Facilitating Preservice Teachers' Socioscientific Issues Curriculum Design in Teacher Education

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Abstract

Socioscientific issues (SSI) are contentious and ill-structured societal issues with substantive connections to science, which require an understanding of science, but are unable to be solved by science alone. Consistent with current K-12 science education reforms, SSI based teaching uses SSI as a context for science learning and has been shown to offer numerous student benefits. While K-12 teachers have expressed positive perceptions of SSI for science learning, they cite uncertainty about how to teach with SSI and lack of access to SSI based curricular materials as reasons for not utilizing a SSI based teaching approach. In response to this need we developed and taught a multi-phase SSI Teaching Module during a Science Methods course for pre-service secondary teachers (PSTs), designed to 1) engage PSTs as learners in an authentic SSI science unit; 2) guide PSTs in making sense of an SSI approach to teaching and learning; and 3) support PSTs in designing SSI-based curricular units. To share our experience with the Teaching Module and encourage teacher educators to consider ways of adapting such an approach to their pre-service teacher education contexts, we present our design and resources from the SSI Teaching Module and describe some of the ways PSTs described their challenges, successes, and responses to the experience, as well as considerations for teacher educators interested in introducing PSTs to SSI.

Introduction

Socioscientific issues (SSI) based teaching is a pedagogical philosophy consistent with current reform movements in K-12 science education (Zeidler, 2014b). SSI are societal issue[s] with substantive connections to science ideas (Sadler, Foulk, & Friedrichsen, 2017, p. 75), which lack structure, are controversial in nature, and for which science understanding is necessary but insufficient to offer complete solutions (Borgerding & Dagistan, 2018; Kolstø, 2006; Owens, Sadler, & Friedrichsen, 2019; Simonneaux, 2007). Because they are values-influenced, lack clear solutions, and bear significant, and often conflicting, implications for society, SSI tend to be contentious (Zeidler, 2014a).

Studies of SSI-focused learning contexts have identified many learner benefits. Students who participated in SSI-based learning experiences have demonstrated gains in understanding of science ideas (Dawson & Venville, 2010, 2013; Sadler, Klosterman, & Topcu, 2011; Sadler, Romine, & Topçu, 2016; Venville & Dawson, 2010), nature of science

(Khishfe & Lederman, 2006; Lederman, Antink, & Bartos, 2014; Sadler, Chambers, & Zeidler, 2004); and scientific practices, such as modeling (Peel, Zangori, Friedrichsen, Hayes, & Sadler, 2019; Zangori, Peel, Kinslow, Friedrichsen, & Sadler, 2017) and argumentation (Venville & Dawson, 2010). Beyond these traditional learning outcomes, studies have also identified benefits such as improved reasoning skills (Kolstø et al., 2006; Sadler et al., 2004; Sadler & Zeidler, 2005; Zeidler, Applebaum, & Sadler, 2011); moral, ethical, and character development (Fowler, Zeidler, & Sadler, 2009; H. Lee, Abd‐El‐Khalick, & Choi, 2006); and increased enthusiasm and interest within science learning contexts (M. K. Lee & Erdogan, 2007; Saunders & Rennie, 2013).

The role of classroom teachers is of primary importance in facilitating reform-oriented learner experiences (Bybee, 1993) such as those based on SSI. Research has revealed that many classroom teachers hold favorable perceptions of SSI; however, despite some K-12 science teachers' recognition of potential benefits to learners, and acknowledgements of the subsequent importance of incorporating SSI into science classroom contexts, research indicates that K-12 science teachers struggle to incorporate an SSI-focused pedagogy in their classrooms, and those who utilize SSI tend to do so infrequently and superficially (H. Lee et al., 2006; Lumpe, Haney, & Czerniak, 1998; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006; Saunders & Rennie, 2013). Three notable explanations for teachers' omission of SSI-focused activities from their classrooms are: teachers' unfamiliarity, lack of experience, and/or discomfort with an SSI-focused teaching approach (H. Lee et al., 2006; Sadler et al., 2006; Saunders & Rennie, 2013); teachers' limited access to SSI-focused curricular resources (Sadler et al., 2006); and discrepancies between teachers' perceptions of SSI and the philosophical basis of the pedagogy (Hansen & Olson, 1996; H. Lee et al., 2006; Sadler et al., 2006).

While a small number of prepared curricular resources for SSI have begun to be made available to teachers (cf. Kinslow & Sadler, 2018; Science Education Resource Center; The ReSTEM Institute; Zeidler & Kahn, 2014a), practical access to SSI curricula remains limited. Literature around SSI features an array of project-specific SSI-focused curricular resources on a variety of topics (Carson & Dawson, 2016; Christenson, Chang Rundgren, & Höglund, 2012; Dawson & Venville, 2010; Eilks, 2002; Eilks, Marks, & Feierabend, 2008; Friedrichsen, Sadler, Graham, & Brown, 2016; Kolstø, 2006; Lederman et al., 2014; H Lee et al., 2013; Peel et al., 2019; Sadler & Zeidler, 2005). However, only very few of the studies (Eilks, 2002; Friedrichsen et al., 2016; Zeidler et al., 2011) have focused on the process or products of SSI curricular design and the curricula from this research generally have not been distributed for classroom use. In addition, research has demonstrated the potentially transformative power to teachers of engaging in the design of reform-oriented, including SSI-focused, curricular resources (Coenders, Terlouw, Dijkstra, & Pieters, 2010; Eilks & Markic, 2011; Hancock, Friedrichsen, Kinslow, & Sadler, 2019; Zeidler et al., 2011).

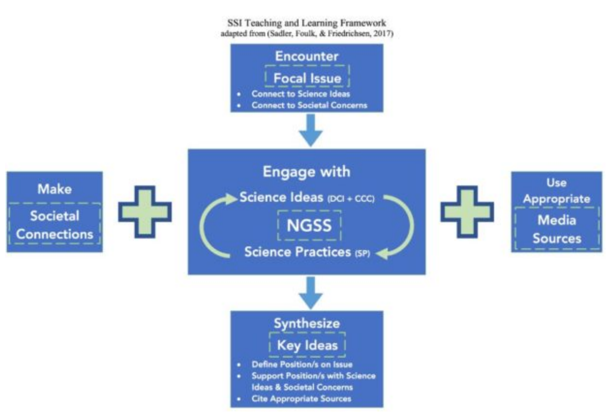
In view of the demonstrated discrepancy between teachers' perceptions and enactment of SSI; limited access to SSI curricular resources; the transformative value of engaging in reform-oriented curricular design; and the potential of SSI-based pedagogy to promote reform-oriented learning experiences; we view supporting teachers in the design of SSI-oriented curricula as a promising approach to educational reform. This project reflects that view. We sought to support pre-service science teachers (PSTs) in their uptake of SSI-based teaching in a Science Methods course through our design and teaching of an SSI Teaching Module intended to: 1) engage PSTs as learners in an authentic SSI science unit; 2) guide PSTs in making sense of an SSI approach to teaching and learning; and 3) support PSTs in designing SSI-based curricular units. The purpose of this paper is to describe our Teaching Module and share related resources with teacher educators, as well as to provide some examples of PSTs' challenges, successes, and responses to the experience. It is our hope that the Teaching Module will serve as an inspiration for teacher educators interested in supporting future science teachers' uptake of SSI.

SSI-TL – A Framework to Operationalize SSI-Based Pedagogy

Our group has developed the *SSI Teaching and Learning* (SSI-TL) *Framework* (Sadler et al., 2017) for the purpose of supporting teachers' uptake of SSI-based teaching. Intended as a guide for classroom teachers, the SSI-TL framework highlights elements we consider to be essential to teaching science with SSI, while also remaining highly adaptable to various subdisciplines, courses, and classroom contexts in K-12 science education. SSI-TL is one instantiation of SSI-based teaching, developed from multiple projects that utilized research-based SSI frameworks featured in previous literature (Foulk, 2016; Friedrichsen et al., 2016; Klosterman & Sadler, 2010; Presley et al., 2013; Sadler, 2011; Sadler et al., 2015; Sadler et al., 2016). This project contributed to the development of SSI-TL, and we drew from an intermediate version of the framework throughout the project (See Figure 1).

Figure 1 (Click on image to enlarge)

SSI-TL Framework



SSI-TL specifies requisite components of SSI-based learning experiences, the sum total of which are necessary for a complete SSI-TL curricular unit. Such a unit consists of a cohesive, two- to three-week sequence of lessons designed around a particular SSI, to promote students' achievement of a defined set of science learning objectives. Within any SSI-TL curricular unit, a focal SSI is foregrounded in the curricular sequence and revisited regularly throughout the unit, in order to serve as both motivation and context for learners' engagement in authentic science practices and sensemaking about science ideas. A continuous focus on the selected SSI also guides students in exploration of societal dimensions of the issue; that is, the potential impacts of the issue on society, such as those of a social, political, or economic nature. Participation in an SSI-TL unit is intended to engage students in sensemaking about both the relevant science ideas and the societal dimensions of the issue. Student learning in SSI-based teaching is assessed with a culminating project in which learners synthesize their understanding of scientific and societal aspects relevant to the issue. In this project, our intermediate version of the SSI-TL framework served as both a representation of SSI-based teaching and a tool to support PSTs' uptake of the approach.

The SSI Teaching Module in a Methods Course

Project Context, Goals, and Audience

The project described in this paper consisted of a six-week SSI Teaching Module that was implemented during a semester-long Science Methods course for secondary PSTs. The Science Methods course was the last in a sequence of three required methods courses in an undergraduate secondary science education program, and occurred immediately prior to the student teaching experience. The focus of the 16-week course was curricular planning and development, and the primary course goal was that PSTs would be able to design a coherent secondary science curricular unit, consisting of a two- to three-week sequence of related lessons organized around selected NGSS performance expectations. The purposes of the six-week SSI Teaching Module were to facilitate PSTs' familiarity with SSI-based teaching; to explicate and challenge, as appropriate, PSTs' perceptions about SSI; and to promote PSTs' learning about SSI-based science teaching, as evidenced by their ability to develop cohesive science curricular units consistent with the SSI-TL framework.

A cohort of 13 PSTs in their final year of undergraduate coursework completed the SSI Teaching Module during Fall 2015. The first author developed and taught the SSI Teaching Module and the Science Methods course and conducted assessment of PSTs' work in the course. The second author served in an advisory capacity during design, enactment, and assessment phases of the Teaching Module and Methods course. Both the second and third authors served as advisors during the writing stages of the project.

Project Design

The SSI Teaching Module consisted of three distinct phases, in which PSTs engaged with SSI-based science education from the perspectives of *learner*, *teacher*, and *curriculum maker.* (See SSI Teaching Module Schedule, below). In the first phase of the SSI Teaching Module, PSTs participated as learners of science in a sample secondary science unit designed using the SSI-TL framework, learning science content which was contextualized in an authentic SSI. (See SSI units for secondary science at our project website: http://ri2.missouri.edu/ri2modules.) In the second phase of the SSI Teaching Module, the PSTs spent time considering their SSI learning experience, this time from a teacher perspective, with explicit attention to the SSI-TL framework and key components of the sample SSI unit. Finally, in the third phase, the PSTs created SSI-based curricular units for use in their future secondary science classrooms. In all phases of the SSI Teaching Module, PSTs were asked to engage in personal reflection about their perceptions of SSI and its potential utility in their future teaching practice, with various writing prompts used during class, reflective writing assignments, and in-class discussion. More detailed description of each phase of the SSI Teaching Module follows (See Table 1).

Table 1 (Click on image to enlarge)

SSI Teaching Module Schedule

Time Period	Focus	Sample Activities
Phase 1: Weeks 1-3	Learning Science with SSI: PSTs participated in lessons from a sample SSI nutrition unit as learners of science content	Introduction of "fat tax" issue, class discussion leading to awareness of questions of both scientific and societal natures, to be explored and answered in subsequent lessons
		Exploration and sensemaking of relevant scientific and societal dimensions of the issue
Phase 2: Week 4	Teaching Science with SSI: PSTs discussed the design and teaching of the Phase 1 experience	Introduction of the SSI-TL framework and comparison to sample unit plans
		Collaborative analysis of externally created SSI curricula
Phase 3: Weeks 5-6	Curriculum Design with SSI: PSTs created and shared designs for SSI-focused curricular units	Co-creation of unit assessment rubric
		Reviewed & provided feedback to peers for SSI curricular unit drafts
		Created SSI curricular units for submission at end of course

SSI Teaching Module – Phase 1: Learning Science with SSI

The first phase of the SSI Teaching Module focused on PSTs' engagement with a sample SSI-TL unit. The sample unit was developed for an Advanced Exercise Science course at the secondary level, using NGSS standards relevant to the topic of energy systems, and presented through a nutritional science lens. The focal SSI for the nutrition unit was taxation of obesogenic foods. The SSI nutrition unit, as representation of the SSI-TL approach, engaged PSTs in several learning activities appropriate for incorporation into their own secondary-level SSI curricular unit designs. During this phase PSTs explored societal dimensions of the issue and engaged in sensemaking about the relevant science ideas, just as secondary students would do. Find the complete "Fat Tax" SSI-TL unit plan on our project website: http://ri2.missouri.edu/ri2modules/Fat Tax/intro.

The nutrition focus of the sample SSI unit was purposely selected for several reasons. First, this choice of topic leveraged the first author's personal background and interest in nutritional sciences. Second, a pair of teaching partners in a local secondary school had approached the first author for help with preparing a unit for a new course they would be teaching. Finally, this topic offered opportunities for the methods students who had content backgrounds in different science disciplines to see the integration of diverse science ideas, and to build upon their own content knowledge. The SSI nutrition unit and the secondary course for which it was prepared represented authentic possibilities for PSTs' future teaching assignments.

As specified in the SSI-TL framework, the SSI nutrition unit was introduced with a focal SSI. PSTs began by reading an article about a proposed "fat tax," and were then asked to articulate and share ideas about the issue, providing reasoning to support their positions. Various positions were proposed, and a lively discussion followed. "Henry," who had previously worked in a grocery store, shared initial support for the tax, justified by his personal observations of patterns in consumer buying habits. "Gregg" pushed back on what he considered to be stereotyping in Henry's example, and argued that taxation of groups of food items toward controlling consumer choice was not within the purview of government agencies and could place an unnecessary burden on population subgroups such as college students and young families, who might depend on convenience foods during particular life phases. Various PSTs shared about personal and family experiences linking nutrition and health, which highlighted the challenge of defining "healthful" nutrition. The result of this introductory activity was PSTs' recognition of their need to better understand both scientific and societal dimensions of the issue.

Because societal dimensions of SSI are a key focus of SSI-based teaching, and because research indicates that science teachers may struggle most with this component of SSI (Sadler et al., 2006), the relevant social aspects of the nutrition focal SSI were heavily featured in the SSI Teaching Module. An example of a nutrition lesson that emphasized societal dimensions of the focal SSI was one that incorporated an SSI Timeline activity (Foulk, Friedrichsen, & Sadler, 2020). In small groups, PSTs explored historically significant nutrition recommendations, summarizing their findings and posting them on a collaborative class timeline. Then the PSTs discussed their collective findings, comparing and contrasting nutrition recommendations through the years, and proposing significant historical events that may have impacted recommendations. Next, the small groups reconvened to research scientific, political, and economic events, which had been selected for their historical significance to nutritional health. PSTs summarized the impact of their assigned events, color coded according to the nature of impacts on historical nutritional recommendations. The result was a very engaged group of learner-participants, and a great deal of discussion about their new understandings of nutrition policy. Following the introduction of the issue and participation in this timeline activity, PSTs expressed an awareness that meaningful interpretation and assessment of commonly shared nutrition advice (e.g., "eat everything in moderation" or "avoid cholesterol and saturated fat") depends on an understanding of scientific ideas about nutrition. Specifically, the PSTs recognized their need to be able to make sense of the structure and function of nutrition macromolecules and their significance in metabolic pathways. As learners, PSTs benefitted from this activity by identifying science concepts they needed to know in order to address the focal issue (See Figure 2 and Figure 3).

Figure 2 (Click on image to enlarge)

SSI Timeline Activity

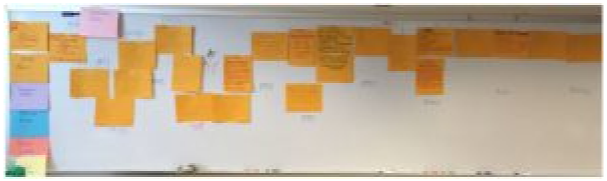


Figure 3 (Click on image to enlarge)

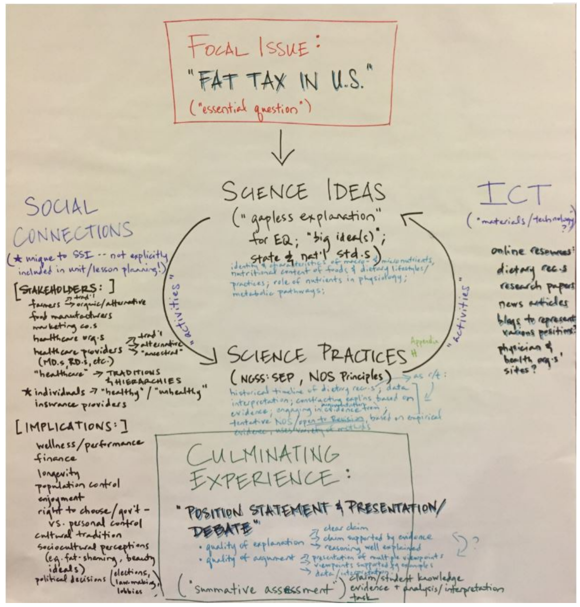
SSI Timeline Categories of Societal Dimensions

SSI Teaching Module – Phase 2: Teaching Science with SSI

The second phase of the SSI Teaching Module allowed PSTs to reflect on their learner experiences with the SSI nutrition unit, from the perspective of teachers. After participating in selected portions of the SSI nutrition unit, the PSTs began the process of unpacking their experience and making sense of the teaching approach. They were first asked to inspect the SSI-TL framework, and then they received written copies of the SSI nutrition unit for comparison. In small groups PSTs discussed elements of the framework they were able to distinguish in the nutrition unit, as well as the purposes they saw for each activity they had identified. A whole class discussion of the unit resulted in a mapping of the unit to the SSI-TL framework (See Figure 4).

Figure 4 (Click on image to enlarge)

Unit Map



In another lesson during the second phase of the SSI Teaching Module, a whole class discussion of the philosophical assumptions of the SSI-TL framework helped PSTs to consider broader educational purposes of the approach (Zeidler, 2014a). The instructor again provided a copy of the framework and asked PSTs to consider ways it compared and contrasted to their experiences as learners of science, and their ideas about teaching science. During the discussion, “Travis” shared, “I would’ve eaten this up as a high school student, because I didn’t always like science classes. I think connecting science to real life is a great way to reach students who might not like science otherwise.” Conversely, “Dale” expressed his concerns about shaking up tried and true teaching methods in his subdiscipline, arguing that there are more beneficial ways to teach than forcing science learning into SSI: “Everything we teach at the high school level for physics was settled 200 years ago. Why should students spend time looking at news stories and history?” The group revisited these conversations about educational philosophy and socioscientific issues frequently.

Following a whole class discussion about the SSI-TL framework and nutrition unit as an exemplar, PSTs used the framework to collaboratively analyze examples of externally created SSI-focused curricula. Small groups identified components of SSI-based teaching such as the focal issue, opportunities to consider societal dimensions of the issue, and connections to relevant science ideas. (Friedrichsen et al., 2016; Schibuk, 2015; Zeidler & Kahn, 2014a, 2014b, 2014c). Finally, individual PSTs completed a structured analysis of these assigned SSI curricular units. This activity served to further help the PSTs in identifying key components of SSI-based science curricula, and to see varied ways that classroom activities, lessons, and units might be created to align with the approach. See the analysis rubric tool designed to support PSTs’ individual curricular analyses (See Figure 5).

Figure 5 (Click on image to enlarge)

Curriculum Analysis Rubric

SSI Curriculum Unit - Analysis Rubric					
Criteria	**Absent** **0**	**Implied** **1**	**Explicit** **2**	**Exemp-lary** **3**	**Score**
Focal Issue: To what extent do you see science content "situated" in an issue (i.e., issue woven throughout unit)? Consider: ▪ Is the issue explicit? implied? ▪ How might the unit be changed to strengthen the presence of an issue, if needed?					
NGSS/State Standards: To what extent does the unit clearly address appropriate national, state, and/or district standards? Consider: • NGSS (PE? DCI? SEP? CCC?) • Common Core • State Standards • District Standards					
Science Content: To what extent does the unit engage learners to explore and explain science content? • What activities serve this purpose? • How effectively do the activities engage learners in "3D" (DCI + SP + CCC) learning?					
Social Connections: To what extent does the unit compel learners to explore & explain societal dimensions of the issue (political, economic, cultural, etc.)? • In what activities are stakeholders' views identified and explored? • Do learners have opportunity to represent new understanding of social dimensions?					
Assessment: To what extent does the unit allow for assessment of understanding? • Diagnostic? Formative? Summative?					
Information Communications Technology: To what extent does the unit draw upon ICT to facilitate learning opportunities? • What activities utilize ICT? For what purposes?					
Closure: To what extent does the unit end with an activity that requires learners to synthesize understanding of both science content and social dimensions in order to address the FI? • What is the nature of the activity?					
Additional Comments:					Total Score

SSI Teaching Module – Phase 3: Designing SSI Curricula

The third and final phase of the SSI Teaching Module focused on curricular design. Because curricular design was the primary goal of the Science Methods course, activities prior to the SSI Teaching Module had been designed to engage PSTs in utilizing NGSS and other educational standards, as well as in structuring and planning for meaningful learning activities in secondary science classrooms. This phase of the SSI Teaching Module was designed to build upon the PSTs’ prior experiences with elements of curriculum planning, and to integrate them with the activities of the previous phases of the module.

Over a series of lessons, in various formats, and with numerous feedback opportunities, the PSTs were supported in their development of a cohesive SSI-focused curricular unit designed around the SSI-TL framework, which served as the culminating course project. With regular instructor feedback, in both in-class collaborative settings and as out-of-class assignments, PSTs selected topics applicable to their science certification areas, brainstormed potential focal SSIs in which to contextualize their science units, and identified NGSS standards most relevant to their topics. In addition to feedback from both instructor comments and class discussions, PSTs used several resources intended as tools to guide their process, including the SSI-TL framework, written requirements for the SSI Curriculum Design task, access to the SSI nutrition unit from phase one of the SSI Teaching Module, and an electronic template in which to create their units (See Figure 6).

Figure 6 (Click on image to enlarge)

Curriculum Design Task Requirements

Final Course Project: Design a 2-3 week SSI-based unit for classroom use. To qualify as a unit, your project must contain a coherent sequence of lessons and accompanying curricular materials related to a particular topic. To qualify as "SSI-based" your unit must situate science instruction within a societally relevant issue, which is affected by authentic social, political, economic, and/or cultural dimensions, has multiple possible solutions, is likely contentious, and for which there is no single "correct" solution. Specifically, you should:

- Select & describe your selected **focal issue** (include related references and/or resources to support your description, as appropriate)
- Describe the **content standards, big idea**, **essential question** for your unit, & explain how they are connected to the focal issue
- Write a **gapless explanation** (your detailed response to the essential q) for the unit
- Specify an entire **sequence of specific lessons** for the unit
- Include **3 detailed lesson plans** for your unit:
  - Introduction of Focal Issue
  - Focus on Social Aspects of Focal Issue
  - Focus on Content
- Design **3 types of assessments** for your unit:
  - formal **formative assessment** (included in **all lesson plans**)
  - **summative assessment for 1 content lesson**: include planning template, task (instructions), & rubric
  - **end-of-unit synthesis project**: include planning template, task (instructions), rubric
- **Rationale & Reflection**. Write a detailed (2-4 page) description of your design process, including:
  - your rationale for the Focal Issue you chose as a context for your science content
  - the reason for the sequence of lessons in your unit
  - your thoughts about the experience of designing and organizing this unit
  - what you view as "what's left" to make your unit polished and ready for the classroom

Draft (submitted to instructor & ready for peer review) due **before class XX/XX**
Final version due **XX/XX**

All activities in phase three of the SSI Teaching Module served to help PSTs draft detailed unit overviews consisting of a two- to three-week sequence of lessons with multiple detailed lesson plans, specifically focused on introducing the focal SSI, exploring societal dimensions of the issue, and activities for mastery of related science content ideas. Assessment of PSTs' units was based upon a detailed scoring rubric collaboratively constructed with the PSTs during the third phase of the Teaching Module. Together the course instructor and PSTs used the Curriculum Design Task Requirements and the SSI-TL framework, as well as the Curriculum Analysis Rubric, to prioritize elements and characteristics of SSI units. Finished units were later assessed for alignment to the SSI-TL framework in terms of unit structure, principles of SSI, and general quality of activities and lessons. See the scoring rubric for the unit design task, below. Note also that NGSS-aligned lesson plan design was a requirement for the PSTs in a previous methods course and continued as an expectation throughout PSTs' education program. Selected PSTs' SSI unit design products are summarized (See Figure 7 and Table 2).

Figure 7 (Click on image to enlarge)

SSI Unit Design Task – Scoring Rubric

SSI Unit Design Task – Scoring Rubric

Structure, Design, & Adherence to Requirements (15)		
(3)	**(2)**	**(0)**
Focal Issue (FI) Description of FI is clear, thorough, well organized, and supported with related references and/or resources.	Description of FI is unclear, incomplete, poorly organized, and/or not supported with related references and/or resources.	Description of FI is not included.
Standards, Big Idea (BI), & Essential Question (EQ) The connection of content standards, BI, and EQ to the FI is clearly explained.	The connection of content standards, BI, & EQ to the FI is briefly, incompletely, and/or not clearly explained.	Explanation of the connection of content standards, BI, & EQ to the FI is not included.
Gapless Explanation (GE) GE is clear, thorough, and accurate; completely answers the EQ; and obviously drives unit planning (connectedness to unit and lesson plans is evident).	GE is difficult to understand, incomplete, or inaccurate; fails to answer the EQ; or is not apparently related to unit and lesson plans.	GE is not included.
Format Unit is organized using Unit Plan, Lesson Plan, and Assessment Rubric templates as designed.	Unit is organized using some, but not all, of Unit Plan, Lesson Plan, or Assessment Rubric templates as designed.	Unit does not follow Unit Plan, Lesson Plan, or Assessment Rubric templates as designed.
Length Of reasonable length for a 2-3 week unit.	Somewhat too lengthy or too short for 2-3 week unit.	Excessively lengthy or excessively short.
Adherence to SSI Principles (30)		
(3)	**(2)**	**(0)**
Focal Issue - Authenticity FI is an authentic dilemma with no "right" answer, informed by the science content in the unit, with significant, obvious social/societal implications.	FI is not believable, with minimal basis in science and/or minimal societal implications, or is not well related to the science content in unit.	FI is not clearly described in unit.
Focal Issue – Position FI is presented first in the unit, ahead of science content.	Unit is front-loaded with science content followed by FI.	FI is not clearly described in unit.
Focal Issue – Prominence FI serves as a context for the entire unit, is made prominent to learners throughout the unit, and is supported by all unit activities.	FI is only mentioned briefly or sporadically, or FI is merely presented as a "current event" or "extension" of unit.	FI is not clearly described in unit.
Science Content – NGSS & 3DL Content clearly includes DCI, SEP, and CCC.	Content omits DCI, SEP, or CCC.	Science content is not clearly described in unit.
Science Content – Relation DCI, SEP, CCC are appropriately related to BI, EQ, GE, & each other.	DCI, SEP, CCC are not appropriately related to BI, EQ, GE, & each other.	Science content is not clearly described in unit.
Science Content – Scale DCI, SEP, CCC are appropriate in scale/size for 2-3 week unit.	DCI, SEP, CCC are too large or small in scale/size for 2-3 week unit	Science content is not clearly described in unit.
Science Content – Accuracy DCI, SEP, CCC are complete and accurate.	DCI, SEP, CCC incomplete or inaccurate.	Science content is not clearly described in unit.
Social Connections - Presence Unit provides learners opportunity to deeply explore various social, political, economic, etc. dimensions of FI.	Unit provides learners limited opportunity to explore social, political, economic, etc. dimensions of FI.	Unit provides no explicit opportunity for learners to explore societal dimensions of FI.
Social Connections – Perspectives Unit provides learners opportunity to deeply investigate perspectives of multiple stakeholders in FI.	Unit provides limited opportunity for learners to investigate multiple perspectives in FI.	Unit provides no explicit opportunity for learners to investigate multiple perspectives in FI.
Synthesis Project Unit ends with opportunity for learners to synthesize understandings of science content and multiple societal dimensions of the FI by planning and/or taking some related action.	Unit ends with opportunity for learners to represent some understandings of science content or social dimensions of FI, or to take some action related to FI.	Unit does not include a culminating project.
Quality of Unit Products (30)		
(3)	**(2)**	**(0)**
Unit Overview - Sequence Sequence of lessons is logical and clear, and results in coherent unit.	Sequence of unit is unclear or results in difficult-to-follow unit.	Sequence of lessons is not specified in Unit Overview.
Unit Overview – Lessons Unit Overview includes clear and descriptive titles for each lesson.	Lesson titles in Unit Overview are too vague or brief to understand.	Lesson titles are not included in Unit Overview.
Unit Overview – Activities Overview includes clear and thorough list (with descriptions) of each lessons' activities.	Descriptions of activities are too vague or brief to understand.	Activity descriptions are not included in Unit Overview.
Unit Overview – Learning Goals Overview lists clear, measurable, and appropriate learning goals for each lesson.	Overview lists learning goals that are not measurable or appropriate for lessons.	Learning goals are not included in Unit Overview.
Lesson Plan (Focal Issue) • clearly describes BI, EQ, GE, & learner objectives. • clearly describes purpose and content of lesson. • clearly describes teacher's and students' roles for duration of lesson.	• BI, EQ, GE, and/or learner objectives not clear. • does not clearly describe purpose and/or content of lesson. • does not clearly describe teacher's or students' roles.	Detailed Focal Issue Lesson plan is not included.
Lesson Plan (Social Connections) • clearly describes BI, EQ, GE, & learner objectives. • clearly describes purpose and content of lesson. • clearly describes teacher's and students' roles for duration of lesson.	• BI, EQ, GE, and/or learner objectives not clear. • does not clearly describe purpose and/or content of lesson. • does not clearly describe teacher's or students' roles.	Detailed Social Connections Lesson plan is not included.
Lesson Plan: Science Content • clearly describes BI, EQ, GE, & learner objectives.		

• clearly describes purpose and content of lesson. • clearly describes teacher's and students' roles for duration of lesson.	• BI, EQ, GE, and/or learner objectives not clear. • does not clearly describe purpose and/or content of lesson. • does not clearly describe teacher's or students' roles.	Detailed Science Content Lesson plan is not included.
Assessments: Diagnostic/Formative All detailed lesson plans include assessments that: • are appropriately and adequately placed throughout each of the three lesson plans to inform teachers' instructional decisions. • are clearly planned and described in enough detail to be replicated. • adequately describe criteria to be able to consistently interpret learners' performances.	Assessments: • are not described in all detailed lesson plans. • are inappropriately placed or inadequate to inform teachers' instructional decisions. • are not described clearly and thoroughly enough to be replicated. • are too vaguely described to be able to consistently interpret learners' performances.	Lesson Plans do not describe diagnostic and formative assessments.
Assessment: Summative (Science Content L. Plan) Assessment • is relevant to science content included in lesson plan. • is clearly planned, with *knowledge*, *evidence*, and *task* specified in detail. • includes scoring rubric with *tasks, dimensions, criteria*, and *scores* clearly specified to *interpret* learners' performances.	Assessment • is not obviously relevant to the science content included in lesson plan. • does not clearly represent *knowledge*, *evidence*, and *task* defined in planning process. • does not include scoring rubric with *tasks, dimensions, criteria*, and *scores* clearly specified.	Science content lesson plan does not describe a plan for summative assessment.
Assessment: Synthesis Project • requires learners to synthesize understanding of related science content & societal dimensions of FI to take a position, plan a course of action, and/or design policy related to FI. • is clearly described (as a *task*) and of appropriate scale for the unit. • scoring rubric includes clear *tasks, dimensions, criteria*, & *scores*.	• addresses only science understanding, or only societal dimension of FI, does not require learners to synthesize ideas, or does not require learners to engage in action r/t FI. • not clearly described (as a *task*) and/or too large or small a task for the unit. • rubric does not include clear *tasks, dimensions, criteria*, and/or *scores*.	Unit does not describe a plan for a synthesis project.

Table 2 (Click on image to enlarge)

Table of Selected PST Curricular Units

PST	Discipline	Focal SSI	Science Topic	NGSS Science Standards
Adam	Bio	Local Management of Invasive Species through Focused Consumption	Maintenance of Ecosystems	**HS-LS2-1** Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. **HS-LS2-2** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales
Bethany	Bio	Agricultural Pesticide Resistance	Microevolution	**HS-LS4-2** 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. **HS-LS4-3** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. **HS-LS4-4** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
Cooper	Phys	Policies Mitigating UV Exposure from Tanning Beds	Electromagnetic Waves	**HS-PS4-1** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength and speed of waves traveling in various media **HS-PS4-4** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of EM radiation have when absorbed my matter
Dale	Phys	U.S. Energy Costs & Risks	Energy Transfer and Transformation	**HS-ETS1-1** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Ethan	Phys	Collisions and Speed Limit Laws	Newton's Laws of Motion, Collisions of Macroscopic Objects	**HS-PS2-1** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. **HS-PS2-3** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
Gregg	Chem	Planned Obsolescence and Consumers	Relationship between Atomic/ Molecular Structure and Function of a Material	**HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. **HS-ETS1-1** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
NGSS	Phys	Pedestrian Cell Phone Use	Uniform Motion	**HS-PS2-1** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
Isla	Phys	Speed Limit Regulations	Accelerated Motion, Inertia	**HS-ETS-1** Design a solution to a complex real world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Jane	Phys	Clean Energy Sources	Energy Conservation & Human Impacts	**HS-PS3-1** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
Lydia	Earth/ Env	Population, Residential Housing Restrictions, and Natural Disasters	Natural Hazards	**HS-ESS3-1** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **HS-ESS3-6** Use a computational representation to illustrate the relationships among earth systems and how those relationships are modified due to human activity.

Discussion & Conclusion

In this project, we sought address the tension between K-12 science teachers' favorable perceptions of SSI-based pedagogy and their simultaneous unlikelihood to utilize SSI in their science classrooms. Specifially, we designed and implemented an SSI Teaching Module intended to leverage the transformative potential of the curriculum design process, in an effort to address commonly cited barriers to SSI-based pedagogy enactment, including: unfamiliarity or discomfort with SSI-based teaching; lack of access to SSI curricular resources; and misalignment between teachers' perceptions and the pedagogical philosophy of SSI. We observed several specific examples of favorable impacts for the PST participants in this experience.

First, PSTs expressed excitement about *learning* with SSI. In a whole class conversation following phase one of the teaching module, Adam described his positive experience as a learner of SSI. Referring specifically to the use of SSI and related societal dimensions in the learning experience, he commented, "I think as a [secondary] student I would've been, like, sucked in from the very first day of the nutrition unit." Adam's sentiment echoed the enthusiasm that Travis had clearly demonstrated during phase one of the SSI Teaching Module. Having previously spoken to the first author privately regarding his uncertainty about a career path in education, Travis exceeded task expectations during the learner phase of the project. In ways that were atypical for him, Travis assumed leadership responsibilities for his group, encouraging his peers to explore and make connections among science and societal dimensions of the issue they were studying. On one occasion, Travis stayed after class to make additional contributions to the collaborative activity from that day's lesson, describing to the first author his own engagement during participation in the SSI nutrition unit in class. During a whole class discussion in phase two of the SSI Teaching Module, Travis spoke favorably of his firsthand experience with SSI and enthusiastically shared with his peers his perception of the potential for SSI to promote learner engagement, particularly for those students who, like himself, are likely to find traditional K-12 science coursework unenjoyable.

Second, PSTs expressed enthusiasm for *teaching* with SSI during phases two and three of the SSI Teaching Module. In class conversations about the SSI-TL framework as well as in written reflections about SSI unit design required with the Unit Design Task, multiple PSTs expressed enthusiasm for SSI and plans to use it, despite its challenges. For example, after designing his unit, “Cooper” wrote, “I found that creating this [SSI] unit about waves was challenging, but also sort of exciting, because it makes me think about how much I’m looking forward to being a teacher.” Similarly, during our whole class discussion about the philosophical underpinnings of SSI, Adam repeatedly expressed his perception of the value of teaching science with SSI. Adam’s SSI curricular unit design was exceptional for his thoughtful choice of issue and the complex connections he made among science ideas and societal dimensions related to the issue, and his comments throughout the learner experience indicated his consideration of the challenges and possible solutions to utilizing SSI in the classroom. During his third year of teaching, Adam reached out to the first author to describe his own use of SSI-based pedagogy and asked for help in supporting veteran teachers in his department to take up the approach. Adam expressed a highly favorable view of teaching with SSI, and the project seemed to prepare him to do so.

Finally, PSTs demonstrated success in designing coherent SSI-TL curricular resources. Consistent with our framework, we considered an SSI unit to be successfully designed if it met the criteria specified in the Curriculum Design Task and Scoring Rubric, by including essential elements and characteristics of SSI and by representing the intent of the approach. Regarding elements and characteristics of SSI and by representing the intent of the approach. Regarding elements and characteristics, a unit overview was required, with specific reference to the science topic and related standards from NGSS, a thorough explanation of pertinent science ideas, and the selected focal SSI in which the unit was contextualized. The overview would also include a brief timeline describing a coherent sequence of lessons related to the topic. In addition, units were to include detailed plans for three specific types of lesson: introduction of the focal issue, exploration of societal dimensions of the issue, and explicit sensemaking about science ideas. Finally, a successful unit would describe plans for assessment, including requirements for a culminating unit project in which learners would demonstrate understanding of science ideas and societal dimensions related to the issue. Throughout the unit design, the selected SSI would feature prominently, and activities would allow for students’ meaningful sensemaking about the science ideas and societal dimensions relevant to the issue.

With participation in the SSI Teaching Module, support from their instructor, and interactions with the learning community in their methods course, each of our participant PSTs satisfied the requirements of the unit design task and designed curricular units consistent with the SSI-TL framework. PSTs were able to identify learning standards relevant to their selected science topics, provide explanations of their topics, and contextualize science learning opportunities within authentic, real-world issues. In addition, PSTs were able to create broad, cohesive overviews of their units, as well as detailed plans for specific lessons. Most notable with regard to the emphasis on SSI, PSTs were able to select relevant, appropriate socioscientific issues for their topics, and to thoughtfully weave these issues into their unit designs. PSTs reflected about general struggles related to selecting focal issues or integrating science ideas and societal dimensions, and the experiences in the SSI Teaching module that they found especially helpful, such as small group discussions during the planning process, and peer feedback on the drafts of their units.

Consistent with current calls for science education reform, we know SSI offer valuable opportunities for student learning, and we believe SSI curriculum design to be a beneficial way to support teachers' uptake of SSI-based teaching. Furthermore, we view teacher education to be an appropriate context to support pre-service and early career teachers' in making sense of and adopting the approach. We share the design of SSI Teaching Module to support other teacher educators in innovating pre-service methods courses toward promoting PSTs' uptake of SSI.

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