a variety of skills among students (see for example Sadler, 2004, Sadler & Zeidler, 2005 and references below). Despite the growing body of evidence that supports SSI as an effective approach in a variety of contexts, there are still challenges that hinder the large-scale adoption and implementation of SSI, as described below. The purpose of this investigation is to explore the experience of teachers taking graduate-level courses that have been explicitly re-designed to support the implementation of SSI. We explore teacher change through science content learning gains, instructional process, teaching practice, and action research. We are motivated in part by an unacceptably high proportion of 4th, 8th and 12th grade students in the US who are at or below the basic level in science on the National Assessment of Educational Progress (NAEP) (National Center for Education Statistics, 2012). Twenty-eight percent of 4th grade students, 36 percent of 8th grade students and 40 percent of 12th grade students were at or below the basic level of scientific proficiency. These results are discouraging as *basic* indicates incomplete mastery of science skills and content. On the other hand, when looking at the percentage of US students scoring at or above proficient, only 34 percent of 4th grade students, 33 percent of 8th grade students and a mere 21 percent of 12th grade students were at or above proficient in science (National Center for Education Statistics, 2012). This situation requires continued attention, and SSI is an approach that may contribute to positive outcomes in science education.

Socioscientific Inquiry

Connected to our curricular change approach, we emphasize the curricular model of Socioscientific Inquiry (SSI), which represents one initiative designed to target interest as well as knowledge and skills in science. In this context, students consider scientific issues that have social implications and comprise a range of trade-offs, concepts, and considerations in order to arrive at informed scientific conclusions (Sadler, 2004). Such issues can range from cloning to environmental challenges to land use decisions (Sadler & Zeidler, 2005). Engaging students in these issues reflects a *science as*

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citizenship emphasis (Kolstø, 2001), and recognizes the critical personal context of learning (Bransford, Brown, & Cocking, 2000). Socioscientific reasoning involves four elements: 1) complexity, 2) incorporation and recognition of diverse perspectives, 3) reliance on continuing exploration, and 4) an ability to view information critically, recognizing potential bias (Sadler, Barab, & Scott, 2007). This approach therefore provides valuable opportunities not only for science reinforcement, but also for an interdisciplinary and contextual approach to science education, including literacy, social studies, and mathematical skill reinforcement.

With respect to science reinforcement, Klosterman and Sadler (2010) showed that high school students who worked through a global warming SSI unit showed statistically significant improvements on two different assessments—one more closely aligned with the SSI unit, and one aligned with the state content standards. This indicates that SSI instruction can be used to successfully address content standards. Furthermore, SSI approaches address national curriculum reform initiatives for students to engage in meaningful problem solving that incorporates the practice of science and using the language of the discipline (i.e. *Benchmarks for Science Literacy*, American Association for the Advancement of Science, 1993; *National Science Education Standards,* National Research Council, 1996). SSI is also being investigated at the undergraduate level, and in one study has been shown to be as effective as traditional instruction in terms of undergraduate biology majors' understanding of scientific inquiry (Eastwood, Sadler, Sherwood & Schlegel, 2013).

How is SSI Being Adopted, and What Are the Associated Challenges?

As reviewed by Zeidler and Nichols (2009), teachers may not be experienced or comfortable with becoming classroom facilitators, rather than instructors who transmit expert knowledge. This challenge of managing classroom activities such as discussions and debates was also highlighted by pre-service high school biology teachers who took a course that emphasized SSI (Kara, 2012). These pre-service teachers also perceived challenges related to having the time to develop SSI instructional materials (as there are not readily available collections of such materials), and concerns of using SSI and adequately covering the mandated biology curriculum (Kara, 2012). In-service teachers have expressed similar concerns. While interviewing middle and high school teachers about SSI (and particularly ethics in SSI), several teachers noted challenges to adopting SSI that included insufficient time, insufficient training and the need to cover the science standards (Sadler, Amirshokoohi, Kazempour & Allspaw, 2006). Furthermore, in order to facilitate discussions of SSI, the teachers themselves must have a certain level of content knowledge about the specific topic, as well as its current relevance.

In a study by Ekborg, Ottander, Silfver and Simons (2013), secondary teachers could choose from among six pre-prepared SSIs to teach in their classes. While the teachers used the SSI cases to engage student interest, and had positive opinions about the level of student engagement, the authors raised concerns that the SSIs were not being used to their full potential. Specifically, ethical issues and the complex relationships that can exist between science and society, and that are valued by SSI researchers, were not being emphasized in the way that the teachers were implementing the SSIs (Ekborg et al., 2013).

Lee and Witz (2009) presented in-depth case studies of four high school science teachers, and their use of SSI. These teachers appeared to be lone adopters, using SSI because of individual internal motivations, without necessarily being aware of reform efforts promoting the use of SSI. While this is encouraging in terms of use of SSI, it also raises the question of whether their implementation of SSI is consistent with the view of SSI researchers.

While SSI can be used to teach and address ethics that reflect values and global perspectives (e.g. Saunders & Rennie, 2011; Lee, Chang, Choi, Kim & Zeidler, 2012), the teaching and inclusion of ethics in science instruction is another barrier to maximizing the potential of SSI. As described in Sadler et al. (2006), while researchers value the inclusion of ethics in SSI (and indeed regard this as a strength of SSI), many teachers are reluctant to infuse ethics into objective science courses. The models presented by Saunders and Rennie (2011) may provide support to teachers in this regard. Another example of using a formal model, or scaffold, to assist teachers implement SSI is described in France, Mora, and Bay (2012). In this case, high school teachers used two specific models in order to facilitate effective classroom discussions during a controversial SSI. This study was also notable in that it involved extensive teacher professional development and collaborative action research involving the researchers and the teachers, which led to increased confidence for the teachers (France et al., 2012).

In a study of graduate biology lab instructors, it was clear that these instructors (who generally do not have formal pedagogical training) had a great deal of knowledge about the SSI related to genetically modified crops, and a deep appreciation for the relevance of this topic for students' lives (Gardner & Jones, 2012). However, this latter aspect—the strong beliefs about the societal importance of the SSI—was generally not emphasized in their teaching (Gardner & Jones, 2012). This again highlights the importance of having skills and knowledge in both the content and in student-centered teaching practices in order to maximize the potential of SSIs in classrooms.

Particular Challenges for Elementary Teachers

At the elementary level, teachers often have little background in sciences, and they tend to place instructional emphasis on reading and mathematics (Griffith & Scharmann, 2008; Rentner et al., 2006). One example of limited science background is provided by Krall, Lott, and Wymer (2009) in which elementary and middle school teachers were surveyed about their content knowledge of photosynthesis and respiration (key science topics in the elementary curriculum). Teachers (particularly in low performance groups) did not do well, and tended to select distracters based on recognized misconceptions of students.

Forbes and Davis (2008) investigated preservice elementary teachers as they evaluated an SSI lesson plan. Because of their limited content knowledge of some of the content in the SSI, the indications were that their implementation of the unit would focus more of the content that they felt familiar with, and that they may shy away from discussing the broader issues that required integration of topics that they were not familiar with. The authors concluded that elementary teachers may be constrained by their (limited) content knowledge when implementing SSI (Forbes & Davis, 2008).

In another survey, Marshall, Horton, Igo, and Switzer (2009) surveyed 1222 K–12 teachers about their practices and beliefs with respect to inquiry in math and science, and found that elementary science teachers had the highest reported usage of inquiry, but that this usage was less than what they considered to be ideal. There was no assessment of the efficacy of inquiry approaches, or of the content knowledge or pedagogical content knowledge (PCK) of the teachers. Thus, while teachers may appear to value inquiry, its application specific to content knowledge, pedagogy, and assessment of student-centered outcomes is not well understood.

This lack of science and inquiry emphasis may be due in part to a shortage of time and scientific knowledge on the part of teachers, but recent research indicates it may also be an unintended consequence of the "No Child Left Behind" Act, which has been shown to result in a narrowing of the curriculum to the emphasized content areas of mathematics and literacy. A recent report indicated that the increased focus on math and reading has resulted in both budgetary and time reductions for science instruction (Griffith & Scharmann, 2008).

This underscores room for improvement of elementary science education, including improvements to teacher practice. Elementary teachers in general exhibit low confidence in teaching science as well as a general lack of ability to communicate about scientific concepts. In a report of preservice teachers' beliefs about science teaching, the researchers found a positive correlation between confidence in teaching science and the number of science content courses taken (Yilmaz-Tuzun, 2007). This indicates that an increase in science experiences at the undergraduate level may increase preservice teachers' confidence for science instruction, which has been supported by other researchers (Bleicher, 2006; Jarrett, 1999). However, confidence is not enough when it comes to quality science instruction; another key factor is the ability to communicate about scientific concepts. In a study among preservice elementary teachers, it was found that this group benefited from explicit and contextualized instruction regarding the nature of science and complex decision-making (Matkins & Bell, 2007). In particular, their knowledge and capacity for communicating about science increased through discussions within issues-based experiences (i.e. global climate change) and about the nature of scientific knowledge. In general, the trend toward positively impacting future science elementary teachers tends to favor experiences that promote confidence building and science knowledge.

There are some bright notes, however. A successful elementary implementation of SSI has been described by Dolan, Nichols, & Zeidler (2009), in which students participated in discussions, expanded their content knowledge and also began to express concerns related to social justice. Additionally, as noted by Zeidler & Nichols (2009), SSI is ideal for elementary instruction, as many aspects of the elementary curriculum come into play (e.g. reading, writing, mathematics) during an SSI unit. Given these bright spots, and the dire need, it is certainly worth investing effort into considering how to help elementary teachers successfully implement SSI in their classrooms.

Supporting Teacher SSI Practice: Collaborative Action Research

As teacher confidence in teaching science has been noted as a barrier to adopting innovative science curricula (for examples, see Appleton, 2008), it is critical to provide quality teacher preparation in science content knowledge and assessment of student-centered outcomes. Providing this support as part of a cohesive curriculum may have advantages over independent professional development workshops that require an investment of teacher time above and beyond existing professional responsibilities (e.g. James et al. 2006), and over time-intensive one-on-one mentoring programs as described by Appleton (2008).

While SSI is a key focus of this project, as noted above inquiry tasks in general and SSI projects in particular tend to exhibit low adoption rates in K–12 settings, despite strong beliefs among teachers that these types of activities are valuable (Marshall et al., 2009). This may stem from a number of sources, but most can be classified under two broad categories: 1) minimal support and resources that would lead toward confidence building and conceptual understanding (described above), and 2) lack of opportunity to reflect on the inquiry teaching process in a collaborative setting that would elicit valuable input and alternative perspectives. We address these barriers through the collaborative action research model, as described below.

When it comes to understanding teacher practice, action research is a valuable tool for meaningful reflection and informed instructional decision making. Within this approach, the researcher (teacher) identifies a problem or question, develops a critical self-study research plan, and systematically collects data in order to arrive at a path of action or deeper understanding regarding the question of inquiry (Capobianco & Joyal, 2008). A key consideration is the quality of the action research method, which Capobianco and Feldman (2006) have addressed with science education teacher and discuss as "a coherent body of goals, objectives, and methods . . . that originate from inquiring, testing out and reflecting upon practical, personal or political issues" (p. 498–499). They further emphasize the importance of collaborative discourse, conversation, and exchange, and emphasize the importance of socially constructed knowledge and understanding.

An important dimension of action research is the purposeful, iterative nature of the work, which has been used at length to help science education students integrate pedagogical and content knowledge. In one study, the teacher used action research to understand how her students were articulating complex chemistry concept and uncovered numerous misconceptions and inaccurate representations (Valanides, Nicolaidou, & Eilks, 2003). The action research work not only uncovered these phenomena, but also provided important insight into how she should adjust and improve her practice. In another study, a university science educator worked with three high school teachers to understand and articulate the impact that ongoing action research projects have had on their teaching (Capobianco, Lincoln, Canuel-Browne, & Trimarchi, 2006). They found that each teacher sought different pathways in her approaches to the research, including gaining new knowledge to increasing confidence in science to inventing curricular approaches when the textbook did not suffice. The authors highlighted the fact that each found different value in the process, but that all felt empowered to take risks and understand the outcomes within their teaching as a result of engaging in action research (Capobianco et al., 2006). Another university science educator echoed this feeling of empowerment in her description of conducting action research projects as a way to understand learning interactions within science classrooms (Marin-Dunlop, 2006). Empowerment translated into confidence for teachers in successfully facilitating classroom discussions during a controversial SSI within the collaborative action research project described above by France and colleagues (2012). In other words, action research results in very different experiences for each researcher, but is consistently described as empowering teachers to understand and move forward in their practice.

Research Purpose

It is this empowerment that we sought to leverage within our intervention and investigation. Action research connects theoretical models behind SSI with actual classroom practice. In other words, action research represents an important process for helping teachers to reflect on and identify areas for improvement within their SSI approaches. We drew from the recommendations of previous science education professionals, who recommend self-study action research coupled with professional community discussions in order to maximize insight and generate a wide range of solution paths, in much the same way that scientists collaborate with each other in research settings (Lynd-Balta et al., 2006). Broadly speaking, our investigation explored the experience of graduate teachers within our curricular model that supports teacher change toward SSI approaches through mentoring, modeling, content development, and collaborative action research. In this context, our purpose was to investigate teacher change through science content learning gains, instructional process, teaching practice, and action research.

Research Methods

Research Design and Context

We used an evaluative case study approach (Merriam, 1997) to examine teacher practice and teacher change in the context of our curricular model: a two-course bundle for graduate teacher education students that was redesigned and implemented through the partnership of a teacher educator and biologist. Within this context, data were used to examine and evaluate the experiences and practices of the teachers who participated in the new courses. Each data source and its analysis are described in more detail below.

Redesigning the Courses and Defining the Case

Our case investigation consisted of a redesigned six-credit, two-course graduate bundle for master's level teachers co-taught through the collaborative effort of a teacher education faculty member and a biology faculty member. The bundle met two different course requirements for a master's degree in education: *Technology & Pedagogy* and *Research as Praxis I* (which typically teaches the action research model of inquiry). The goal of the course was for the participants to develop and implement an SSI project within a classroom setting. Furthermore, participants were directed to ask a question of their teaching practice that connected to their SSI implementation. They proceeded to investigate this question though action research with collaborative input from their peers (this marks a key distinction between action research and collaborative action research).

Course content consisted of modeling technology-enhanced science instruction and inquiry approaches in the context of an SSI unit entitled "Is My Food Safe?" We developed a series of six online tutorials to model how we planned and addressed each component of developing the unit: developing the driving question, making decisions about teachable topics, narrowing and defining the learning goals (and connecting them to standards), developing the learning objectives, creating the assessment, and planning lessons. In-class activities consisted of instruction, modeling, and workshop formats as relevant: modeling biology content experiences; modeling the inquiry process; modeling uses of technology tools, manipulatives, and biology equipment for learner investigations; delivering mini-lectures, performing biology labs, describing or discussing applications to classroom teaching; discussing participant ideas for classroom implementations; developing action research plans; and discussing the implementation and role of action research in understanding personal teaching practice. We investigated the case through examining the learning outcomes, teaching practice, and experiences of the graduate teachers.

Participants

Prior to the beginning of the semester, we recruited graduate teachers through graduate email listservs, local school announcements and flyers, and word-of-mouth. Data were collected from among seven students enrolled in the redesigned two-course bundle that met requirements for a master's degree of education program in a large, southwestern university. We use the term *graduate teachers* throughout this paper to capture the fact that these students were enrolled in master's degree courses intended for K–12 licensed, practicing teachers (though only five of the graduate teachers were licensed at the time of the study). The two-course bundle was developed to model and emphasize SSI teaching approaches and was paired with a requirement for collaborative action research to enable the graduate teachers to simultaneously and systematically examine their SSI practice. The students had different course choices that could have met the degree requirements; in other words, participation in our model was one of several choices.

Of the seven graduate teachers, three were practicing K–12 teachers at the time of the study: one high school biology, one kindergarten, and one second grade. Two were licensed but not currently practicing in the classroom: one was a recent graduate of secondary mathematics education and one was a former special education teacher providing district-level mathematics support for K–8 teachers. Of the remaining two participants, one was an astronomy teacher at the community college and one was a doctoral student in Curriculum & Instruction.

Data Sources and Analysis

Pre and Post Content Test

Graduate teachers were invited to complete the pre-test on the first day of class, and the post-test on the last day of class. The content test consisted of 18 items and covered biology content we expected students to learn as they participated in the activities designed to model SSI approaches and engage the participants in meaningful experiences. Sixteen of the items were multiple choice, closed response questions and two items were open ended. One open-ended item dealt with the concept of evolution by natural selection and one dealt with photosynthesis and photosynthetic organisms. The multiple-choice/closed response items were worth one point each, and each open-ended item was scored out of two possible points, awarded for completeness and for accuracy. The major themes of the content test included the scientific process, genotype-phenotype relationships, natural selection and energy flow in ecosystems. Three sample items are as follows:

1. Can you draw a conclusion from an experiment before you have collected and analyzed the data?
    a. yes, your predictions are the same as conclusions
    b. yes, the experiment only serves to verify what you already know is going to occur
    c. no, the conclusion can only be drawn after the data have been found to support your hypothesis
    d. no, the conclusion must be based on the data
2. What is the impact of natural selection on allele frequencies in a population?
    a. it can cause the allele frequencies to change in unpredictable ways
    b. it has no effect on allele frequencies
    c. it causes specific types of changes in allele frequencies, depending on the selective pressure
    d. natural selection only acts on phenotypes, therefore it has nothing to do with allele frequencies
3. What is the ultimate source of energy entering almost all ecosystems?
    a. fats
    b. carbohydrates
    c. heat
    d. sunlight

We evaluated the outcomes of the post-test with descriptive statistics and a paired-samples t-test. While our low sample size ($n = 7$) makes it difficult to draw strong inferences or have high confidence these results would be replicated, we feel it is important to evaluate the strength of SSI for conveying a positive learner experience (something that has been well documented in the prior research) *and* learning gains (which has not been well documented, particularly for teachers).

Pre and Post Understanding SSI Scenario Survey

As with the content test, graduate teachers were invited to complete the pre-survey on the first day of class, and the post-survey on the last day of class. The *Understanding SSI Scenario Survey* was developed to document change in participant ideas and beliefs regarding how they approach science in the classroom. This measure was based on an instrument developed by Brush and Saye (2014) to capture similar perceptions in problem-based historical inquiry. We first provided students with an image and medical case summary of an individual who developed a systemic infection from a piercing. The graduate teachers were asked to describe the relevant science concepts as well as potential ideas for teaching this content in the classroom. The second section consisted of four items related to the infection scenario that asked graduate teachers to rank potential classroom practices in order of instructional importance. Each practice represented either an inquiry or non-inquiry approach and related to one of the following four categories: 1) Learning Objectives, 2) Introductory Activities, 3) Instructional Activities, and 4) Assessment Activities. Figure 1 is an example of the item asking graduate teachers to rank learning objectives and provide a justification. In order to evaluate the changes in curricular decisions made by participants, we examined the differences in the ways the participants ranked choices between the pre- and post-survey responses through a descriptive trend analysis (Saye et al., 2009–2010). Numerical data from the survey were analyzed using descriptive statistics. Participants' initial responses to the survey were compared to their responses as they were completing the graduate courses. In addition, participants' responses to open-ended questions were analyzed qualitatively for further explanation of their rankings and selection of survey items.

Figure 1. Learning objective rank order and justification.

21. When developing a socioscientific inquiry unit related to the material presented in question 20 for your students, rank order the following **learning objectives** in terms of the importance of each for accomplishing your goals for this unit by placing a number corresponding to the item's importance in the right column.

Item Number	Learning Objective	Item Rank (1-6)
1	Students will describe the two major types of cells in living organisms, and give examples of organisms with each type of cell.	
2	Students will explain why antibiotics can kill bacteria, but are harmless to humans.	
3	Students will explain how the use of antibiotics contributes to the emergence of antibiotic-resistant bacteria.	
4	When accessing popular media reports of outbreaks of infectious disease, students will be able to infer the type of infectious agent, the source of infection, and make recommendations about preventing further infections.	
5	Students will be able to argue either side in a debate about regulations governing parlors that create body art (including piercings and tattoos).	
6	Students will describe the adaptations that allow some bacteria to live on skin, and explain why intestinal bacteria wouldn't be likely to survive on skin.	

22. Consider only your top three ranked choices from item 21. In the space provided, briefly explain why you ordered them in this way and why these three choices are preferable to the other possible selections.

Post-Course Focus Group

During the final class session of the semester, graduate teachers were invited to participate in a focus group designed to elicit strengths, weaknesses, and experiences of the courses. An outside researcher with no connection to the courses or the university conducted the focus group based on a semi-structured protocol developed by the researcher in concert with the instructors. They were asked about their overall experiences in the course, their specific processes developing their SSI units and accompanying action research projects, the implementation of their projects, and any suggestions for improving the experience (see Appendix A for the full interview protocol). The focus group lasted almost one hour.

We analyzed the focus group data with an interpretive framework that we pre-established to understand more about the strengths, weaknesses, and participant experiences within the course (Erickson, 1986).

Action Research Projects

The graduate teachers submitted an action research project to document their progress and implementation of their SSI instructional units. Graduate teachers were initially introduced to action research through readings from the course textbook (Mills, 2006), presentations by the instructors and in-class discussions. As practice, graduate teachers were asked to think about action research questions that could accompany each class meeting. Graduate teachers were then introduced to important concepts necessary for action research, including prior literature, assessment, types of data, and aligning the assessment methods with the action research question. The graduate teachers also had several opportunities to share their action research question with their peers, so that they could receive peer feedback. They submitted an action research proposal before initiating their action research projects, so that the instructors could provide pre-implementation feedback. Our analysis consisted of project review for insight into the meaning of SSI as it specifically relates to the participants' current and intended teaching practices.

Results and Interpretation

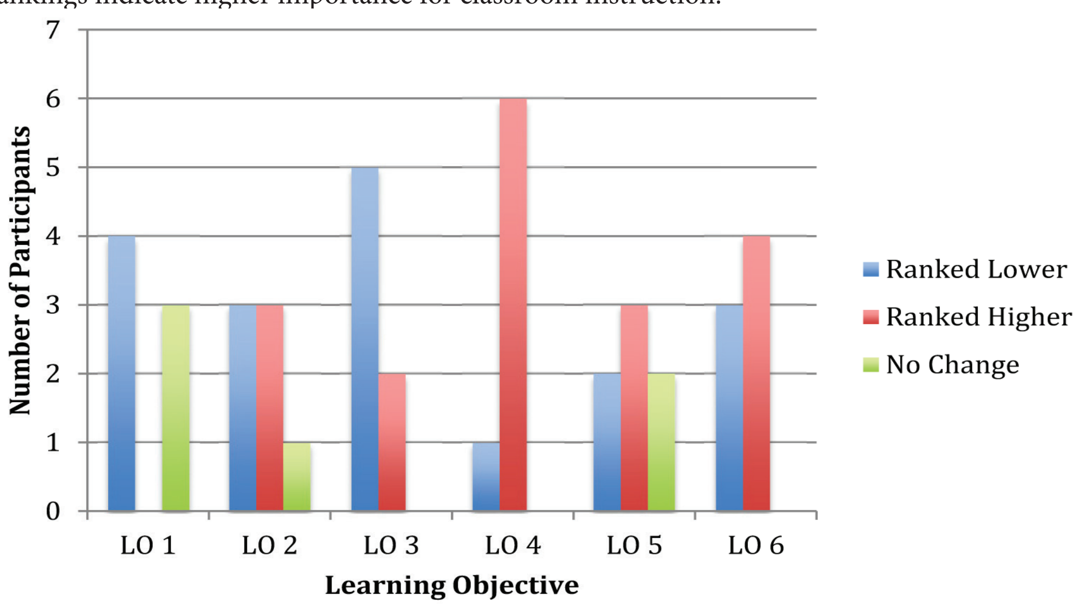
Content Test

The maximum score graduate teachers could have achieved on the content test was 19. The mean for the pre-test was fairly low, M_{pre} = 9.7, SD = 4.3, and there was a marked increase for the post-test, M_{post} = 12.6, SD = 2.8. A paired samples t-test revealed the gains were significant, p = .02, $t(6)$ = -2.9, and the effect size was moderately strong, r = .37. However, as noted above, our low sample size (n = 7) makes it difficult to draw strong inferences or have high confidence these results would be replicated.

Understanding SSI Scenario Survey

With the scenario survey, we performed a descriptive trend analysis for each of item to evaluate change in rankings from pre- to post-survey for each of the four categories: 1) Learning Objectives, 2) Introductory Activities, 3) Instructional Activities, and 4) Assessment Activities. We found no discernable trend of change in rankings from pre- to post-survey for Introductory Activities, Instructional Activities, or Assessment Activities; that is, in general, the participants' responses trended toward more of an inquiry orientation toward both

Figure 2. Pre- and post-rank order for learning objectives.
NOTE: Lower rankings indicate higher importance for classroom instruction.



the beginning and the end of the course. For the Learning Objectives category, we found a trend that indicated change in rankings for two of the items, as displayed in Figure 2.

This graph displays a ranking change trend from pre to post for between objectives three and four. In other words, on the post-survey, most students ranked objective three lower (more important) and ranked objective four higher (less important) than they had on the pre-survey. These two objectives are as follows:

> Objective 3: Students will explain how the use of antibiotics contributes to the emergence of antibiotic-resistant bacteria.
>
> Objective 4: When accessing popular media reports of outbreaks of infectious disease, students will be able to infer the type of infectious agent, the source of infection, and make recommendations about preventing further infections.

For the post-course survey, the trend was to rank the more inquiry-oriented learning objective as less important and the more knowledge-based objective as more important. This represents a curious finding. In order to gain insight regarding this shift, we turned to graduate teachers' justifications for their rankings both pre and post:

Key Pre-Survey Comments:

> In order to fully comprehend the topic, the students must understand how these antibiotics work—and sometimes, don't. This, of course, then begs the question of how bacteria work. That leads to an understanding of cellular biology in general, but the top priority should be understanding diseases. Tattoo parlors can wait a bit—they won't hurt you if you don't go in.
>
> I ranked item 4 first because it allows and promotes the greatest amount of creativity and critical thinking. Item 5 allows a fair amount of creativity and a large amount of research because the students have to defend one side. Items 6 and 3 involve little creativity, but a fair amount of critical thinking. Lastly, items 1 and 2 are generic textbook problems with little creativity.
>
> #4 I was torn between these I have no particular reason.

Key Post-Survey Comments:

> I chose 1–3 as my top choice b/c these seemed to have the most general forms of information that could be applied to many situations. I find it important to pick a RELEVANT topic for an SSI until in order to make the most impact on student learning and comprehension of a topic(s). #1–3 provided with essential general information that can be adapted to fit other areas of bacteria-related studies.
>
> #4 would be an intro to #5 and they would play hand in hand. #5 is important because it allows the students to realize that infection can happen from piercing and enables them to look for a prevention plan. #6 will force the students to argue on each side about the policies for parlors and body art shops. It allows them to think about the situation and debate about it.
>
> #3 is open-ended and also has great potential for a hands-on activity.
>
> I chose identification of the two types of cells as the most important because all the other discussions/investigations would need to be based on this knowledge. The second idea, understanding why antibiotics kill bacteria but not humans, seems to be the next step in moving to the third, which is actually extremely important to human survival.
>
> I believe it is important for students to know that there are different cells types in living organisms. Students have to be able to apply scientific concepts to societal application. Students should be globally aware and able to point out scientific concepts when they arise in society.
>
> Being that I teach 2nd grade, I believe that those will be enough for them.

When comparing the pre- and post-survey comments, we noted much richer justifications for their rankings in the following the course as opposed to before the course. However, we did not expect to observe ranking trends that prioritized knowledge-based over inquiry-based instructional objectives. In the post-survey, graduate teacher comments primarily centered on the importance of content knowledge. We hypothesize this stems from the fact that for most of the graduate teachers (with the exception of the high school biology teacher), their exposure to and expectation to learn the content was new and unexpected. When they struggled with the concepts or ideas, it likely highlighted a gap in their own foundational knowledge and led them to wonder how they could ever teach this content without deep understanding. It is possible this translated into a pattern of wanting students to know the content deeply as well. This is not a bad trend, and it points to one of our instructional assertions in the course: that deep content learning most effectively happens in inquiry-based settings. Furthermore, while we interpret this outcome as representative of the graduate teachers' value for deep content learning, we are not convinced they attributed this to the inquiry instruction they experienced. However, we do not assume that this finding means inquiry diminished in value for these participants, only that it diminished in importance as compared to knowledge.

Focus Group Summary

During the focus group, the researcher sought to elicit students' perspectives regarding strengths, weaknesses, and experiences within the SSI courses. We found that graduate teachers spoke to three general themes: the integrated nature of our curricular approach, the impact on their teaching, and recommendations for future iterations. Each of these is discussed in more detail below.

The Integrated Approach

Because we purposefully and intentionally modeled the SSI approach, made explicit that we expected content learning, and demonstrated technology as a resource, we asked specifically about graduate teachers' impressions of these facets of the course. Most were generally positive and one aspect they particularly liked was the intersecting methods of biology content and technology to support learning. For example, when asked about useful resources and support, one graduate teacher stated, "Most definitely the technology aspect. I understood what was going on with science so it was easy for me, but the technology aspects were all new to me and I loved it. Prezi, webquests, etc." Another concurred: "I agree with technology. I didn't like technology [before], but it was great for this. I was able to incorporate technology in my SSI units. I have done it before but not as focused previously. Technology and having models of SSI were most helpful."

However, some graduate teachers had difficulty framing how the integrated pieces came together, and they seemed to privilege one useful aspect over the others. Here are three different respondents discussing the value of the integrated approach:

> Most beneficial, I would say would be definitely the technology, the technology aspect for myself, because I felt that I guess she (the biology professor) was teaching some biology, but she really didn't have time to completely finish the topic. It was just like bits and pieces. . . . I understood what was going on, so it was beneficial for me the whole time, the science concepts that were presented, but the technology pieces of just different websites to use, different resources to use, the Prezi was a big thing for me. I really liked that, and I have my kids use that in class already pretty much like that next day, "OK. You (kids) are gonna do this." And WebQuests. Stuff like that that I've never used in class. I think it's just that for me was the most beneficial.

> See, I love biology. So, and I had a lot of biology in high school and early on. So, it was like a reminder for me, and I was totally engaged and interested in it, but what can I do with bacteria with my kindergarteners? Nothing. You know. So, it was like the model overall. . . . This is the process. This is what you can do. That was awesome, but the topic of bacteria in my classroom? No.

> My problem is, I am even a math person, but I am trying to figure out how I am supposed to present the data. So, maybe one of the classes can focus on that part a little more, a little harder, something. I mean, I get what data means, but it's just, in this paper, what's supposed to look like. I am sort of lost there.

These responses indicate a general appreciation for the approach, but also an attempt to separate all the integrated pieces and pull out the meaningful aspects from there.

Impact on teaching

All of the graduate teachers expressed that this experience had a positive impact on their teaching, though only the practicing teachers were able to experience this in an authentic manner directly related to their current practice.

> Biology Teacher: I only taught [my unit to] one section of genetics, and I think in general I know that I am going to redesign all of my courses to follow sort of this format, because it organizes me in my day today and in my unit. I felt through the incorporation of driving questions that really engage students in a way that I don't think I have seen before. It's almost like constructivist sort of way of doing things. As in, "This is what we're gonna do, but I am not gonna tell you how exactly we are gonna get there. It is your job to make sure we get there. And we are going to construct some of your own knowledge and I will be there to help you along the way." And I really felt that it enhanced my teaching method. So that's what I am taking from this course, and that's how about go about things from now on.

> 2nd Grade Teacher: In our classroom, my unit was on recycling and pollution in environment, and we are down from 3 full trashcans to a half can of trash and two bins of recycling goods. And I hear parents say their kids are forcing them. They [students] come to school and say

> 'I told my mom she had to get a plastic recycling bin for a house. Parents are actually going out and putting more effort towards their [students'] learning because kids are coming home and sharing why they need to do this and reason behind things. The societal impact that this is having, I am hoping this is gonna be huge... Like we pointed out [earlier], in elementary school 'oh, there's no time for science.' Well, it is very important to do science in lower grades. This course made me want to make time to teach science. I enjoy teaching science. I feel more confident.
>
> Kindergarten Teacher: I think with me I liked going into process of whole action research projects learning how to do a action research project and having the end goal in mind. Along with what [we] said about the driving questions, we pretty much established that in class so we will have the driving questions, which were yearlong questions, and then we have a smaller version of our question each week. We always continually revert back to our main driving question over, over, and over and kids started seeing a connection that all the stuff that we talked about science is all connected somehow. I really liked the driving question idea and I liked the idea of how to do action research even if I don't formally do action research. It's in my class now. If there's an idea, I will go through and review the literature first of all and try to come up with what other people did. And then, I really liked the idea of SSI unit where it socially relevant. It is socially relevant learning and it's not just making them have higher test scores or do better on standardized assessments. I am making an impact something in their lives that's important, like life skills in academic fashion. I like that. . . . You know, if you go to any of my district meetings or anything, it's like 'No, there's no time for science, no time for science.' They are not supportive. So, this class gave me more confidence to want to teach it more, and knowing that there is a lot of support for science in elementary school.
>
> Community College Instructor: I am actually planning a course now if I can get a permission to teach it where it's astronomy and biology that's dual taught. I see myself using these methods a lot.

Each elementary and secondary teacher's comments demonstrate a deep and nuanced understanding of the "how" and "why" related to SSI. Not unexpectedly, however, those not currently practicing had a more difficult time expressing similar impact on their teaching:

> Math Teacher: I am secondary math. I am seeing through this class more possibilities to spread into biology. You know, interdisciplinary. They talk about exponential growth. They cover it a little, but I think there's a lot more that could be tied in.
>
> District Resource Teacher: For me, the driving question and then presenting the driving question was valuable. I mean I am really thinking about 'Well, OK. I don't know what really do with science part' and then I got the science part without really thinking about doing science. So, I think that was the important part for me. The driving question that I know that I am gonna use here and now.
>
> Doctoral Student: Yeah, probably the most useful that I garnered from [this class] was how to start a website and I doubled biology knowledge in the first day, so, biology was good, and website start up was good.

The math teacher expresses a desire to integrate interdisciplinary approaches, but does not have an immediate context for this discussion. The doctoral student, who was previously a health educator, does not have a context for longer range curriculum planning or integrated delivery of instruction, so it is not surprising that her experiences discuss some of the more surface, yet highly relevant to her, benefits. For the district resource teacher, she discusses using the driving question approach to curriculum "here and now," which we interpreted to mean she intends to encourage this approach among the teachers she supports.

Participant recommendations

While all of the graduate teachers expressed value in the course experience, they suggested a number of ideas to improve the course. Graduate teachers had a difficult time with the Action Research project. An idea that took hold early in the course was that the driving question for the SSI unit was the same as the overarching question for the Action Research project. No matter how we tried to reframe the separate but connected aspects of these two requirements, participant misunderstandings persisted *even after submission* of the Action Research project:

> The definitions are extremely vague. 'What is SSI? What is action research?' These are not definable concepts.
>
> Well, I didn't have any confusion on what they were. But I did feel like when I tried to plan what my SSI was gonna be, I also had, in my mind, I needed to put them together. They told me that . . . they are two separate things. So, I guess my feeling would be, my recommendation would

be to recognize that some people have a big picture at the end and they need to work backward to it how these two pieces are gonna fit together to make a picture.

I wasn't able to separate them, yeah.

An example or two of what exactly they are talking about (SSI and AR) would be kinda handy. I like to work from examples. It's just a vague concept.

[Action Research is] something that I will be never going to use in my classroom, not because it's not useful but because there's no time for me to do it.

[Action Research] is not something I will use it in my classroom because of time, but I know the process now.

Only one graduate teacher expressed a deep understanding of the connections between trying something new in teaching and systematically investigating an question of relevance regarding the new approach: "I really liked the driving question idea and I liked the idea of how to do action research even if I don't formally do action research. It's in my class now. If there's an idea, I will go through and review the literature first of all and try to come up with what other people did."

Other ideas centered on the logistics of the course, such as posting scoring rubrics or putting systems into place regarding the availability of the equipment and resources we modeled during the course. We mentioned these resources were available for use during the course or after, but failed to implement a reliable system for check-out, as one participant noted, "[I] liked the availability of the resources. The other stuff was available and it was a good thing but I'm not sure how they were used." Another individual similarly discussed this: "I had to make a special trip to get [the clickers] and it was difficult logistically. More would have been borrowed if they were easier to access."

Participant action research projects

Table 1 summarizes each participant's SSI project approach by detailing the SSI question, the action research question of investigation, and the implementation summary. Because we emphasized the SSI model, it was an important goal for the projects to incorporate science in a meaningful way. Because only four participants were practicing teachers, those not actively practicing (such as the education doctoral student and

Table 1. SSI project and implementation summary.

Participant	SSI Project	Action Research Project Title	Implementation Summary
High School Biology Teacher	Who owns your DNA?	"Two Heads Are Better Than One": An Evaluation of Group Assessment	One-week implementation with 3 biology classes
Special Education Teacher (district-level math specialist)	What's in your brain?	How does Teaching Style Affect a Learner?	Three-day implementation with an honors biology class
Education Doctoral Student (non-licensed community educator)	Why is diabetes prevalent in our community?	A Socio-scientific Inquiry Unit of Culturally Relevant Approaches to Teaching the Native American Student the Issues of Diabetes in their Community	Multi-grade high school science class at a pueblo high school over the course of one week
Community College Astronomy Instructor	What do high-energy objects tell us?	Team Based Learning in a Community College Class	Implementation in one 3-hour class session
Kindergarten Teacher	What does the environment mean to us?	Environmental Education and Its Effect of Pro-Environmental Behaviors at Home	Semester-long implementation with kindergarten course
Second Grade Teacher	Should I Leave That Light On?	Preoperational Stage and Content and Scientific and Social Awareness	One-week collaborative implementation with a second-grade class
Secondary Mathematics Teacher (certified, full-time graduate student)	Should I Leave That Light On? (taught in collaboration with the second grade teacher)	Should I Leave That Light On?: Perceptions of Electricity and its Conservation	One-week collaborative implementation with a second-grade class

the district-level math specialist) sought partner teachers for their implementations, though it was the participants who delivered the primary instruction, not the partner teachers. Two of the graduate teachers collaborated on the co-planning and co-teaching of their SSI unit ("Should I Leave That Light On?").

Participants asked a wide range of questions about their practice for the focus of their action research projects. When we examined their action research narrative reports, we were especially interested in signals of change to the graduate teachers' practice and indicators of intention to sustain practice when it came to use of SSI, as described in more detail below.

Signals of change

Several teachers highlighted changes to their practice. Two of the teachers spoke of their change explicitly, and used the metaphor of *vehicle* to discuss their change: the biology teacher and the district specialist.

> Change is never an easy undertaking. The way we have always done things tends to get easier and easier, so as creatures of habit, change is taboo. This semester I had the opportunity to become a social scientist and my classroom was the arena in which my experiment took place. I have been teaching science education for 14 years, this semester my journey into the realm of change was challenging on several levels [sic]. I had to put myself and my methods under the microscope, and my self-examination can at times be crucial as I am my toughest critic (biology teacher, AR report, p. 2).

She then went on to describe SSI as a method that facilitated change in her practice and action research as "the vehicle" (biology teacher, AR report, p. 2) used to examine her change. The district math specialist was a former special education teacher, so was used to trying new things and working within a cross-disciplinary manner in her practice. She said that inquiry was a natural component of her teaching. Her action research project focused on wanting to know more about learning styles. She noted that she had over 20 years' experience teaching, and that it she consistently valued trying new things. In fact, hers was the only report to include a heading entitled "Change of Practice." One outcome for her project was a deeper understanding of the role of technology and its role as a vehicle for change in her practice:

> One of the things important to the children of these times is teaching with technologies. The students of today are headed into a futuristic world. The power point, clickers, and video technology used here may, in the next decade, be seen as relics of a simpler time. Those of use who are middle aged will never respond to technological inventions with the same fearlessness as the young do today… I would hate to see the gap between mature teachers and their students widen. We need to be flexible because we are preparing students for jobs that have not been created in the marketplace that has not yet been invented. This point became clear to me while conducting this research project (district specialist, AR report, pp. 10–11).

Three graduate teachers undertook investigations to understand how their SSI classroom practices might impact behaviors at home: the kindergarten teacher and the second grade teacher working in collaboration with the secondary math teacher, each noting this is something any of them had tried before. All three reported the type of outcomes they had hoped to observe when they interpreted the results from the student self-report of home behaviors and activities, which represented a "risk" and "something never tried before." The kindergarten teacher compared her results to those of the three other non-SSI kindergarten classroom outcomes on the same measures. For example, she reported "a 16% increase in pro-environmental behaviors at home" when comparing her results to the other kindergarten respondents. She also noted that 19 out of 20 of her students met Kindergarten Benchmarks in reading and math, though it is unfortunate she did not indicate the benchmarks rates for the comparison class. She reflected on her observed outcomes stating, "These assessment pieces were critical to my research because they demonstrate a high-percentage of proficiency in reading and math while I simultaneously focused my instruction on Science" (kindergarten teacher, action research report, p. 16).

It is important to note that not every graduate teacher signaled change in his or her practice through the action research projects. The full-time education doctoral student was formerly a community educator without any prior teaching experience in formal settings. It is likely that she did not signal any changes to her teaching practice because she did not have prior practice to compare it against. The community college instructor did not implement a true SSI unit in his classroom; rather, he changed one content topic and added a team-based component to it. The result was a change in one aspect of his practice, but nothing he noted as significant in his action research narrative.

Indicators of sustained SSI practice

Almost every graduate teacher indicated that the changes in their practice as a result of this experience would be sustained over time. As the district support individual noted, "it leads to the conclusion that *all* lessons should include tasks [like these]" (district specialist, AR report, p. 12). Similarly, the high school biology teacher outlined a future plan that included restructuring all her courses to include SSI, assisting other teachers with course changes, integrating more technology, and developing a website that will include "the driving question for each of the units that we will be covering in the class" (biology teacher, AR report, p. 14). She further wrote, "As stated before change is never easy, however I believe that I underwent a change in teaching style and method which was positive [*sic*]. Action research provided the vehicle to induce this change. The development of the socio-scientific unit as a means of action research was extremely interesting and gave me a different outlook on lesson delivery and teaching methods" (biology teacher, AR report, p. 14).

The three teachers of elementary students (second grade and kindergarten) indicated they experienced tremendous value in this experience primarily based on of the learning gains and student outcomes as a result of the SSI approaches they tried. The second grade teacher stated, "I am satisfied with the results of my research. I was able to answer the questions I had. [My] students are as capable as other students to be responsible energy users. They are also capable of becoming more environmental aware and they can transfer content knowledge to their personal lives" [*sic*] (second grade teacher, AR report, p. 10). Similarly, her collaborating partner teacher wrote, this unit was very successful in its purpose of modifying the attitudes and behaviors of students. In summary, this action research project indicated that energy (in our case electricity) education and energy conservation education played a part in the attitudinal and behavioral modifications in students" (secondary mathematics teacher, AR report, p. 17). The kindergarten teacher spoke about not only the need to continue her SSI work and potentially convince the other kindergarten teacher to adopt these methods: "My research encouraged me to persuade others to adopt this teaching method as well" (kindergarten teacher, AR report, p. 16).

While the education doctoral student did not indicate changes to her practice (as we discuss above), we did note signs of her promoting SSI methods when given future opportunity to do so, and she spoke about the importance of her project because of the gap that exists in understanding the types of approaches that work best with Native American learners. She wrote,

> The Action Research Project that was implemented through a socio-scientific inquiry unit was primarily integrating science and culture in the classroom. I had a difficult time with this project because I couldn't find much published literature specifically on science education, science performance, and health knowledge of Native American students. Although I didn't have the literature as a foreground, I was fortunate enough to find a school and a class that was willing to implement the Action Research plan in the classroom. Based on the data and the results we find that student interest increased. The surveys were a great tool for gaining insight from the students. Although this was a well-thought out project, I fell that there is room for improvement. Time seemed to be a big issue for me. This was my first time teaching a class but also my first time trying to change something in someone else's classroom. I am fortunate that the teacher I was working with was receptive to the project and the findings. I would definitely like to assist other teachers in implementing culturally based curriculum in their classroom" [sic]. (education doctoral student, AR report, pp. 12–13)

Discussion

In this investigation, we sought to understand the learning experiences of graduate teachers within the case of redesigned courses aimed at preparing teachers to implement SSI approaches in the classroom. Data was collected to measure changes in science content knowledge, perceptions of SSI instruction, strengths of the experience, and recommendations for future refinements of the approach to teacher development.

With regard to changes in graduate teachers' knowledge of biology content, not only were the scores significantly higher following their experience in the course, but every teacher demonstrated improvement from pre- to post-test. This represents an important first step in understanding both how we prepare teachers for SSI methods, but also how we boost content understanding in the process. One limitation of the current body of research on SSI methods is that researchers have generally prioritized investigations of student inquiry, problem-solving, argumentation, and reasoning (see for example Sadler, 2009; Sadler, Barab, & Scott, 2007; Walker & Zeidler, 2007). Furthermore, researchers have not typically acknowledged the role of teacher content knowledge in this context. Our approach suggests that within the current models for teacher education, teachers with a weak knowledge base can achieve important learning gains. However, we acknowledge that our model emphasized only the content area of biology, which is a limitation for teachers needing broader experiences in other content domains.

As we further consider the role of the content knowledge in our model, we also noted that teachers tended to prioritize content over inquiry-focused objectives in the pre- and post-scenario survey. Furthermore, we did not observe any other discernable trends of rankings for the other types of instructional activities. Because the content was new for most of the teachers, we hypothesized that teachers felt both uncomfortable with their lack of knowledge, and within this position, they prioritized knowledge integration over inquiry investigations. This underscores the notion that teacher change is difficult, and does not happen easily or within a defined time frame of a semester. For example, Brush and Saye (this issue) found differences in preservice teacher prioritization of inquiry-based activities when compared to more traditional ones, but these changes occurred over a two-year period of time. These results suggest that teacher change is involved, lengthy, and impacted by a variety of influences.

In our case, we noted that most teachers likely felt pressure to develop expertise with previously unknown content, and only one teacher had previous expertise in our modeled SSI topic as a high school biology teacher. While we were encouraged to find significant knowledge gains on the pre- to post-test comparison, we also hypothesize that the shift in emphasis on something different from the teachers' own expertise likely highlighted their own lack of knowledge and amplified the importance of deep content knowledge. Almost thirty years ago, Shulman (1986) began to explore this relationship between content knowledge and pedagogical approaches, which is when he coined the term pedagogical content knowledge (PCK). Using the PCK framework as a guide for interpretation, we might consider that is not likely that graduate teachers can enact complex pedagogical approaches like SSI when they lack deep knowledge that would enable them to understand the disciplinary organization that includes both substantive and syntactic structures (Shulman, 1986).

However, Shulman's framework does not reflect other primary findings in this study: most teachers signaled changes in their practice and communicated intent to sustain those changes, which we see as an indicator of perceived value for inquiry. In fact, when we consider the full range of outcomes in this study, we observed indicators for both the value of content and the value of inquiry. The fact that the graduate teachers demonstrated knowledge gains and detailed positive perceptions of their SSI experiences confirms both that these types of experiences are valuable in professional development and can also lead to knowledge gains. We cannot know from this study if the graduate teachers sustained their SSI practices, but the model we have presented reflects an important first step. We attribute this to the modeling, online tutorials, and workshop experiences that fostered opportunities for the teachers to learn from us both content and SSI approaches. We contrast our findings with those of Sadler et al. (2006) in which participants noted several challenges toward SSI implementation, including resources and training. Providing a wider range of experiences and input may be a key.

We also consider the outcomes of the action research investigations that provided the platform for them to systematically examine their practice of SSI. However, we acknowledge that deeper expressions of understanding regarding and intentions toward using SSI approaches in the future came from those teachers currently practicing in the classroom. Connected to this, it is worth noting that teachers expressed some degree of frustration with the action research requirement, suggesting that it did not fully serve to support their pedagogical risk-taking as we had hoped. We consider that their experience demanded a lot of them when to came to learning both new content and a new pedagogical approach, and perhaps too much than could be expected within the span of one semester.

Recommendations

As a result of this work, our recommendations fall into two primary categories: making explicit the connection between SSI and content knowledge building, and maximizing use of collaborative action research for SSI professional development.

Making Explicit the Connection between SSI and Content Knowledge Building

While the teachers gained significant biology content knowledge as a result of their participation in our program and they experienced success with their SSI implementations, we were left with questions regarding their actual capacity for sustained SSI use over time. The teachers expressed more value in their participation as students of SSI over their participation as teachers utilizing SSI methods. We suggest that in these types of settings, SSI facilitators can do more to engage teachers in the processes of reflection as they are modeling the techniques. Krajcik and colleagues suggest that it is the modeling accompanied by time for reflection and feedback that yield the most meaningful kind of experience for teachers (Krajcik, Blumenfeld, Marx, & Soloway, 1994).

We also observe that modeling, while tremendously effective, cannot do the work of demonstrating actual classroom practice and the range of associated techniques with a given innovation or approach. Additionally, our success with the six online tutorials toward SSI development was encouraging, but not likely enough to sustain changes in practice. The goal of sustaining practice in SSI has also been noted by other teacher educators as a persistent concern (Eastwood et al., 2012; Ekborg et al., 2013; Kara, 2012). We suggest that online community building and videocase modeling holds tremendous promise for promoting both the SSI model as well as common practices as within actual classrooms. While a videocase library does not yet exist for SSI practice, we note other successful videocase libraries in other domains. For example the *Persistent Issues in History Wise-Practice Case Database* (Brush & Saye, in press) consists of a library of cases spanning upper elementary through secondary classrooms, representing a wide range of content topics, and capturing the practices of over 20 teachers. Each case is indexed according to distinct and specific practices (such as "attention grabbers" or persuasive presentations), and users can access both video demonstrations as well as classroom materials developed by the teacher to accompany the cases.

Maximizing use of Collaborative Action Research for SSI Professional Development

While we observed that the teachers' project narratives were deep, meaningful, and reflective of important instructional practices in SSI, the teachers questioned the value of the action research projects as contributing to their overall success with SSI approaches. We hypothesize that they likely felt overwhelmed by too many things at once: new content and new pedagogy. When we reflect on other researchers' use of collaborative action research, we note that common to their success was a setting in which teachers selected their own topics for investigation out of their *own current practices.* In other words, the teachers' goals for taking risks and making changes to their practice were fore-fronted, not a defined projects' goals (e. g. Capobianco et al., 2006; Capobianco & Joyal, 2008; Capobianco & Feldman, 2006; Valanides et al., 2003). We recommend that teacher voice and choice may need to be made more central throughout the SSI process.

In addition, we suggest that time was a factor hindering the effectiveness of collaborative action research in the development toward sustained SSI practices. The two-course sequence in this case was bundled within the same semester, though there would be no reason why it could not be divided over the course of two semesters. Doing so would alleviate the burden placed on the teachers during the simultaneous learning of content, SSI approaches, and action research models. A two-semester model may lose participants to attrition, but make it more manageable for teachers to focus on content learning, SSI approaches, and planning in semester one along with research planning, SSI implementation, and collaborative action research investigation in semester two. In this way, the courses would stay coupled, but not bundled within the same semester. This would likely yield a more meaningful experience sustained by greater mentoring and support, more time to reflect on new practices, and more time for development.

Implications for Research

In this study, we have documented some key findings: namely, the ability of SSI to promote increased content knowledge among teachers, change in teacher practice toward SSI, and the successful implementations of SSI in a wide range of settings. However, the strength of these findings are curbed by the low number of participants, which not only diminished the power of our research model, it also changes the nature of the interaction between the instructors and the participants. The low student-to-instructor ratio meant each student received significant input and individualized attention, which is not always possible in larger courses. Therefore, we suggest that future research should investigate if these types of changes occur in other settings and with larger numbers of participants. Furthermore, future research should follow up with teachers beyond the course or workshop experience to investigate structures that support sustained SSI over time. We have also mention the need for more examples of SSI in practice, different examples in other content areas, and videocase modeling that would capture the work and practice of teachers. Finally, we need greater mechanisms for supporting the increase of teacher science knowledge within the elementary school grades.

Conclusion

With the new Next Generation Science Standards (NGSS Lead States, 2013), there is a need for the integrated and synthetic teaching of science that is supported by SSI. Curriculum designers, organizers of professional development workshops and science resource specialists have the opportunity to support teachers to fully leverage the NGSS to improve student learning of science. Incorporating and sustaining SSI practice seem to rely on the capacity to form durable teams of teachers who can cooperatively reflect and discuss on their teaching. What we have documented with this study reflects a range of approaches that may lead to sustained SSI practice and success.

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Appendix A

Focus Group Questions for Teachers

1. Discuss the types of curriculum projects you have been developing and implementing for your classes through your participation in this class.
   a. What topics/content are you covering in these projects? How did you go about selecting these topics?
   b. What new things did you try in your instruction as a result of this course? What risks did you take?
   c. Have you been able to implement all (or part) of your projects with your students? If so, what has been he reaction of your students towards your project(s)?
   d. If you have been able to implement your project(s), what evidence do you have that the projects have been effective in terms of positive student learning outcomes?
2. Discuss the process you went through in developing the curriculum projects for your class.
   a. What types of resources/instructional support did you find most (and least) useful as you developed your projects?
   b. If you have been able to implement your projects with your students, what aspects of the class have you found most beneficial in helping prepare you to actually teach your units?
   c. What advice/suggestions would you give to the course instructor(s) to improve the overall effectiveness of the class itself?
3. Discuss how the development and implementation of your projects have impacted your knowledge of science.
   a. Do you believe that participation in this class has positively impacted your overall knowledge of science content? If so, how?
   b. Do you believe that participation in this class has helped you feel more confident to teach science to your own students? If so, how?
   c. Do you believe that participation in this project will influence the amount of science content you include in your curriculum in the future? If so, how?
4. Are there any other comments/suggestions you would like to provide to the instructors/project staff?