

PRE-SERVICE SCIENCE TEACHERS' BELIEFS RELATED TO
TEACHING AND LEARNING WITH SOCIOSCIENTIFIC ISSUES

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by

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PRE-SERVICE SCIENCE TEACHERS' BELIEFS RELATED TO
TEACHING AND LEARNING WITH SOCIOSCIENTIFIC ISSUES

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DOCTOR OF PHILOSOPHY OF LEARNING, TEACHING, AND CURRICULUM
EMPHASIS IN SCIENCE EDUCATION

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DEDICATION

*It is the glory of God to conceal things,
but the glory of kings is to search things out.*
— Proverbs 25:2 (ESV)

To experience the profound pleasure of “searching things out”—asking questions, noticing patterns, making sense of and proposing explanations about the natural and socially constructed worlds—is a treasure for humankind. The luxury of investing years of this life in acts of *learning* about *teaching* about *learning* about *teaching* has brought me indescribable satisfaction.

To the One Who conceals,

for allowing me this opportunity,
and for taking joy in my process of discovery—
about my research, my field, myself, and this world.
I treasure it all, the challenges and the celebrations, as gifts designed by Your hand,
an experience of the glory that originates with You (Psalm 8:3-5).

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for hearing my voice in the process, and for honoring who I am.
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Most of all, thanks for engaging in your own journeys of meaning making.
Your lives inspire me.

and

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for managing much of the day-to-day to keep us afloat
during the last leg of this marathon.
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I look forward to our next chapter.

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ABSTRACT

Socioscientific issues (SSI) are the hallmark of a reform-oriented approach to science teaching and learning (Sadler, Foulk, & Friedrichsen, 2017) that foregrounds controversial and unstructured societal challenges with substantive connections to science ideas, as contexts for students' learning about science and its societal implications (Borgerding & Dagistan, 2018; Kolstø, 2006; Owens, Sadler, & Friedrichsen, 2019). Although many K-12 science teachers express support for SSI and its numerous learner benefits (Sadler, 2004; Zeidler, 2014), even teachers who hold this view tend to utilize SSI inconsistently and superficially, if at all (Lee & Witz, 2009; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006; Saunders & Rennie, 2013).

Teachers' practices are essential in facilitating students' reform-oriented learning experiences (Bybee, 1993), and teachers' beliefs are related to their uptake of science education reforms (Fletcher & Luft, 2011). Yet, little is known about the ways beliefs influence teachers' uptake of SSI-based practices. Even less is known about how pre-service teachers' (PST) beliefs influence their adoption of SSI for teaching and learning.

To address this gap in understanding I explored PSTs' beliefs about SSI, as they engaged in SSI-focused learning activities and curriculum design, in an SSI-focused methods course built around the SSI teaching and learning (SSI-TL) framework (Sadler et al., 2017). PSTs' beliefs about SSI were influenced by their existing beliefs about science teaching and learning, and PSTs were able to design curricular units consistent with the SSI-TL framework. In this multiple manuscript dissertation, I present details about the SSI-focused methods course, empirical findings, and implications for teacher education and research.

CHAPTER ONE

INTRODUCTION

The role of classroom teachers is of primary importance in facilitating reform-oriented learner experiences (Bybee, 1993). Socioscientific issues (SSI) based teaching and learning is a reform-oriented approach with a long history of empirically supported learner benefits (Sadler, 2004; Zeidler, 2014). Yet, research indicates that K-12 science teachers' uptake of SSI-related reforms remains limited (Lee & Witz, 2009; Sadler et al., 2006; Saunders & Rennie, 2013). Little is known about how to best support teachers' adoption of SSI. Even less is known about doing so in teacher education contexts.

This multiple manuscript dissertation explored pre-service teachers' (PSTs') ideas about SSI teaching and learning in an SSI-focused methods course. Research indicates the importance of beliefs in teachers' adoption of educational reforms (Fletcher & Luft, 2011), and early career teachers have shown a capacity for adoption of reform-oriented beliefs (Crawford, 2007). I set out to create an SSI-focused learning experience for PSTs to increase their familiarity with SSI teaching and learning, support their engagement in SSI curriculum design, and reveal their beliefs related to SSI teaching and learning.

My work on this project included designing an SSI curriculum unit; creating and teaching a science methods course that utilized the unit and other SSI curricular resources; facilitating a series of structured learning experiences; prompting PSTs' reflections about SSI throughout the methods course; and scaffolding PSTs' designs of SSI curriculum units as a culminating course project. Each of these project components utilized a specific SSI-focused teaching and learning framework, and all were enacted within typical parameters of science methods coursework. The manuscripts that resulted

from the study include a description of the methods course design for dissemination to teacher educators; sharing of an activity from the SSI unit with a K-12 practitioner audience; and a qualitative empirical study about the PSTs' SSI-related beliefs and curricular designs. This dissertation is a compilation of those three works.

Chapter Two presents the design of the SSI-focused methods course in which this project was contextualized. I present a project overview for teacher educator practitioner audiences, describe the methods course design, and share examples of materials I created to support PSTs' learning experiences around SSI teaching and learning. The manuscript was submitted for consideration by *Innovations in Science Teacher Education* in June 2019 and has been accepted for publication in an upcoming volume of the journal.

Chapter Three is a manuscript written for secondary science teachers that presents an activity from the example SSI science unit for secondary science classrooms. Because science teachers may struggle most with teaching about the societal aspects of SSI, I chose to highlight an activity for engaging students in exploring societal dimensions of SSI and include suggestions for incorporating the strategy in secondary science contexts. I wrote the manuscript for *The Science Teacher*, a publication of the National Science Teachers Association, and submitted toward a call for manuscripts about Interdisciplinary Science. The manuscript presented here is currently in review.

Chapter Four presents empirical analyses of two major data sources in response to two research questions, and associated findings. First was an analysis of interview data collected during the SSI-focused methods course to characterize PSTs' beliefs about teaching and learning with SSI. Second was an analysis of the curriculum units for SSI

teaching and learning that PSTs designed during participation in the methods course. A write-up of the work will be revised and condensed to be submitted for publication.

CHAPTER TWO

FACILITATING PRE-SERVICE TEACHERS' SOCIOSCIENTIFIC ISSUES

CURRICULUM DESIGN IN TEACHER EDUCATION

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 et al., 2017), 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 et al., 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; 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 (Lee et al., 2006; Lumpe, Haney, & Czerniak, 1998; Sadler et al., 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 (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; 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 (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

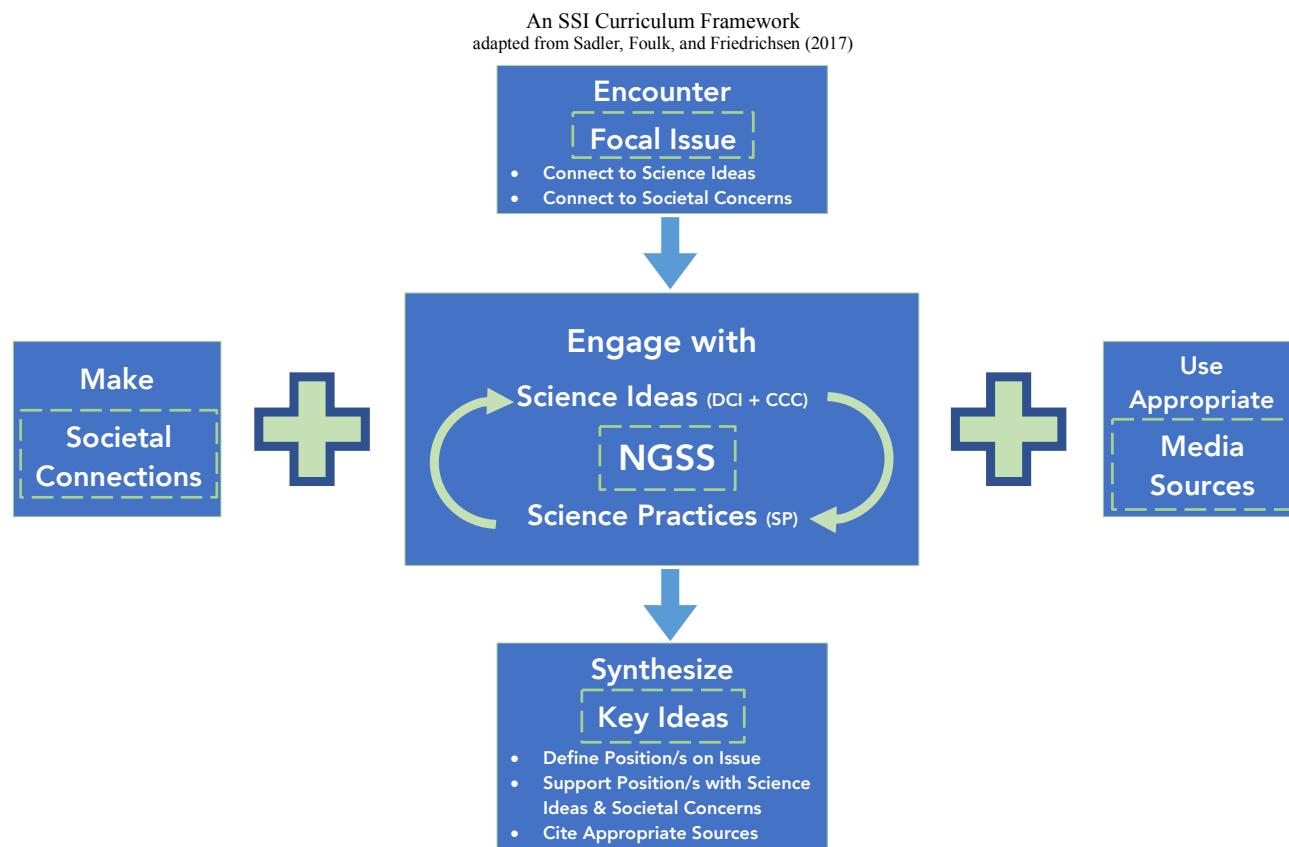
inspiration for teacher educators interested in supporting future science teachers' uptake of SSI.

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).

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

Figure 1. Socioscientific Teaching and Learning Framework



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 Table 1). 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 sample SSI units at our project website: <http://ri2.missouri.edu/ri2modules>). In the SSI Teaching Module second phase, the PSTs considered 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, using various writing prompts during class, reflective writing assignments, and in-class discussion. More detailed description of the SSI Teaching Module follows.

Table 1. SSI Teaching Module Schedule

Time Period	Focus	Sample Activities
Phase 1: Weeks 1-3	<u>Learning Science with SSI:</u> 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	<u>Teaching Science with SSI:</u> 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	<u>Curriculum Design with SSI:</u> 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.

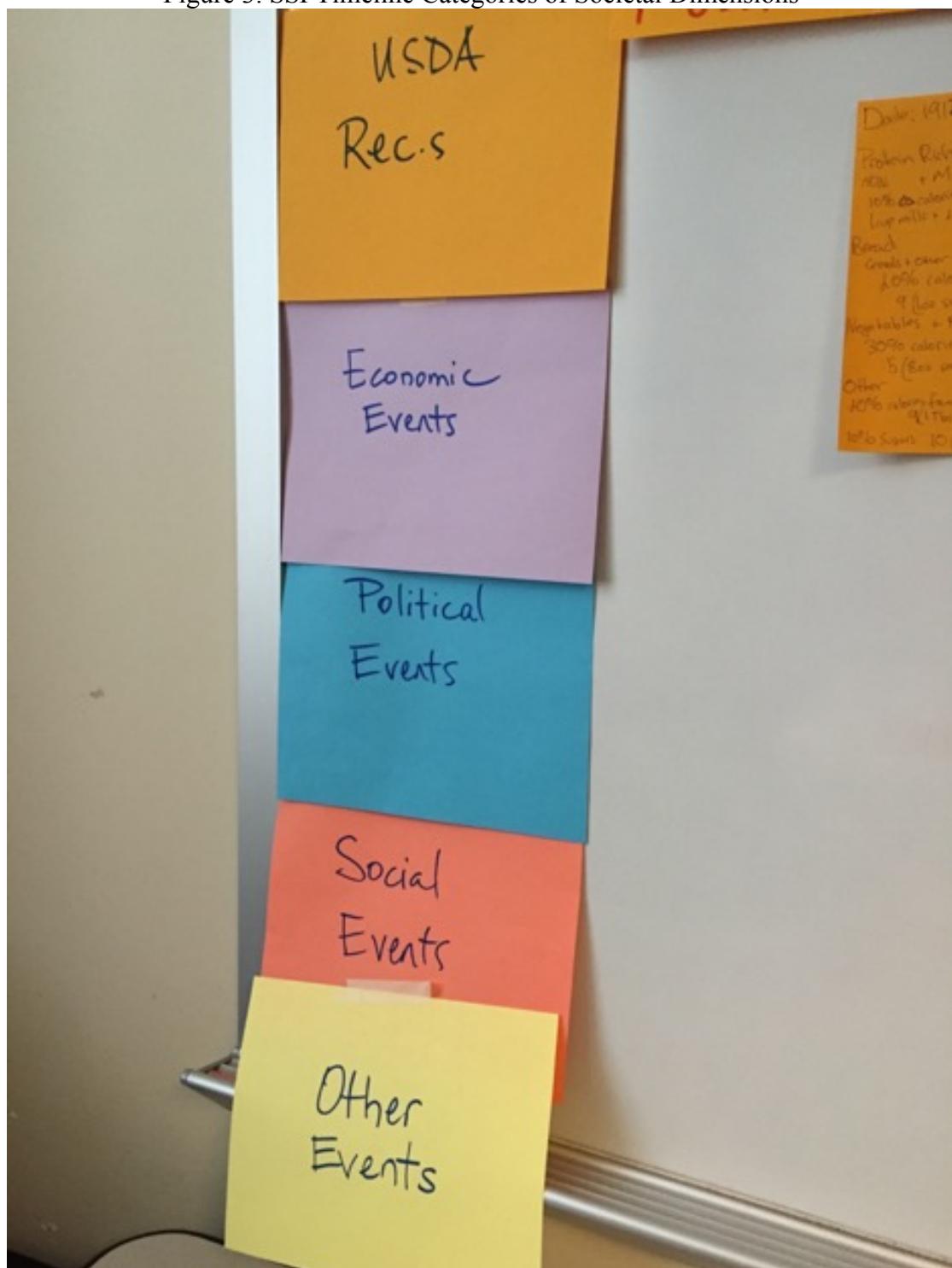
As specified in the SSI-TL framework, the SSI nutrition unit was introduced with a focal SSI. PSTs began by reading an article about a proposed “fat tax,” and were then asked to articulate and share ideas about the issue, providing reasoning to support their positions. Various positions were proposed, 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, in review). 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 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 Figures 2 and 3).

Figure 2. SSI Timeline Activity



Figure 3. SSI Timeline Categories of Societal Dimensions

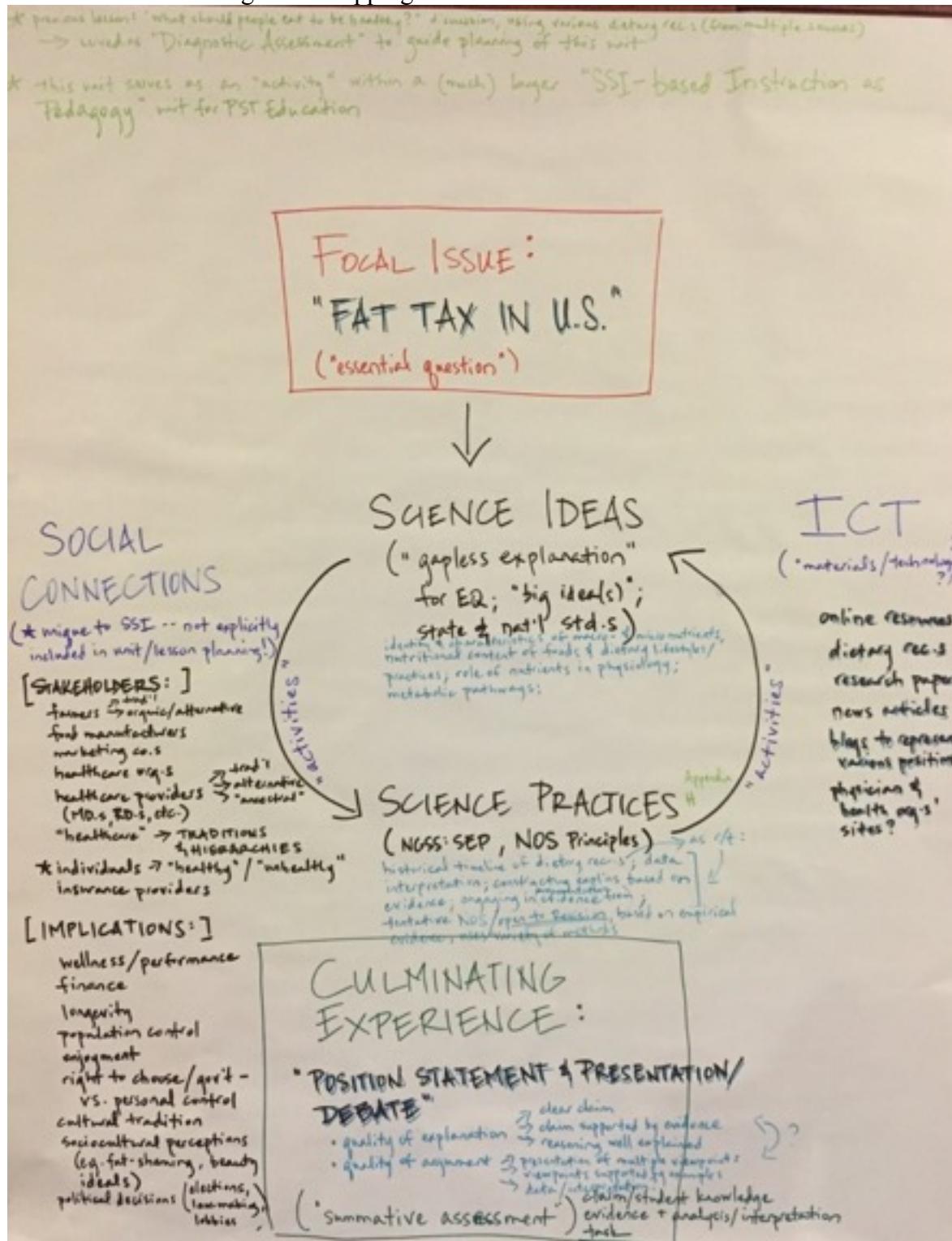


SSI Teaching Module – Phase 2: teaching science with SSI.

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 unpacked their experience and made 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).

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 frequently revisited these conversations about

Figure 4. Mapping of Unit to SSI-TL Framework



educational philosophy and socioscientific issues.

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).

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

Figure 5. SSI Curriculum Analysis Rubric

Curriculum Analysis Rubric					
Criteria	Absent 0	Implied 1	Explicit 2	Exemplary 3	Score
Focal Issue: To what extent do you see science content "situated" in an issue (i.e., issue woven throughout unit)? Consider: <ul style="list-style-type: none"> ▪ 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: <ul style="list-style-type: none"> • 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? <ul style="list-style-type: none"> • 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.)? <ul style="list-style-type: none"> • 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? <ul style="list-style-type: none"> • Diagnostic? Formative? Summative? 					
Information Communications Technology: To what extent does the unit draw upon ICT to facilitate learning opportunities? <ul style="list-style-type: none"> • 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? <ul style="list-style-type: none"> • What is the nature of the activity? 					
Additional Comments:					Total:

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).

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 (See Figure 7), 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 (Figure 7). 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. A summary of selected PSTs' SSI unit design products is provided for review (See Table 2).

Figure 6. SSI Curriculum Unit Design Task Requirements

SSI Curriculum Unit Design Task Requirements
<p>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:</p> <ul style="list-style-type: none">○ 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:<ul style="list-style-type: none">○ Introduction of Focal Issue○ Focus on Social Aspects of Focal Issue○ Focus on Content○ Design 3 types of assessments for your unit:<ul style="list-style-type: none">○ 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:<ul style="list-style-type: none">○ 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 <p>Draft (submitted to instructor & ready for peer review) due before class XX/XX Final version due XX/XX</p>

Figure 7. SSI Unit Design Task Scoring Rubric

SSI Unit Design– 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) <ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • clearly describes BI, EQ, GE, & learner objectives. • clearly describes purpose and content of lesson. 	<ul style="list-style-type: none"> • 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.

<ul style="list-style-type: none"> clearly describes teacher's and students' roles for duration of lesson. 		
Lesson Plan: Science Content <ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> is relevant to science content included in lesson plan. is clearly planned, with <i>knowledge, evidence, and task</i> specified in detail. includes scoring rubric with <i>tasks, dimensions, criteria, and scores</i> clearly specified to interpret learners' performances. 	Assessment <ul style="list-style-type: none"> is not obviously relevant to the science content included in lesson plan. does not clearly represent <i>knowledge, evidence, and task</i> defined in planning process. does not include scoring rubric with <i>tasks, dimensions, criteria, and scores</i> clearly specified. 	Science content lesson plan does not describe a plan for summative assessment.
Assessment: Synthesis Project <ul style="list-style-type: none"> 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 <i>task</i>) and of appropriate scale for the unit. scoring rubric includes clear <i>tasks, dimensions, criteria, & scores</i>. 	<ul style="list-style-type: none"> 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 <i>task</i>) and/or too large or small a task for the unit. rubric does not include clear <i>tasks, dimensions, criteria, and/or scores</i>. 	Unit does not describe a plan for a synthesis project.

Table 2. Selected PST Participants' SSI-Based Unit Designs

PST	Discipline	Focal SSI	Science Topic	NGSS Science Standards
Adam	Bio	Local Management of Invasive Species through Focused Consumption	Maintenance of Ecosystems	<p>HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</p> <p>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</p>
Bethany	Bio	Agricultural Pesticide Resistance	Microevolution	<p>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.</p> <p>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.</p> <p>HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</p>
Cooper	Phys	Policies Mitigating UV Exposure from Tanning Beds	Electromagnetic Waves	<p>HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength and speed of waves traveling in various media</p> <p>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 by matter</p>
Dale	Phys	U.S. Energy Costs & Risks	Energy Transfer and Transformation	<p>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.</p> <p>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.</p>

Discussion and Conclusion

In this project, we sought to 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. Specifically, 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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CHAPTER THREE

EMBEDDING SCIENCE IN SOCIOSCIENTIFIC ISSUES:

TEACHING WITH A TIMELINE ACTIVITY

Introduction

Embedding science learning in real-world issues is a research-based way to generate student enthusiasm, interest, and motivation for science (Zeidler & Kahn, 2014). Many of the real-life decisions our students will face in their lifetimes will require an ability to make sense of scientific ideas and information within the context of daily life. Students will face issues that pose significant consequences to themselves, their families, their communities, and their world. In science classrooms, this means that *all* students, regardless of future career paths, need to have meaningful science learning experiences that equip them to make informed decisions about the issues that will affect their health and their environment throughout their lives. While achieving the performance expectations of the *Next Generation Science Standards* is necessary for all students, this will *not be enough*.

As a means of addressing this need, we advocate teaching secondary science in the context of *socioscientific issues* (SSI). SSI are authentic societal challenges with connections to science, like climate change, antibiotic resistance, and fracking (Owens et al., 2019; Sadler et al., 2017). Because they are controversial real-world dilemmas, addressing SSI requires both an understanding of relevant science ideas and thoughtful consideration of an issue's social, economic, political, and ethical aspects. For our students to become informed voters and members of society, they need experiences grappling with these complex issues and seeing how science and their daily lives

intersect. SSI-based units integrate relevant science ideas with social aspects of the SSI, and include lessons focused explicitly on each. Because of this, teaching science with SSI may require additional, innovative instructional strategies. We developed a Timeline lesson that utilizes one such strategy, specifically to help students explore societal aspects of an SSI.

Timeline Lesson in an Energy Systems Nutrition Unit

We developed the Timeline lesson, which takes approximately two 55-minute class periods, to guide high school students in exploring societal aspects of an issue featured in an SSI curricular unit. Our unit is centered around the SSI of a proposed tax on obesogenic foods and is designed to teach about Energy Systems through nutrition at the high school level. The fat tax issue serves as a context for science learning activities focused on relevant science ideas about macronutrients, nutritional pathways, and human nutritional needs. Since its first use, the timeline lesson has been successfully adapted for use with various topics in multiple course settings. We offer a detailed description of the timeline activity in our societal aspects lesson, as used in the nutrition unit, as well as suggestions for use with other topics. For a look at how the societal aspects lesson fits into the complete Nutrition in Energy Systems unit, as well as how the societal aspects are integrated with relevant science ideas in the unit, see the project website:

[http://ri2.missouri.edu/ri2modules/Fat Tax/intro](http://ri2.missouri.edu/ri2modules/Fat%20Tax/intro).

Timeline day 1: history of nutrition recommendations.

The Energy Systems unit begins with an introduction of the SSI in the form of an ethical dilemma: *Should the U.S. government consider a “fat tax” to encourage citizens to make more “optimal” nutrition choices?* Students are asked to take a position on the

issue and support it with clear reasoning. The Timeline is the fifth lesson of the unit and follows explorations of cultural aspects of the issue, relevant science ideas, and an application of these ideas to students' own nutritional choices,

On the first day of the Timeline activity students revisit the fat tax dilemma to revise their initial responses to the question, modifying their positions as needed, and providing evidence and reasoning from the class activities in which they have participated thus far. In addition, students are asked to respond to a new sub-prompt: *To me, eating for good health means....* As a lead-in to the Timeline, this prompt is intended to help students articulate personal beliefs about the topic of nutritional recommendations. In order to challenge students' ideas in the Timeline activity, it is important to first make them aware of their initial beliefs.

Next, students are divided into small groups and assigned sets of historical nutrition recommendations to investigate and summarize. Assigned topics (1-2 per group) include: *Atwater's 1894 Farmer's Bulletin No. 23 & Principles of Nutrition and Nutritive Value of Food* (1902), USDA's *Food for Young Children* (1916-1933), Basic 7, Basic 4, U.S. Dietary Guidelines for Americans (1980-present), Food Guide Pyramid, MyPyramid, and MyPlate. Small groups are asked to write their summaries on a colored sheet of paper, to be posted on a wall as a collaborative timeline. In their summaries, students are instructed to identify: title of recommendations, year of publication, intended demographic, apparent purpose (e.g., prevention of nutrition deficiencies, response to food availability, prevention of chronic disease, etc.), and general or notable ideas. (See examples of student work, below.) As small groups finish their summaries, they post them on the class timeline.

When the timeline has been completely constructed, and significant dates highlighted as appropriate, each group presents their findings to the class. A subsequent whole class discussion allows students to recognize ways that the target populations, emphases, and content of nutrition recommendations have changed throughout history. For example, around the turn of the 20th century, when vitamins were first being discovered, nutrition recommendations were targeted at ensuring children consumed enough of particular foods to prevent diseases of deficiency. By WWII the focus of nutrition recommendations shifted toward the general population, creating groups of foods to allow for appropriate substitutions, in an attempt to address overall food scarcity. Day 1 of the Timeline allows students to note these and other patterns throughout history, which in turn enables students to recognize the need to better understand the scientific and societal factors affecting historical nutrition campaigns. (See Figures 1 and 2).

Timeline day 2: historically significant events.

Day 2 of the Timeline opens with a question about the previous day's work: *How have your ideas about eating for good health changed since yesterday's Timeline activity?* After individuals respond to the opening prompt, small groups reconvene to investigate and summarize assigned historical events of nutritional significance. Topics include discovery of vitamins, World War I, the Dust Bowl, World War II, the Green Revolution, and the McGovern Committee. In addition, groups summarize some key nutritional science events, including Ancel Keys' Seven Countries Study, the Diet-Heart Hypothesis, and the Noakes Hearing.

Student groups record summaries of their assigned events on color coded paper, according to their classification as events of a scientific or societal nature. Societal events

Figure 6. SSI Timeline Part

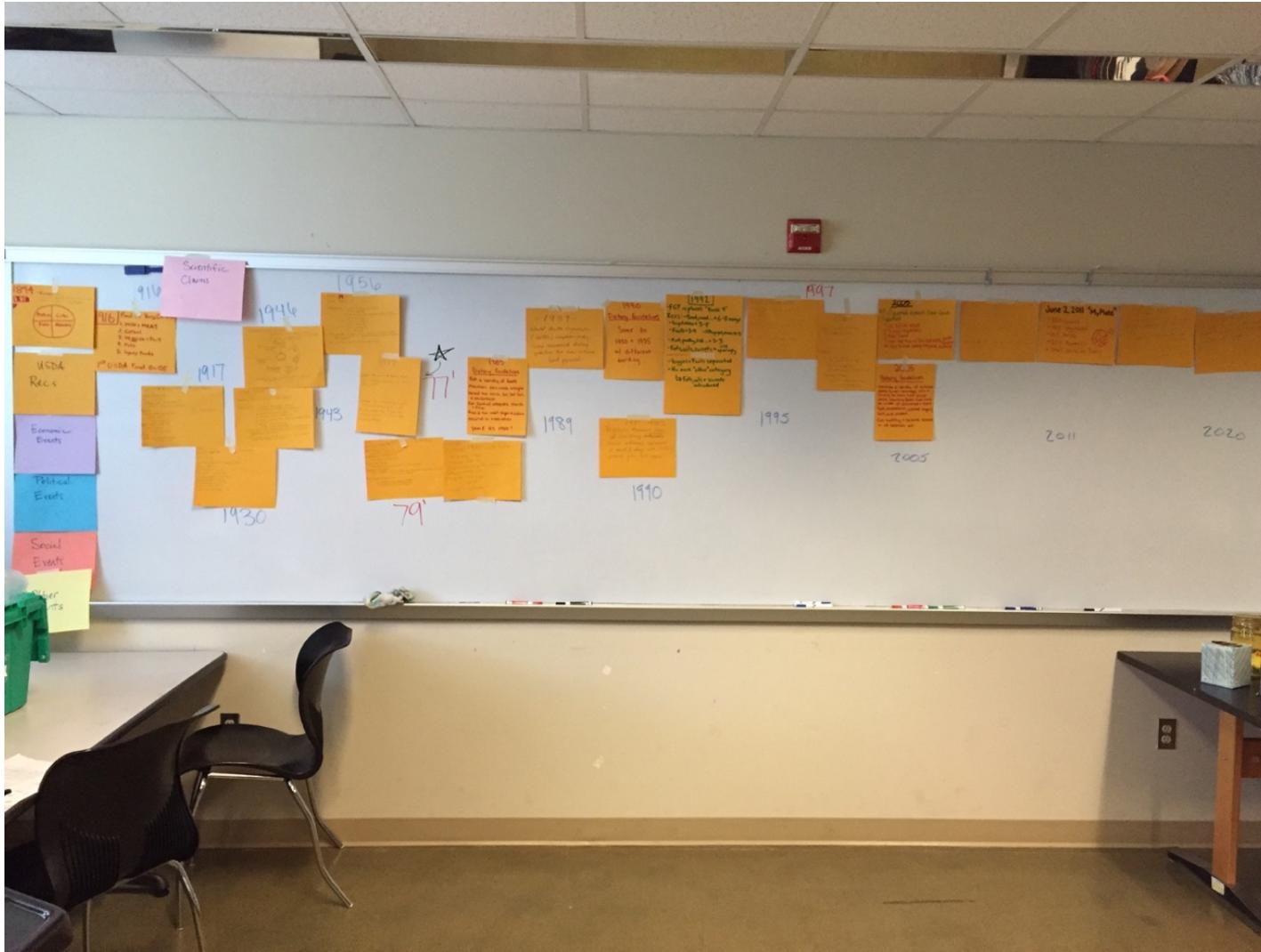
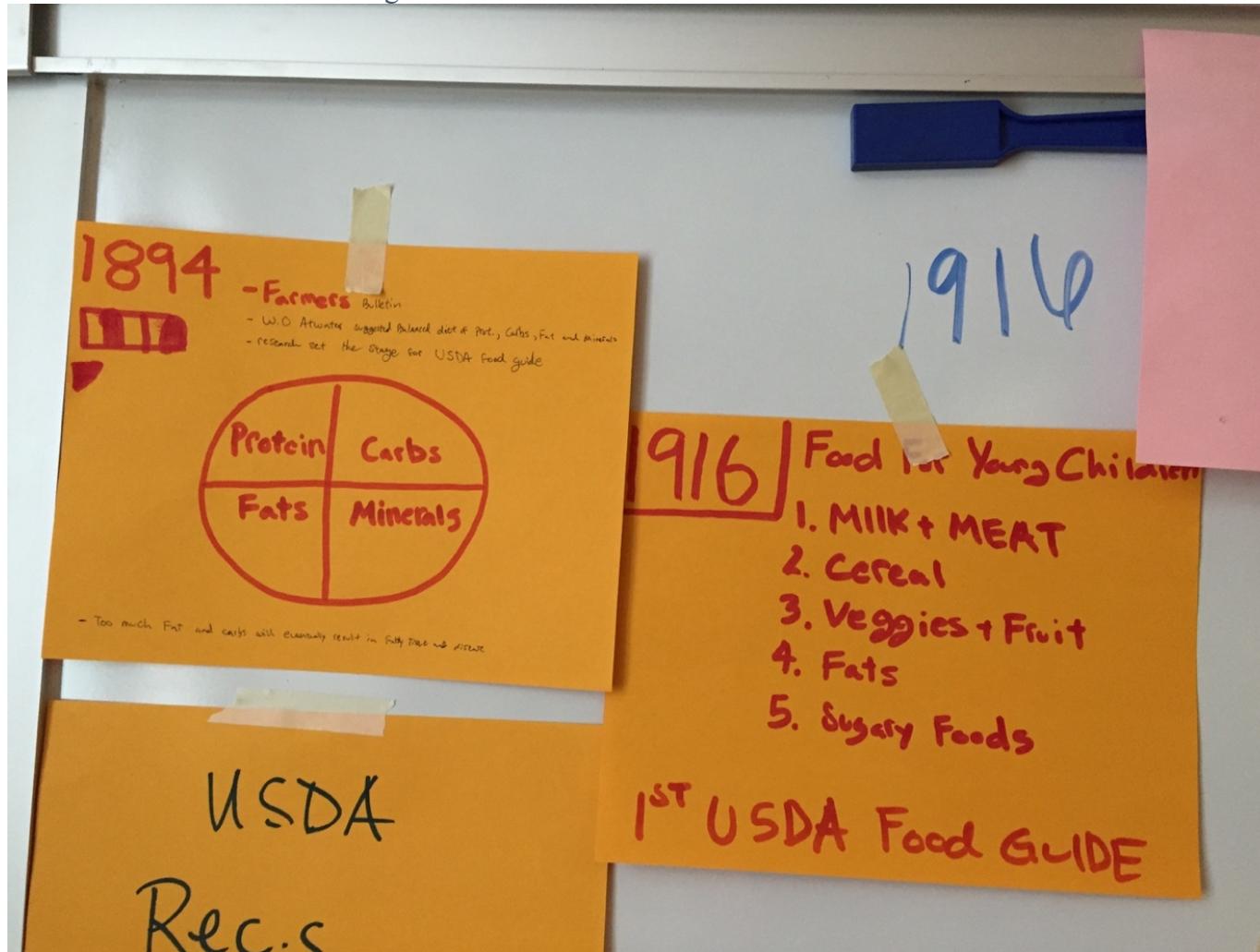


Figure 7. SSI Timeline: Part 1 Timeline Entries



are further classified to specify whether they represent political, economic, social, or “other” impacts. Groups then post their summaries under the Day 1 nutrition recommendation summaries, in chronological order on the timeline (See Figure 3). In addition to using color-coded paper to identify the category of scientific or social dimensions represented (See Figure 4), student groups are asked to provide: title and year/s of the event, brief summary of the event’s main characteristics, stakeholders to whom the event was relevant, and connections of the event to human nutrition (See Figure 5). For example, the Green Revolution of the mid-20th century, resulting from advances in agricultural technology, led to bountiful crop production. The availability of abundant food supplies had obvious *economic* impacts on the U.S. agricultural industry. This corresponded to a change in focus for nutrition recommendations of the era, away from prevention of deficiencies, toward general health.

Some events, such as the Seven Countries Study and the Diet-Heart Hypothesis, are of obvious scientific nature. Both are examples of scientific research that used medical data to draw conclusions about relationships between specific macronutrients and human physiology. Other historical events had impacts in more than one category, which can be recorded using multiple colors, as appropriate.

When the timeline is complete, student groups again present their summaries of events and engage in a whole class discussion. This enables students to recognize the changing and tentative nature of the science informing nutrition trends, as well as the profound impact of historical events on nutrition concerns, beliefs, and recommendations. In our complete unit, the Timeline activity leads naturally to lessons regarding current scientific understanding of chemical structures and biological functions of

Figure 8. SSI Timeline Part 2 (Includes Historically Significant Events)

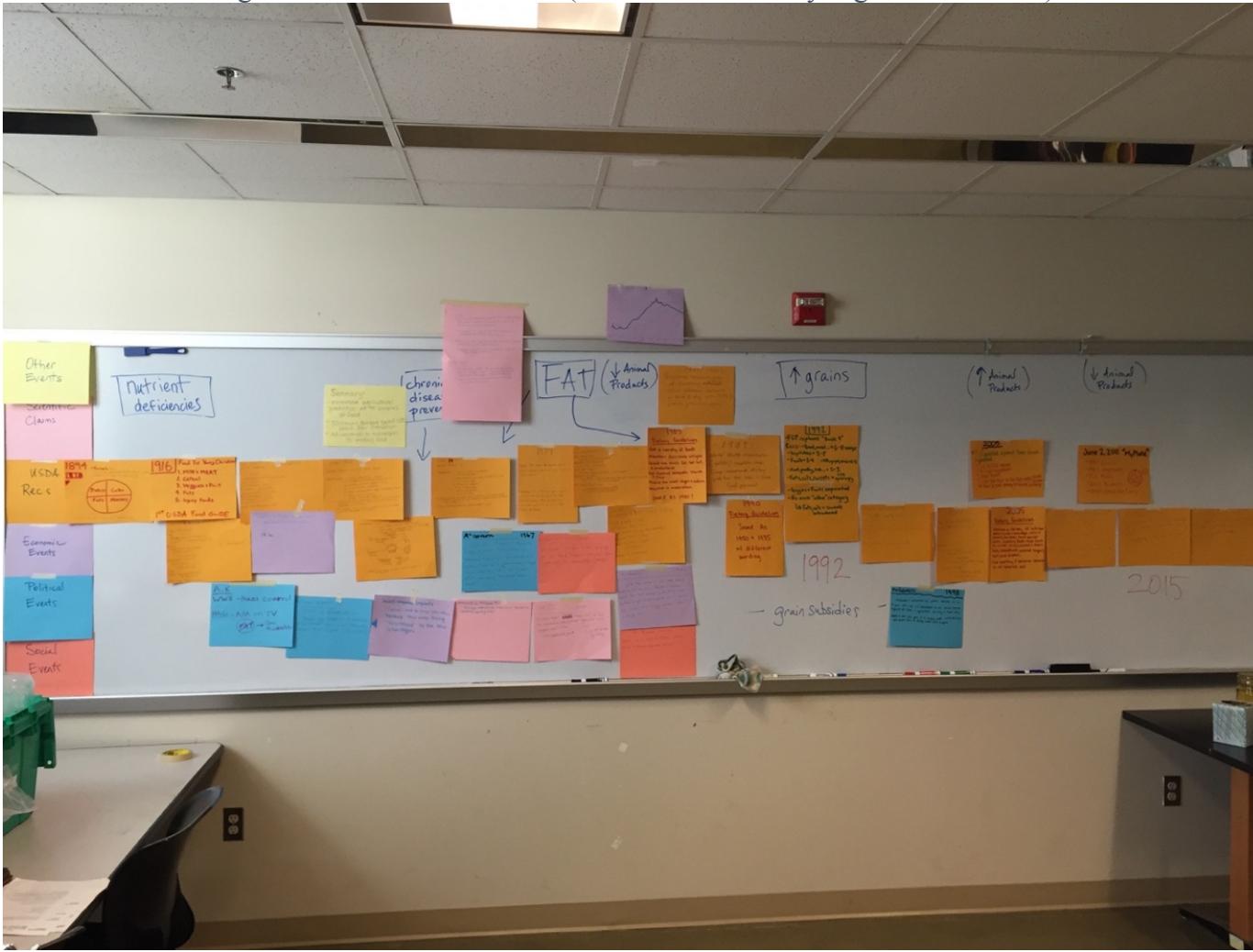


Figure 9. SSI Timeline: Categories of Societal Dimensions

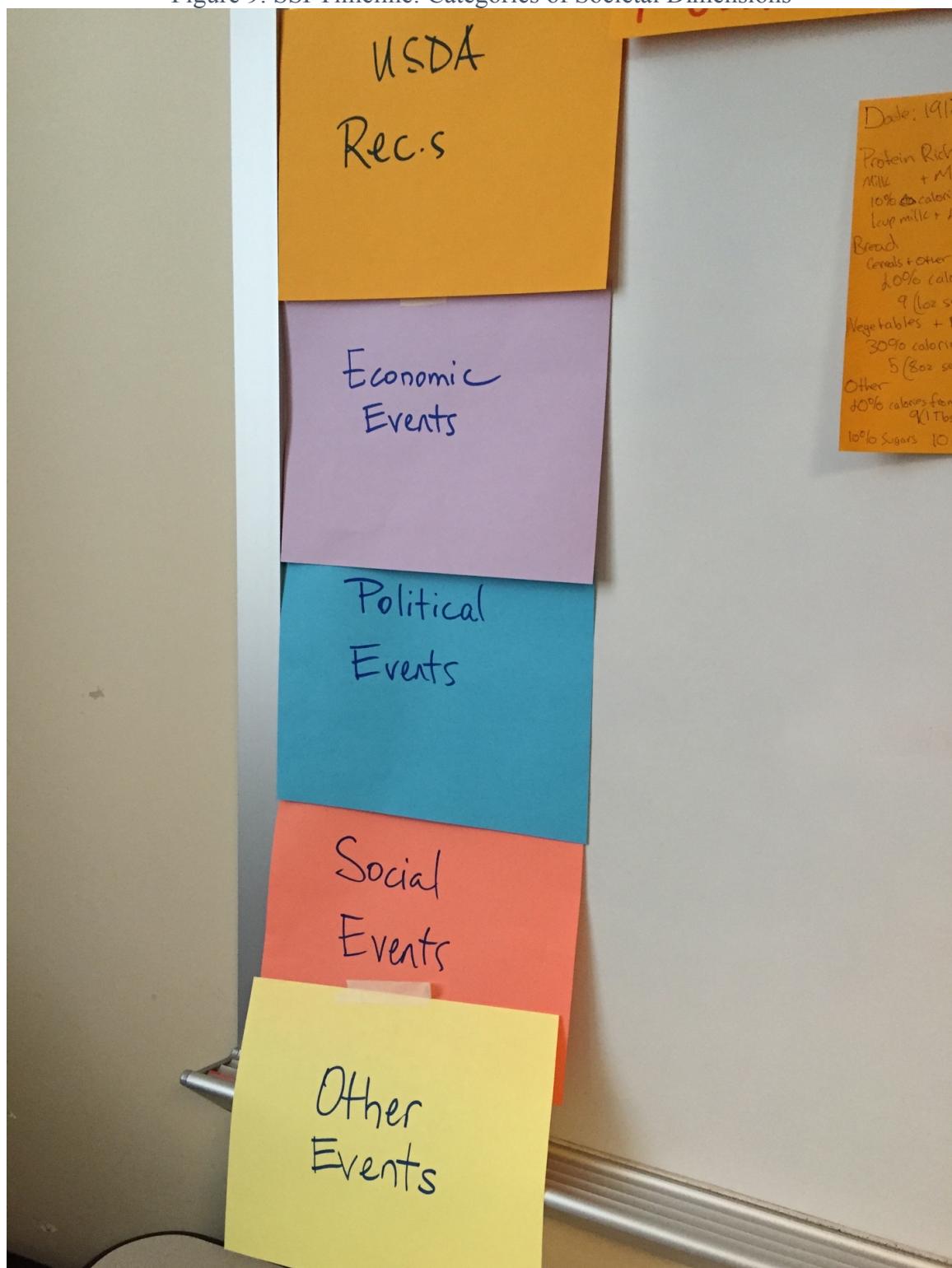


Figure 10. SSI Timeline: Examples of Part 2 Timeline Entries

Socio Economic Impact:

- Farmers had to move into cities because they were being "outproduced" by the new technologies

Political Impact:

- product of globalization
 - Shown by creation of several international agricultural research centers that shared information.

macromolecules, metabolic pathways, and human nutrition requirements.

Benefits of the timeline.

By constructing the timeline, students are able to make sense of key historical events of scientific, political, cultural, social, and economic natures that have influenced public (and their own) perception about nutrition. Students see the influence of wars, government policy, natural disasters, and marketing on nutrition recommendations. Through engagement in this activity, students recognize various positions of stakeholders such as the food manufacturing, agriculture, and healthcare industries, as well as ways that nutrition guidelines have been influenced by key scientific studies. Our students were remarkably enthusiastic and engaged in the topic of nutrition. Through the unit, they gained a deep understanding of the fat tax issue. To develop an informed position on the issue, they recognized the need to ask questions that require not only an understanding of science, but also a deep exploration of the changing social context. This activity motivated students to apply what they learned about the structure and function of macronutrients to calculations of nutritional energy, and the reactants and products of metabolic pathways. In addition, the timeline activity revealed the impacts of nutrition on public health, as well as government intervention and nutrition policy.

NGSS connections.

The nutrition unit focused on NGSS disciplinary core ideas from Life Science (HS-LS-1-6 and HS-LS-1-7) and Chemistry (HS-PS-1-2 and HS-PS-1-7). Throughout the nutrition unit students engaged in the scientific practices of explanation construction, argumentation, and scientific modeling. Energy systems were emphasized as the

crosscutting concept in the unit. Nature of science ideas such as the creativity, bias, and tentative nature of science, were featured in the Timeline activity.

Alternative contexts for the timeline lesson.

We have shared our Timeline lesson at a number of teacher workshops, and teacher participants have responded favorably to the activity. Many shared ways they have adapted the lesson for use in their own classrooms, and have reported positive results as their students explored societal dimensions of SSI appropriate to multiple science courses. Examples of alternative uses include variations of the nutrition timeline in a cellular respiration unit for a biology course; in a food security unit for a contemporary issues course; and in a unit on performance enhancing substances in an exercise science course. Another example features a timeline of historical events related to flooding and river management for a watersheds unit in an environmental science course.

Conclusion

Teaching science with socioscientific issues allows students to make meaningful use of science for application to real-world decision-making, rather than simply learning isolated science facts. This requires a shift in teachers' approaches to planning and teaching, to provide students focused opportunities to explore social aspects of SSIs beyond science content. The Timeline is a lesson that can help teachers integrate the social, political, and economic aspects of science issues into existing curriculum units and is consistent with what we know about best practices for SSI based teaching and learning. We encourage you to try it in a science unit.

For more guidance regarding teaching science with socioscientific issues, please see the [RI]² Teaching and Learning framework at our project website:

<http://ri2.missouri.edu/ri2teaching-learning-framework>

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Appendix

Fat Tax: Nutrition for Optimum Health & Performance Lesson 5 Guide: Nutrition Timeline

Title: A Timeline of Nutrition Recommendations and Historically Significant Events – Stakeholders, Claims, & Changing Ideas		
Subject/Topic/Grade Level: [11 th -12 th], Advanced High School: Exercise Science, Advanced Biology		
Alignment with NGSS: <i>at unit level,</i>		
<ul style="list-style-type: none">Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules (HS-LS1-6).Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy (HS-LS1-7) <p>What Crosscutting Concept(s) is addressed in this lesson? <i>Energy Systems</i></p> <p>NOS Connections: <i>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</i> <i>A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS4-1)</i></p>	<p>What Scientific and/or Engineering Practice(s) is addressed in this lesson?</p> <ul style="list-style-type: none"><i>Constructing Explanations</i><i>Engaging in Argument from Evidence</i><i>Obtaining, Evaluating, and Communicating Information</i>	<p>What is the SSI Aim of this lesson?</p> <i>awareness of historical patterns in nutrition science, aims and goals of published guidelines, multiple perspectives and various stakeholders represented in the issue, limitations of science, societal aspects of the issue</i>
<p>Common Core Standards Addressed:</p> <p><u>CCSS.ELA-Literacy.RH.11-12.2</u> Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.</p> <p><u>CCSS.ELA-Literacy.RH.11-12.3</u></p> <p>Evaluate various explanations for actions or events and determine which explanation best accords with textual evidence, acknowledging where the text leaves matters uncertain.</p>		

[CCSS.ELA-Literacy.RH.11-12.7](#)

Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, as well as in words) in order to address a question or solve a problem.

[CCSS.ELA-Literacy.RH.11-12.8](#)

Evaluate an author's premises, claims, and evidence by corroborating or challenging them with other information.

[CCSS.ELA-Literacy.RH.11-12.9](#)

Integrate information from diverse sources, both primary and secondary, into a coherent understanding of an idea or event, noting discrepancies among sources.

[CCSS.ELA-Literacy.RST.11-12.2](#)

Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

[CCSS.ELA-Literacy.RST.11-12.8](#)

Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

[CCSS.ELA-Literacy.RST.11-12.9](#)

Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

[CCSS.ELA-Literacy.WHST.11-12.1.a](#)

Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

At the end of the lesson...*Students will be able to:*

1. describe in detail a set of nutrition recommendations
2. describe in detail one historically significant nutrition-related event
3. collaboratively compile timeline of nutrition recommendations and historically significant nutrition-related events
4. describe patterns, trends, changes over time in nutrition guidelines, and existence of conflicting recommendations
5. describe connections between historical events and nutrition guidelines of the time (e.g., influences of significant events on nutrition guidelines, and vice versa), and identify societal aspects guidelines (e.g., characterize political, social, economic, etc. ramifications)

Assessment: How will I know if my students achieved my learning goals? (formative and summative)

1. small groups will create summaries of assigned nutrition recommendations
2. small groups will create summaries of assigned historical events
3. whole class will create a timeline of recommendations and historical events
4. students will describe in patterns, trends, and connections, using specific evidence and clear reasoning

Activities	Teacher's Role	Students' Role
Day 1 (55 min.)		

starter question	present the question and ask students to consider: <i>to me, eating for good health means...</i>	individually construct a clear response to the question
investigation of historical nutrition recommendations	assign small groups one or more of the topics: Basic 7, Basic 4, FGP, MyPyramid, MyPlate, US Dietary Guidelines, etc. (see weblinks resource); circulate to guide students' creation of summaries	investigate assigned topic in small groups, create a summary to be posted on timeline
creation of timeline	guide whole class assembly of timeline	post summaries to appropriate location on timeline
timeline discussion	facilitate synthesis discussion of patterns, trends, changes over time in nutrition recommendations, existence of conflicting recommendations	small groups share out summaries with the class, participate in synthesis discussion of whole class findings
Day 2 (55 min.)		
starter question	present the question and ask students to consider: <i>historically, eating for good health has meant...</i>	individually construct a clear response to the question
investigation of historically significant event	assign small groups one or more of the topics: Green Revolution, WWI, WWII, McGovern Committee, 7 Countries Study, etc. (see weblinks resource); circulate to guide students in creating their summaries and identifying societal aspects related to their assigned event	investigate assigned topic in small groups, create a summary to be posted on timeline; add nutrition connections to color-coded sheets to represent specific societal aspects of the issue related to their assigned event (e.g., political, social, economic, etc. ramifications)
addition to timeline	guide groups to post their summaries to the existing timeline from the previous day	post summaries to appropriate location on timeline
timeline discussion	facilitate synthesis discussion of connections between events and nutrition guidelines of the time (e.g., influences of significant events on nutrition guidelines, and vice versa)	small groups share out findings with the class, participate in synthesis discussion of whole class findings
Accommodations: How will I alter my lesson to meet a diverse range of student abilities?		
<i>Activities will be varied to include whole class discussion, small group work, and individual work; individual assignments will be differentiated as needed; discussions will include references to diversity of perspectives, and respect/appreciation for diversity will be strongly emphasized.</i>		

Fat Tax: Nutrition for Optimum Health & Performance Unit Overview

Focal Issue: Should the U.S. consider a "fat tax" to encourage citizens to make more "optimal" nutrition choices?

Big Idea: Nutrition choices are important because the body's structure and function are determined by nutrients consumed.

Essential Science Question: How can dietary intake affect health and human performance?

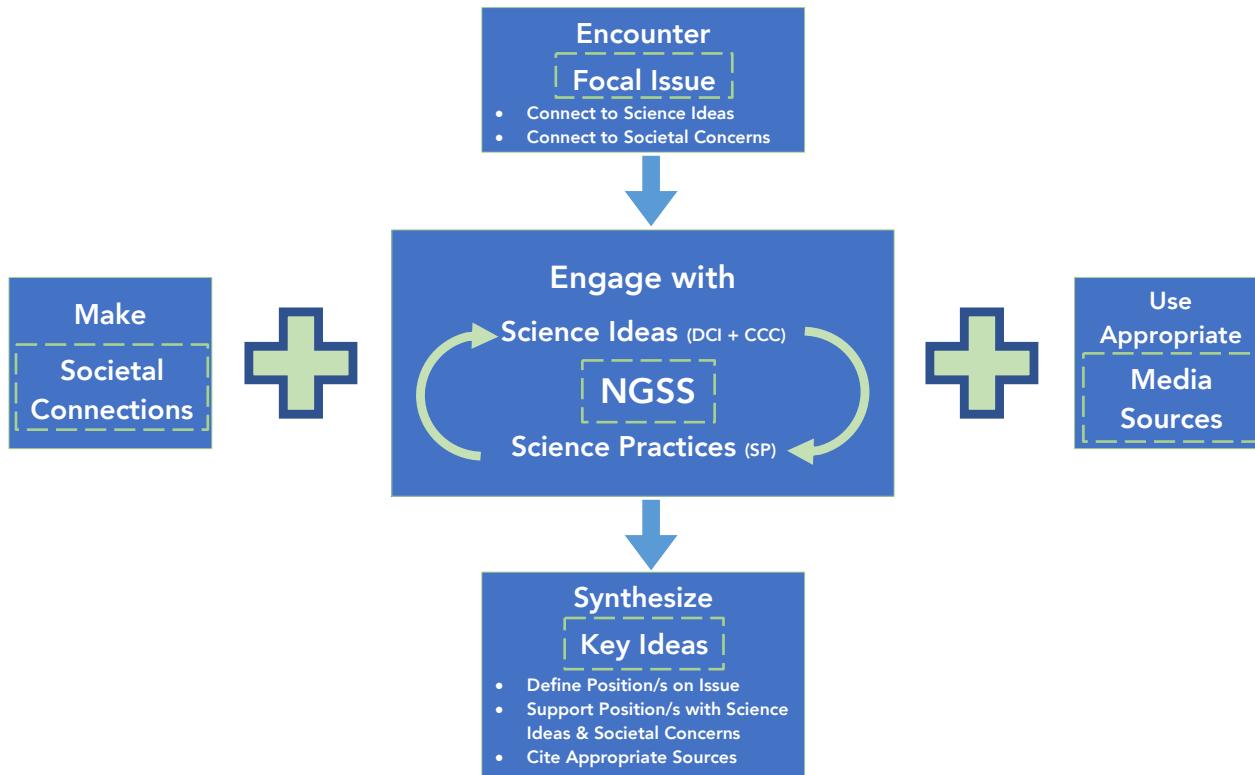
Lesson	Activities	Learning Goals
1	<p>Introduction to the "Fat Tax" <i>Should the U.S. consider a "fat tax" to encourage citizens to make more "optimal" nutrition choices?</i></p> <ul style="list-style-type: none"> Starter: read selection of news articles about the issue of "fat taxes" (e.g., in the U.S., Denmark, Mexico, & the U.K.) & write response to q; read classmates' responses & comment on 2+ Whole Class Discussion: meaning, implications, pros, cons (teacher makes notes to document student ideas) <p>Classifying Arguments</p> <ul style="list-style-type: none"> Whole Class: characterize nature of group's arguments from previous discussion (e.g., scientific, economic, political, social, public health, etc.), with explicit attention to stakeholders emphasize complexity of issue & varied motivations behind different types of arguments point out patterns in student responses (<i>most not scientific in nature, typically</i>) discuss affordances & limitations of non-scientific & scientific arguments (ability or inability for moral/ ethical judgment, ability or inability to explain & predict, etc.) <i>revisit issue:</i> following discussion, revise response to fat tax 	<p>*SSI Aim: awareness of issue and own position, recognition of complexity of issue, informed by multiple perspectives, of various natures, and representing various stakeholders</p> <ul style="list-style-type: none"> describe the concept of a "fat tax" & significant historical/cultural events related to "fat taxes" articulate personal views about a "fat tax" in the U.S., including pros, cons, and potential implications engage in discussion that characterizes nature of arguments (<i>scientific, plus social, political, economic, etc.</i>) distinguish between <i>scientific</i> and <i>social</i> arguments, and identify limitations of each type discuss/acknowledge various viewpoints about the issue explore possible stakeholders in the issue (<i>who might be affected by this tax? In what ways? Who might be in favor or opposed? Why?</i>) characterize the focal issue as complex identify science questions: e.g., <i>What constitutes "good" and "poor" nutrition choices, and why?</i>
2	<p>Cross-Cultural Comparison of Nutrition Guidelines</p> <ul style="list-style-type: none"> Starter: <i>Healthful nutrition is...</i> World Food Rec.s Exploration <ul style="list-style-type: none"> provide each group with copies of Asian, African, Australian, Mediterranean, Latin American, Vegetarian, USDA MyPlate resources 	<p>*SSI Aim: establish driving science question and the need to explore related science ideas: <i>How can dietary intake affect health and human performance?</i></p> <ul style="list-style-type: none"> identify various influences on nutrition rec.s (e.g., cultural tradition, personal preference, physiological needs, financial limitations, geographic accessibility, etc.)

	<ul style="list-style-type: none"> ○ For each, identify: source, target audience, purpose; ○ Compare/contrast rec.s across all ○ Whole Class Discussion 	<ul style="list-style-type: none"> ● describe variety within food recs: no "one size fits all," yet is there some "bottom line"...?
3	<p>Science Content Part I: Macronutrients (Carbohydrate, Protein, & Fat)</p> <ul style="list-style-type: none"> ● Energy in Food: Calorimetry Lab (Use calorimetry to measure kCal in food, & compare to food label) ● Select 1 meal from food diary and: <ul style="list-style-type: none"> ○ identify major food sources of 3 macronutrients ○ demonstrate calculations of energy values & macronutrient ratios (calculate or use app values) 	<p>*SSI Aim: consideration of commonalities among dietary choices in terms of macronutrient content and potential effects on health and human performance</p> <ul style="list-style-type: none"> ● Identify and calculate "kCal" as measurement of food energy ● Create representations of chemical structures of CHO (gluc), Pro (aa), Fat (TG & SFA, MUFA, PUFA) ● Determine function of macronutrients, correlated to structures <p><i>Students begin recording 3-day Food Diary for later use (input to app or online software, e.g., myfitnesspal)</i></p>
4	<p>Science Content Part I: Micronutrients (Vitamins & Minerals)</p> <ul style="list-style-type: none"> ● Vitamin Titration Lab ● Using same meal from food diary as previous day, identify major sources of micronutrients & describe possible effects of consuming these micronutrients 	<p>*SSI Aim: consideration of commonalities among dietary choices in terms of micronutrient content and potential effects on health and human performance</p> <ul style="list-style-type: none"> ● Classify vitamins vs. minerals, based on chemical characteristics ● Identify general functions of these classes of micronutrients
5a	<p>Timeline of USDA Nutrition Guidelines, Part I</p> <ul style="list-style-type: none"> ● Starter Q: <i>To me, eating for good health means...</i> ● Small groups investigate historical USDA rec.s: Basic 7, Basic 4, FGP, MyPyramid, MyPlate, US Dietary Guidelines, etc. ● Collaborative timeline creation ● Whole class timeline discussion 	<p>*SSI Aim: awareness of historical patterns in nutrition science, aims and goals of published guidelines, multiple perspectives and various stakeholders represented in the issue</p> <ul style="list-style-type: none"> ● (per group) describe in detail one set of U.S. dietary guidelines ● (whole class) collaboratively compile timeline of nutrition recommendations ● describe patterns, trends, changes over time in nutrition guidelines, and existence of conflicting recommendations

5b	<p>Timeline of USDA Nutrition Guidelines, Part II</p> <ul style="list-style-type: none"> Small group exploration of historically significant nutrition events (e.g.: Green Rev'n, WWI, WWII, McGovern Committee, 7 Countries Study, others) Whole class discussion: connections to & influence on nutrition recommendations? 	<p>*SSI Aim: awareness of limitations of science, societal aspects of the issue, informed by multiple perspectives, representing various stakeholders</p> <ul style="list-style-type: none"> (per group) describe in detail one historically significant nutrition-related event (whole class) collaboratively add summary of event to timeline of nutrition recommendations, and <i>identify societal aspects of the events</i> (e.g., characterize political, social, economic, etc. ramifications) describe connections to nutrition guidelines (e.g., influences of significant events on nutrition guidelines, and vice versa)
6	<p>Self-Analysis: 3-d Food Diary</p> <ul style="list-style-type: none"> input to app or online software analyze (calculate or use app): <ul style="list-style-type: none"> macronutrient ratios micronutrient values compare to researched dietary rec.s (Timeline lesson) describe how 3-d record meets "optimal" ntn rec.s, what you did "well" regarding your food intake (explain), and what changes would "improve" your diet-as-recorded (explain) compare to a different set of guidelines & answer the above q.s what conclusions can you draw about the answer to our EQ (support w/ your analysis)? trade responses with a classmate. 	<p>*SSI Aim: recognition of the interaction of personal, social, economic, ethical, and other societal aspects of the issue, with the scientific, as applied to one's own (and others') experience; <i>how might a "fat tax" affect the social, ethical, or other societal impacts (e.g., cost) of the meal you recorded? how might these influence your choices? what impacts on health or performance would you expect as a result?</i></p> <ul style="list-style-type: none"> demonstrate analysis of dietary intake through calculations of macronutrient and micronutrient contents interpret nutrition guidelines as applied to a sample dietary intake
7	<p>Science Content, Part II: Metabolic Pathways & Hormonal Regulation</p> <ul style="list-style-type: none"> Small group readings: CHO, Fat, Pro metabolism Construct collaborative "metabolism map" to include all assigned pathways (directional arrows, centered on pyruvate & ACoA, all possible paths traced) Whole class discussion of roles of insulin, glucagon, adrenaline 	<p>*SSI Aim: consideration of impact of dietary choices on health and human performance, in terms of metabolic pathways and hormones</p> <ul style="list-style-type: none"> identify and describe anabolic and catabolic biochemical reactions that occur within an organism identify major storage sites and roles of glycogen and triglycerides in the body describe functions of insulin, glucagon, and adrenalin during fasting and exercise

8	<p>Revisit 3-d Food Diary</p> <ul style="list-style-type: none"> • select 1 meal; identify food sources of macronutrients • construct model of metabolic pathways that this meal's nutrient components follow after digestion • describe hormonal response to & influence on pathway 	<p>*SSI Aim: Connections to Timeline, EQ, SSI (e.g., how does this meal compare to current nutrition guidelines? how might it look different if influenced by those of a different time period? what effect might a "fat tax" have on this meal & your choices?)</p>
9	<p>Summative Content Assessment</p>	<p>demonstrate understanding of relevant science ideas related to macronutrients, micronutrients, metabolic pathways, and hormonal regulation.</p>
10	<p>Culminating Synthesis Project Using what you have learned about optimal nutrition, energy cycles, metabolic pathways, differences in nutrition guidelines in various cultures, and the history and societal implications of U.S. nutrition recommendations, write a position paper that answers the SSI question.</p>	<p>*SSI Aim: Synthesize relevant science ideas and societal aspects related to the focal SSI, to compose a response to the question, supported with evidence and reasoning. <i>Should the U.S. consider a "fat tax" to encourage citizens to make more "optimal" nutrition choices?</i></p>

An SSI Curriculum Framework
adapted from Sadler, Foulk, and Friedrichsen (2017)



CHAPTER FOUR

PRE-SERVICE SCIENCE TEACHERS' BELIEFS AND CURRICULUM DESIGN

PRACTICE AROUND SSI TEACHING AND LEARNING

Introduction

To achieve scientific literacy among the general populace, K-12 science education must lead to students' appreciation for and competence with science in their lives and their world (Feinstein, 2011, p. 180; Kolstø, 2001). This means students must experience the negotiation of authentic scientific issues in real-world contexts, which necessarily bear consequences on their communities. These "societal issue[s] with substantive connections to science and principles" (Sadler et al., 2017, p. 75), such as antibiotic resistance, genetic modification, and climate change, are known as *socioscientific issues* (SSI) (Sadler, 2004). Engaging students in reasoning and science sense-making around these complex and societally relevant SSI is necessary for achievement of scientific literacy, itself an essential component of democratic citizenry (Kolstø, 2001; Zeidler, Sadler, Simmons, & Howes, 2005).

Current K-12 science education reform efforts call for development of scientific literacy for all learners, through active engagement in "three-dimensional learning" around science ideas and practices (National Research Council, 2012; NGSS Lead States, 2013). This combination of learner outcomes authentic to science is a means to the desired goal of "Vision II" scientific literacy (Roberts, 2007; Roberts & Bybee, 2014), in which one is able to make informed use of scientific ideas situated in public and environmental arenas, while also attending to contextual considerations of a societal and ethical nature (Zeidler, 2014b). In SSI-focused science classrooms, three-dimensional

learning experiences are facilitated in the context of an SSI, and learners engage in activities in which they must utilize science practices to investigate related scientific ideas, while also exploring societal dimensions of the issue (e.g., social, ethical, political, or economic), including implications of related decision-making (Eilks, Marks, & Feierabend, 2008; Kolstø, 2001; Kolstø et al., 2006; Sadler, Chambers, & Zeidler, 2004; Sadler & Zeidler, 2005; Zeidler, 2014a; Zeidler, Applebaum, & Sadler, 2011; Zeidler et al., 2005).

A large body of research has identified many benefits to learners in SSI-focused learning contexts, including gains in understanding of science ideas (Dawson & Venville, 2010, 2013; Sadler, Klosterman, & Topcu, 2011; Sadler, Romine, & Topçu, 2016; Venville & Dawson, 2010) and the nature of science (Khishfe & Lederman, 2006; Lederman, Antink, & Bartos, 2014; Sadler et al., 2004), as well as in scientific practices such as modeling (Peel, Zangori, Friedrichsen, Hayes, & Sadler, 2019; Zangori, Peel, Kinslow, Friedrichsen, & Sadler, 2017) and argumentation (Venville & Dawson, 2010). In addition, students have demonstrated benefits beyond traditional learning outcomes, such as evidence of reasoning skills (Kolstø et al., 2006; Sadler et al., 2004; Sadler & Zeidler, 2005; Zeidler et al., 2011); moral, ethical, and character development (Fowler, Zeidler, & Sadler, 2009; Lee et al., 2006); and an increase in enthusiasm and interest within science learning contexts (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 SSI. However, little is known about how to promote teachers' uptake of an SSI-oriented pedagogical approach. Research indicates that despite many K-12 science teachers' favorable views of SSI, they struggle

to incorporate SSI-focused pedagogy in their classrooms, and those who utilize SSI tend to do so infrequently and superficially (Lee, Abd-El-Khalick, & Choi, 2006; Lumpe, Haney, & Czerniak, 1998; Sadler et al., 2006; Saunders & Rennie, 2013). Explanations for teachers' resistance to integrating SSI-focused activities into their classrooms that have been advanced in the literature include discrepancies between teachers' beliefs and the philosophical basis of the pedagogy (Hansen & Olson, 1996; Lee et al., 2006; Sadler et al., 2006); limited access to SSI-focused curricular resources (Sadler et al., 2006); and lack of familiarity, experience, and/or comfort with an SSI-focused teaching approach (Lee et al., 2006; Sadler et al., 2006; Saunders & Rennie, 2013).

Research underscores the critical influence of early career teachers' beliefs on their uptake of educational reforms (Fletcher & Luft, 2011), and early career teachers have shown great promise toward the adoption of reform-oriented beliefs (Crawford, 2007). In view of the promise of an SSI-based pedagogy for promoting scientific literacy; the demonstrated incongruence between teachers' SSI perceptions and enactment practices; and the potential for early career teachers' adoption of reform-oriented beliefs; the challenge of supporting pre-service science teachers to begin aligning their beliefs with SSI-focused teaching practices necessitates further investigation.

This work was a response to that need. We sought to address each of the issues cited for teachers' reluctance toward SSI teaching and learning by analyzing alignment of their beliefs to SSI pedagogical philosophy; facilitating their exploration of SSI-based pedagogy; and supporting their practice of SSI-based curricular design. Specifically, in this project we sought to explore the SSI-related beliefs of a group of pre-service teachers as they engaged in the practice of curriculum design in an SSI-focused methods course.

To learn more about their beliefs during participation in the SSI-focused methods course, we investigated both the nature of PSTs' beliefs about SSI teaching and learning, and PSTs' designs for SSI-focused curricular units.

Theoretical Framework

This study is framed by research around the key theoretical construct of teacher beliefs. In addition, we leverage a specific framework for SSI teaching and learning.

Teacher beliefs.

Teachers' beliefs strongly influence decision making and classroom practice (Bryan, 2012; Haney & McArthur, 2002; Hutner & Markman, 2016; Jones & Carter, 2007; Jones & Leagon, 2014; Wallace, 2014). Consequently, researchers have sought to understand and leverage the nature of relationships among such closely related constructs as beliefs, attitudes, knowledge, and practice; and have argued that ultimately, efforts to influence teachers' uptake of reform-oriented practice must also address teacher beliefs in order to yield meaningful results (Fletcher & Luft, 2011). Fletcher and Luft (2011) called teachers' beliefs a construct that had "fascinated and frustrated researchers for over 30 years" (p. 1125). Despite historical challenges related to research around the "messy construct" (Pajares, 1992, p. 307) of teacher beliefs, there remains a need to understand teachers' belief systems as determinants of their teaching decisions and practices (Nespor, 1987).

A challenge of research in the area of beliefs arises from the fact that beliefs are difficult to separate from closely related constructs, such as attitudes and knowledge, and thus may be defined in interchangeable, varied, sometimes contradictory ways (Hutner & Markman, 2016; Jones & Carter, 2007; Jones & Leagon, 2014; Pajares, 1992). In the

literature, the term *beliefs* has been used synonymously with *attitudes*; called by different names such as *perceptions* or *views* (Jones & Carter, 2007; Jones & Leagon, 2014); and conceptualized as part of a set of interconnected constructs, as in *practical knowledge*, an amalgam of teachers' beliefs and knowledge resulting from their professional experiences (Meijer, Verloop, & Beijaard, 1999, 2001; Van Driel, Beijaard, & Verloop, 2001). Many authors distinguish beliefs from knowledge, attitudes, and other related constructs, using epistemological definitions based on the social condition of agreement, or on the presence of additional factual information (Jones & Carter, 2007; Jones & Leagon, 2014; Richardson, 1996). Hutner and Markman (2016) propose a functional definition, instead, in which only active beliefs serve to mediate development of other beliefs and practices, and the beliefs that are inherently more important to a person are most likely activated. Less relevant beliefs can be assumed to be dormant. According to Hutner and Markman (2016), "new representations, such as a new belief, that are created are influenced by only those representations that are active during the learning process." (p. 9).

One area of research interest regarding beliefs is the extent of alignment between beliefs and practice, especially in relation to educational reforms and innovations in practice (Hutner & Markman, 2016). Beliefs have been found to influence teachers' planning for inquiry instruction (Crawford, 2007) and uptake of reform-oriented pedagogy (Hutchins & Friedrichsen, 2012). Lee et al. (2006) found that teachers' efficacy beliefs were influenced by such factors as other beliefs (e.g., epistemological) and attitudes, and in turn, significantly influenced SSI-focused teaching behaviors. A comparison between National Board Certified teachers and non-board certified

counterparts found that self-efficacy beliefs were highly correlated to teachers' deep reflection about their teaching practices (Woods & Rhoades, 2013).

While research indicates that the relationship between changes in practice and changes in beliefs cannot be presumed to be linear, the same body of research makes clear that changes in practice with teacher education interventions tend to be superficial or short-lived in interventions that fail to also address teachers' beliefs (Jones & Carter, 2007; Jones & Leagon, 2014). The phenomenon of affecting teachers' practices and behaviors by targeting their beliefs is empirically supported (Zint, 2002), and challenging beliefs is a long-standing fundamental goal of teacher education and professional development programs (Richardson, 2003). This justifies the exhortation that teacher educators actively attend to beliefs when attempting to support pre-service teachers' uptake of reform-oriented practice (Fletcher & Luft, 2011).

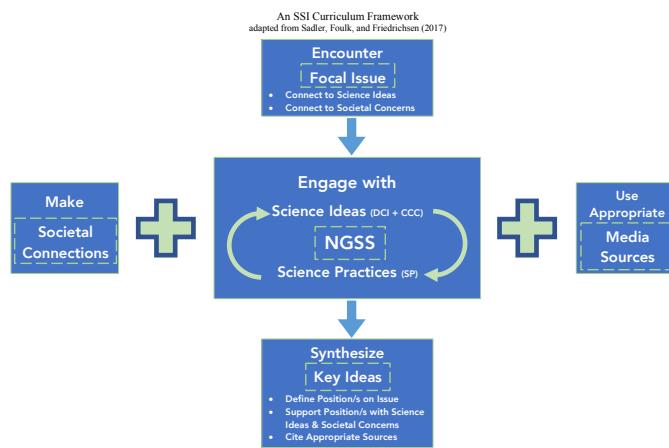
We view beliefs as being values-laden and personal, and having both affective and cognitive natures (Fletcher & Luft, 2011; Nespor, 1987). In this project we conceptualize teachers' beliefs as personal views about an action, behavior, or idea; held to be true, though based upon personal experiences, formed through personal negotiation in a social context (Nespor, 1987). Although beliefs and the cognitive construct of knowledge have been distinguished from one another by the lack or presence of a component of objective truth (Richardson, 1996), we agree with Kagan (1992), that there is so little about teaching that is objectively correct or true, that much of what is called knowledge with respect to teachers is, in fact, belief. Likewise, we agree with the view of Hutner and Markman (2016), that for practical purposes, beliefs, attitudes, and knowledge are indistinguishable cognitive representations, relevant when activated,

which serve to mediate other cognitive representations (including other beliefs, goals, desired outcomes, and future actions), as well as thoughts or actions (i.e., practice). We maintain that beliefs serve as a lens through which teachers interpret their professional roles and responsibilities, and which guide teachers' instructional decisions and practices (Fletcher & Luft, 2011; Jones & Carter, 2007; Jones & Leagon, 2014; Nespor, 1987).

Socioscientific issues teaching and learning: a teaching framework for SSI.

In conjunction with the key theoretical constructs described above, we draw heavily from the *Socioscientific Issues Teaching and Learning Framework* (SSI-TL) (Sadler et al., 2017). This instructional framework builds upon previous literature around SSI, and is representative of an evolutionary step from a broad pedagogical philosophy

Figure 1: Socioscientific Issues Teaching and Learning Framework



for SSI (Zeidler, 2014a) toward a more operationalized approach to science teaching and learning. A successor to the Presley et al. (2013) *Framework for SSI-Based Education* and the *Instructional Model for SSI-Based Education* (Sadler et al., 2015), SSI-TL seeks to further refine and make accessible the practical integration of SSI for science teachers. SSI-TL foregrounds a focal SSI in a curricular unit and revisits it throughout lessons

within the unit, while engaging students in sensemaking of both the science ideas and societal dimensions relevant to the issue (See Figure 1). In our study, the SSI-TL framework was both a representation of a particular SSI-based teaching approach and a tool to support PSTs' uptake of the approach. SSI-TL also informed our data analysis related to PSTs' beliefs and curricular designs.

Literature Review

A review of relevant literature revealed no research that directly addressed pre-service teachers' SSI-focused beliefs and uptake of SSI-based teaching practices. Alternatively, this study leveraged closely related literature bodies, including research around SSI curriculum design, in-service teachers' perspectives about SSI, and SSI in pre-service teacher education.

SSI curricular materials.

Some science education research has begun to position K-12 classroom teachers as curriculum designers, highlighting the curriculum development process as a significant component of teaching practice and a contributor to professional growth. For example, a small group of veteran secondary science teachers collaborated with a research team to design a reform-based curricular unit in response to new national science standards (Coenders & Terlouw, 2015; Coenders, Terlouw, Dijkstra, & Pieters, 2010). Coenders and Terlouw (2015) were interested in both design and enactment of the units, and results indicated that the teachers' knowledge and beliefs changed in both the curriculum design and enactment phases. The authors described the teachers' curriculum design process as a powerful experience in their preparation for reform-based innovations (Coenders & Terlouw, 2015; Coenders et al., 2010).

A recent movement in multiple education fields such as math, science, art, literacy, and physical education, builds upon work in which teachers' professional role is conceptualized to include curriculum making as a discrete practice, (Clandinin & Connelly, 1990; Connelly & Clandinin, 1988; Remillard, 1999), in contrast to historical tradition that positioned teachers as mere implementers of externally designed curricula (Craig, 2010, 2013; Oh, You, Kim, & Craig, 2013; Wallace & Priestley, 2017). Craig (2012) argues that a focus on curriculum design in teacher education settings can impact teachers' enactment practices in meaningful ways.

In the SSI literature, researchers and teachers have developed curricula for use in research studies that focus on a wide array of socioscientific topics, such as alternative energy production (Christenson, Chang Rundgren, & Höglund, 2012; Eilks, 2002), climate change (Carson & Dawson, 2016; Christenson et al., 2012; Peel et al., 2019), genetic modification (Carson & Dawson, 2016; Christenson et al., 2012; Dawson & Venville, 2010; Lederman et al., 2014; Lee et al., 2013; Sadler & Zeidler, 2005), antibiotic resistance (Friedrichsen, Sadler, Graham, & Brown, 2016), and environmental impacts of human activity (Eilks et al., 2008; Kolstø, 2006). However, only a few of the studies (Eilks, 2002; Friedrichsen et al., 2016; Zeidler et al., 2011) focused on the process or products of SSI curricular design, and the curricula generally have not been made available for classroom use. Among the few publications that highlight the products or processes of curricular design, common approaches for design have involved individual curricular development by a teacher-researcher (Eilks, 2002), or close collaboration between a research team and an individual classroom teacher (Friedrichsen et al., 2016; Owens, et al., 2019; Zeidler et al., 2011). A recent study investigated the design process

of a small number of teachers in a professional development setting, and found that small groups of teachers were able to work collaboratively with the aid of scaffolds, such as sample units and explicit discussion of the SSI-TL framework, to create SSI-TL curricular units for use in classroom learning communities (Hancock, Friedrichsen, Kinslow, & Sadler, 2019).

Other tools have been created to support classroom teachers' incorporation of SSI into their classrooms. Lederman et al. (2014) provided a collection of detailed suggestions for researchers to consider regarding teachers' use of genetics-focused SSI in secondary science classrooms. Kinslow and Sadler (2018) provided a practitioner resource about socioscientific reasoning through a single SSI-focused unit for environmental science. Zeidler and Kahn (2014) published a practitioner resource with a collection of SSI curricular units designed for use in various science sub-disciplines and grade levels, from which a K-12 science teacher might be able to pick and choose a few units appropriate for a given science classroom.

Given the origin of many SSI curricula as components of research projects and the small number of resources published for classroom teachers, existing SSI-based curricula tend to be highly varied, idiosyncratic, and of limited availability in K-12 contexts. For these reasons, the curriculum design process must be regarded as an integral practice for SSI teaching and learning.

In-service teachers and SSI.

Teachers' beliefs were found to influence behaviors when teaching science with SSI. In some cases, teachers' beliefs regarding SSI conflicted with their practice or prevented uptake of the approach. When Feierabend, Jokmin, and Eilks (2011)

investigated experienced teachers' views on teaching about the issue of climate change, they found that even though the teachers universally believed in the importance of teaching about the issue, few incorporated it into their own classrooms. Lee et al. (2006) proposed that the disparity they saw between teachers' beliefs and SSI-focused teaching practices may have been mediated by the teachers' low self-efficacy about teaching with SSI. In an investigation of teachers' perceptions about teaching ethics with SSI, Sadler et al. (2006) classified teachers into SSI profiles based on pedagogical orientations, concluding that teachers' (sometimes conflicting) beliefs drove their SSI-based practice, prompting Zeidler (2014a) to emphasize the importance of understanding teachers' pedagogical beliefs when attempting to foster uptake of an SSI-based teaching approach.

In other cases, teachers' perceptions served to motivate the uptake of SSI-focused teaching. In a year-long project of SSI-based curriculum development and enactment, the beliefs of elementary teachers mediated their uptake of an SSI-based pedagogy (Zangori, Foulk, Sadler, & Peel, 2018). Results indicated that, while all the teachers perceived benefits of SSI for their students, its alignment with their deeply held personal passions and ideas about education motivated the greatest enthusiasm for the approach. In a recent study by Hancock et al. (2019) that followed teacher participants in an SSI-focused professional development project, findings indicated that some teacher participants working in collaborative small groups were able to mobilize their personal passions in their successful design of SSI-focused curricula. In a study of secondary educators, Lee and Witz (2009) described four teachers who had designed and enacted SSI-based learning experiences in their classrooms on their own accord. They were motivated by their own personal values and ideals, which aligned with the pedagogical approach.

Practices needed to successfully enact an SSI-based teaching approach extend beyond those generally considered to characterize good teaching. Owens et al. (2019) analyzed the teaching practices during enactment of an SSI-based curricular unit by a teacher they described as experienced and successful at SSI-based science teaching. The curricular unit had been revised in multiple iterations of co-design and enactment by the teacher and a research team (Friedrichsen et al., 2016; Friedrichsen, Sadler, Graham, & Selby, 2015; Sadler et al., 2015). This study found that during enactment of the curriculum, the teacher demonstrated specific teaching practices unique to SSI, and that these practices enabled her to use the SSI-based approach effectively.

Participation in the process of SSI curricular design as part of adopting an SSI approach was shown to be transformative of some teachers' beliefs about science education, and in turn, their classroom practice. Zeidler et al. (2011) presented the results of a collaboration between a research team and a secondary science teacher to redesign an advanced biology course and provide support during enactment. Though the authors described the teacher and the research context as a "rarity" (p. 281), their results showed that with participation in the study, this teacher described changes in his own beliefs about his students, science teaching, and learning; as well as intentional changes he made to his teaching methods as a result. In similar work by Eilks and Markic (2011), a longitudinal study of teacher-researcher collaborations showed that teachers' participation in iterative cycles of SSI-focused curriculum design and enactment transformed not only their beliefs, but also their teaching practices.

Pre-service teachers and SSI.

In many studies about SSI in a teacher education context, PSTs were an accessible sample of learners, and the variables investigated were related to PSTs' science learning in SSI classrooms, similar to many previous studies of learner outcomes in relation to SSI. Several studies investigated PSTs' argumentation and informal reasoning with participation in an SSI learning experience (Fowler et al., 2009; Justi & Mendonça, 2016; Ozturk & Yilmaz-Tüzün, 2017; Topçu, Yilmaz-Tüzün, & Sadler, 2011). Although the authors of one study reasoned that SSI-focused coursework should be added to science teacher education programs (Ozturk & Yilmaz-Tüzün, 2017), in each of these studies, PSTs' engagement with SSI was not directly linked to their teaching practices.

Some research focused on SSI and PSTs' beliefs or perceptions. Borgerding and Dagistan (2018) presented an exploration of PSTs' views about controversial issues, including SSI, and their plans for teaching about these issues. Findings included PSTs' classification of several example issues into pre-determined categories based on types of controversies, and the general teaching strategies PSTs identified for teaching about these issues. Barrett and Nieswandt (2010) looked at PSTs' beliefs with respect to teaching ethics with SSI, and found that PSTs exhibited subject-specific variation in their beliefs about the goals and purposes of education, as compared to their pedagogical beliefs. From their analyses of in-depth interviews with PSTs of chemistry and physics, the authors found that the ways PSTs talked about their professional and academic lives placed them into four archetypes of identity, such as the Model Scientist/Engineer, who held the belief that SSI does not belong in science education. Kilinç et al. (2014) presented a quantitative analysis of interactions among PSTs' epistemological beliefs, teaching goals, and views about the role the teacher should play in SSI discourse. Barrett

and Nieswandt (2010), concluded that teacher educators should design activities to explicate and challenge PSTs' beliefs in order to support the uptake of SSI-oriented practices. Notably, in each of these studies regarding PSTs and SSI, there was no mention of a specific issues-based teaching framework, nor of a program intended to support PSTs' uptake of SSI-focused pedagogy.

PSTs' design of coherent SSI curricular units has not been a focus of research. Existing research around PSTs and reform-oriented curricula has focused on the ways they *adapted* (Crawford, 2007; Forbes, 2013; Forbes & Davis, 2010b) or *critiqued* (Davis, 2006), rather than designing curricula. In a study by Topçu, Foulk, Sadler, Pitiporntapin, and Atabey (2017), PSTs developed SSI-focused curricular materials and enacted them as a practice teaching activity with peers. However, the purpose of the study was to develop an observation protocol based upon the PSTs' fidelity to a teaching framework, and did not focus on the participants' design process. Similarly, research linking PSTs' beliefs to SSI and curricula is limited. In a study of elementary PSTs, Forbes and Davis (2008) explored the teachers' critique and modifications regarding an existing SSI-focused curriculum, and characterized the informal reasoning demonstrated by the PSTs during the process. In the elementary education context, the authors argued for the use of educative curricula, and not the design of curricular materials, to support this population in the uptake of reform-oriented science teaching practices.

Teacher education as a context for curriculum design and challenging beliefs.

Teacher education can be an important context for addressing beliefs that PSTs have formed through their experiences as students in science classrooms, and attending to PSTs' beliefs is as important as attending to their content or pedagogical expertise

(Fletcher & Luft, 2011). Contrary to more experienced teachers, whose beliefs have been found to be more deeply established and therefore more difficult to change, pre-service and early career teachers can more readily adopt new beliefs (Crawford, 2007). One study sought to investigate a link between PST beliefs and curriculum design. Rojas-Perilla (2018) presented a multiple case study in which he analyzed formal lesson plans designed by PSTs, to determine the influence of teachers' beliefs and goals on the cognitive demand of learning activities they designed. Participants' designs for curricular materials were limited to multiple standalone lessons, rather than sequences of lessons intended to be taught as cohesive units of study, and did not explicitly incorporate SSI.

Regarding teachers' beliefs about SSI-based science pedagogies, a mere awareness of the SSI pedagogical paradigm and its potential learner benefits may be inadequate to motivate teachers to use the approach (Lee et al., 2006). Rather, it may be necessary for science teacher educators to facilitate experiences that reveal teachers' beliefs about epistemology, science teaching and learning, and SSI-based teaching and learning in particular. Analysis of beliefs for alignment to an SSI pedagogical paradigm can inform the design of innovative teacher education experiences (Fletcher & Luft, 2011) to challenge teachers' beliefs and inspire uptake of reform-oriented practices such as those implicit in the SSI-TL framework.

Facilitating and supporting teachers' exploration of SSI-TL, at the pivotal pre-service phase of their career, can reveal and challenge their systems of epistemological & self-efficacy beliefs in ways that influence PSTs toward future reform-oriented practice. An investigation of the relationships among PSTs' beliefs about SSI-TL and their developing practice of SSI-TL curriculum design, in the context of an SSI-TL-focused

methods course, serves to inform the research and teacher education communities about ways to design and enact supports for moving PSTs toward more reform-oriented belief systems and corresponding future practice.

Summary.

We know little about teachers' beliefs regarding SSI-TL, or the impact of beliefs on teachers' design of SSI-based curricular materials. We know even less about ways that PSTs' beliefs might impact their uptake of SSI-TL curriculum design and potential future practice of the SSI-TL approach. However, research has shown evidence of misalignment between teachers' SSI-related beliefs and practices, as demonstrated the coexistence of teachers' enthusiasm for SSI with a reluctance to integrate them into science classroom activities. We have also seen evidence that teachers can create SSI-TL curricular units. Literature supports the ideas that teachers' beliefs influence their teaching practice, that pre-service and early career teachers more readily adopt reform-oriented beliefs, and that curriculum making is a distinct teaching practice. These ideas, in combination with the strong literature base that positions SSI-focused instruction as a means to the ends of Three-Dimensional Learning and Vision II Scientific Literacy, justify a view that there is value to the field in better understanding the ways that PSTs think about SSI in science education, and the potential of teacher education for supporting PSTs' uptake of the SSI-TL approach. Our work builds on these premises.

The purpose of this study was to explore PSTs' beliefs about SSI-TL and uptake of the practice of SSI-TL curricular design, in the context of an SSI-focused methods course. With participation in an immersive SSI-TL Teaching Module, designed to promote familiarity with an SSI-based approach through multiple, varied experiences

explicitly focused on the SSI-TL framework, PSTs had many opportunities to form ideas about the teaching approach, and to put the approach into practice by designing SSI-TL curricula. Through our study we sought to learn:

1. *What was the nature of PSTs' beliefs about SSI teaching and learning during their participation in an SSI-focused methods course on curriculum design?*
2. *What did PSTs' SSI-TL curricular unit designs reveal regarding their beliefs about the essential elements and characteristics of SSI teaching and learning during their participation in an SSI-focused methods course on curriculum design?*

Methods

Project context, study participants, and researcher positionality.

This study took place in a teacher education context in a U.S. midwestern university, in which the first author was enrolled as a graduate student, and the second and third authors served as graduate co-advisors. As part of the first author's graduate experience she had taught or co-taught multiple undergraduate and graduate courses in science and science education. The study took place in the context of the third of three science methods course required for undergraduate secondary science education students, during the third consecutive semester in which the first author served as instructor for the same cohort of secondary science methods students.

Our study focused on the cohort of eleven pre-service secondary science teachers enrolled in the required science methods III course. The first author designed the 16-week course with emphasis on curricular planning and design. The major course goal was that PSTs would create coherent science curricular units, comprised of a 2- to 3-week sequence of lessons organized and unified around a selected science topic and relevant

NGSS content standards, crosscutting concepts, and practices. The course took place during the semester immediately prior to the participants' student teaching experience.

The methods course included a six-week SSI-TL Teaching Module (Foulk, Sadler, & Friedrichsen, *in press*), which followed a general introduction to curriculum design. The dual purposes of the SSI-TL Teaching Module were to facilitate PSTs' exploration of SSI-TL as an instructional approach, and to promote PSTs' ability to design cohesive SSI-TL curricular units. We employed Remillard's (1999) model of *teacher as curriculum maker*, in which curriculum design is regarded as a distinct teaching practice and teachers engage in *curriculum mapping* to weave individual lessons and activities into coherent units and courses of study. Like Remillard, we consider the role of a classroom teacher to exceed "teacher as a conduit" of an externally provided, "teacher-proof" curriculum (Remillard, 1999, p. 316), and we instead view curriculum making as a professional skill for PSTs to practice in a teacher education context. Over a series of lessons and with numerous feedback opportunities, PSTs were challenged to develop cohesive SSI-focused curricular units around the SSI-TL framework. This curricular design task was our course culminating project, in fulfillment of the primary course goal that PSTs would be able to design coherent science curricular units.

To investigate PSTs' beliefs about the SSI-TL approach, and their uptake of SSI-TL curricular design as a means of operationalizing the broader pedagogical philosophy of SSI, we offered an invitation to participate in our project to all 13 PSTs enrolled in the methods course. Initially, 12 PSTs provided informed consent, which we collected in accordance with university IRB policy. However, because only 11 completed the study,

data from the 12th participant was not retained. Throughout the project, each participant was identified by a code or pseudonym to keep their identities confidential.

To further protect participant PSTs, we concealed identities of study participants while the course was underway. A graduate student colleague of the first author with SSI-related research experience assisted in administering and collecting study consent forms, assigning participant codes, conducting participant interviews, and storing forms and data in a secure location not accessible to the first author. This enabled the first author to perform responsibilities as course instructor with no access to identifying participant information, in order for PSTs to freely choose whether to participate, without fear of any influence on the evaluation of their course performance. Course assignments that served as sources of data were assigned to all students and added to the existing body of data after course grades were submitted, following the end of the semester in which the study took place.

We selected four focus PSTs from the larger participant cohort to take part in in-depth data collection using a survey of SSI beliefs, efficacy, attitudes, and interest to gather their initial ideas about teaching with SSI. We created the *BEAI Survey* by combining elements of SSI-based instruction (Presley et al., 2013) with question stems adapted from the STEBI-B (Enochs & Riggs, 1990). The survey contained 35 items with a 5-choice Likert scale. (See Appendix for the BEAI Survey). We administered the survey to all participants prior to beginning any SSI-focused coursework. We then scored the surveys and ranked scores from most positive to most negative. Using purposeful selection methods (Creswell, 2003), we selected four focus PSTs to represent the broadest range of initial beliefs about SSI in science classrooms, based on BEAI Survey

scores. Focus PSTs included two with the most positive and most negative orientations toward SSI, and two with orientations nearest the middle of the range (See Table 1).

Each of the four focus PSTs was an undergraduate studying secondary science education, with emphasis in a specific science discipline corresponding to one of the state's secondary science certification areas. Each focus PST was also enrolled in a dual degree program, including a B.S.Ed. in secondary science education in addition to a B.S. in their science discipline. Two of the participants were completing dual degrees in Biology and Secondary Biology Education, and two were completing dual degrees in Physics and Physics Education. The four focus participants included three males and one female. All PSTs were concurrently enrolled in a required fieldwork course in which they regularly observed and assisted in teaching secondary students in a science classroom, with guidance from an in-service mentor teacher.

Table 1: Project Focus Participants

Participant	Discipline	Program	Gender	Selection Rationale
Adam	Biology	Dual Biology/ Biology Education	M	Highest BEAI score
Bethany	Biology	Dual Biology/ Biology Education	F	Mid-range BEAI scores
Ethan	Physics	Dual Physics/ Physics Education	M	Mid-range BEAI scores
Henry	Physics	Dual Physics/ Physics Education	M	Lowest BEAI score

Data collection.

We conducted three individual semi-structured interviews per focus participant, each approximately 45-90 minutes in duration, at the beginning, middle, and end of the project. Each interview utilized the same set of questions, intended to reveal PSTs' beliefs about SSI-TL at each phase of the project. All interviews were conducted by the same graduate student colleague with interview experience as previously described. (See Appendix for Interview Protocol.)

PSTs created individual SSI-TL curricular units as a culminating project for the methods course. Curriculum design task requirements specified that PSTs would create a unit overview as an organizer in which they identified and described unit-level information, including a focal SSI (Sadler et al., 2015), content and practice standards (NGSS Lead States, 2013); and big idea, essential question, and gapless explanation (Thompson, Windschitl, & Braaten, 2013). The overview was to contain a complete sequence of lessons with descriptions for the unit, along with detailed lesson plans and relevant resources for three specific lessons: introduction of the focal SSI, a lesson focused on societal dimensions of the issue, and a lesson focused on science ideas. In addition, PSTs were to include plans for formative assessment in all lesson plans, a summative content assessment, and a complete plan for the end-of-unit synthesis project, with instructions and scoring guide. Finally, PSTs were to write a rationale and reflection about their curriculum designs and processes. (See Appendix for Curriculum Design Task Requirements).

Interview transcripts and SSI-TL curricular designs served as primary data sources for analysis. Secondary data sources collected from all participants included individual written reflections about SSI-TL, collected pre-, mid-, and post-project, and assigned as coursework. The first author also wrote researcher field notes during relevant group discussions to capture participant comments about their perspectives of SSI-TL, which were transcribed following the semester in which the study took place.

Data analysis.

We engaged in data analysis in two phases, using different methods to analyze different sets of data for each research question. In both phases we analyzed multiple

sources of data, first analyzing primary sources, then drawing iteratively from secondary sources for data that would confirm or conflict with findings (See Table 2). Throughout analysis we kept an audit trail. Primary analysis of all data was conducted by the first author, who met frequently with the second and third authors to share data, analysis results, and conclusions. During these repeated sessions of peer debriefing, the research team worked toward consensus building as they reviewed extensive examples of analysis. The use of multiple data sources, an audit trail, and collaborative consensus building between coauthors contributed to trustworthiness of the study (Lincoln & Guba, 1985; Miles, Huberman, & Saldana, 2014).

To address our first research question, we engaged in iterative cycles of qualitative

| Table 2. Data Sources with Analysis Plan Overview

Data Sources	Analysis Strategies
RQ1: exploring the nature of PSTs' SSI-TL beliefs	Conducted iterative cycles of thematic coding, summary, comparison, representation (Miles et al., 2014) to analyze interview transcripts:
<u>Primary sources:</u> Transcripts from 3 semi-structured individual interviews (pre-, mid-, post-project) with each focus PST	<p>1) examined transcripts, per participant, for <i>descriptive</i> category codes, both <i>a priori</i> and <i>emergent</i>.</p> <p>2) examined coded data from round 1 for <i>interpretive emergent</i> codes related to individual PSTs' beliefs about SSI-TL.</p> <p>3) identified most salient codes per case using constant comparative analysis.</p> <p>4) created narrative summary per descriptive coding category, per case, supported with data.</p> <p>5) conducted cross-case analysis for emergent themes.</p> <p>6) created narrative summaries per cross-case theme, supported with data.</p>
<u>Secondary sources:</u> <ul style="list-style-type: none"> • 3 Reflective Writings (pre-, mid-, post-project) • Researcher Field Notes (recorded during class discussions, mid- and post-project) 	<ul style="list-style-type: none"> • for each round of coding, reviewed written reflections and researcher field notes as secondary data sources, toward corroboration of preliminary themes • culled themes as necessary.
RQ2: exploring PSTs' uptake of SSI-TL curricular design practice	

<u>Primary sources:</u> PSTs' SSI-TL Units: (include overview, lesson plans, and assessments with rubrics)	Analyzed PST-created curricular units using our adaptation of Hatch's (2002) Typological Qualitative Analysis, drawing typologies from SSI-TL framework:	
<u>Secondary sources:</u> • Reflective Writings • Researcher Field Notes	1) Corroborated findings with Reflective Writings, Peer Reviews, Group Critiques, & my Field Notes as supporting secondary sources. 2) Summarized characterization of units, per participant. 3) Conducted cross-participant analysis to construct a broad characterization of PSTs' curricular units.	
<u>Data Source Key</u>		
A = Adam	1 = 1 st individual interview (pre-project)	MPR = mid-project written reflection
B = Bethany	2 = 2 nd individual interview (mid-project)	PPR = post-project written reflection
E = Ethan	3 = 3 rd individual interview (post-project)	FG = focus group (whole class, mid-project)
H = Henry		U = curricular unit (post-project)
<i>Example: E₂ = Ethan, 2nd individual interview</i>		

thematic coding, summary, comparison, and representation (Miles et al., 2014) of interview data. We explored PSTs' beliefs regarding SSI teaching and learning in a multistep analysis process. We examined transcripts for *descriptive* category codes, both those *a priori* codes related to SSI pedagogical philosophy (Zeidler, 2014a), the SSI-TL framework (Presley et al., 2013; Sadler et al., 2017), and our interview questions; and codes that emerged from the data during analysis. Some examples of descriptive codes included *what counts as science; beliefs about the purpose(s), aims, and desired outcomes of science teaching and learning; and beliefs about roles and responsibilities of teachers and students in science classrooms*. We revisited our codes frequently and collapsed, renamed, and combined codes as appropriate.

Next, we examined our coded data to arrive at *interpretive* codes for individual PSTs' beliefs, supported by data exemplars. One early finding that lead us to revise our analysis plan was that PSTs universally described their perceptions of SSI-TL in terms of more general beliefs about K-12 science teaching and learning. This influenced the way that we conducted analyses and represented findings for our first research question. We modified our descriptive codes to first reflect a focus on K-12 science teaching and

learning, constructed interpretive codes, and provided data exemplars for this broader category of PSTs' beliefs before following the same process for PSTs' beliefs specific to SSI-TL. For example, as Ethan described his beliefs about the purpose of SSI-TL, he spoke in terms of his beliefs about the purpose of K-12 science. Consistent with many comments Ethan made throughout the project, he described ideal science teaching and learning as giving students "a practical instance of where their learning could actually be used" (E₁). Based on this and other data exemplars, our interpretive code for Ethan's belief about the purposes, aims, and desired outcomes of K-12 science teaching and learning was *science education serves to help students make real-world sense of science*. Similarly, regarding the purposes of SSI-TL, Ethan told us that with SSI, "They learn the content you needed them to learn, and they learn the life lesson part at the same time" (E₃), and our interpretive code for this was *SSI-TL allows students to learn about science and life lessons* (See Tables 3 and 4).

Next, we identified the most salient codes per participant, based upon the relative incidence of each code, and constructed narrative summaries per descriptive code for each case. Our narrative descriptions were multiple pages long and helped us characterize the beliefs of each participant. Finally, we analyzed the four cases for emergent cross-case themes, generalizing those beliefs that had emerged and the ways they interacted, as evidenced by iterative comparative analysis across participant narratives.

Our second data analysis phase consisted of an adaptation of Hatch's (2002) typological qualitative analysis method, drawing typologies from the SSI-TL framework (Presley et al., 2013; Sadler et al., 2017), to analyze PST-created curricular units. The first author read through each PSTs' unit to identify all data related to one typology at a

Table 3. Selections from Analysis of PSTs' Beliefs about K-12 Science Teaching and Learning

	Descriptive Codes	Interpretive Codes with Data Exemplars				
	Adam	Bethany		Ethan		Henry
	Science in K-12 Science Teaching and Learning	<p><i>Science is an endeavor, a way of Thinking and communicating</i> “science is [both] this huge body of knowledge [and] the methods of how we got to the body of knowledge.” (A₃)</p>	<p><i>Science has a specific (but ill-defined) nature.</i></p>	<p>Science consists of “concepts and the nature of science, and all of those aspects” (B₁)</p>	<p><i>Science is a collection of ideas and practices that help us navigate personal worlds.</i></p>	<p>“Science isn’t one single method, and there’s really no clear-cut, correct way to do it. It’s just that you can do it and make something meaningful out of it.” (E₃)</p>
	Aims & Purposes of K-12 Science Teaching and Learning	<p><i>Goals and Purposes include 3DL for meaning-making, real-world connections, and representing science as authentic endeavor</i> “[M]y teaching philosophy [is] teaching the skills of how to do science and what is science, not what content do we use in science.” (A₃)</p>	<p><i>Should help students be contributing citizens.</i></p>	<p>“Science is the best approach to helping inform students of scientific practices because they’re gonna go through their entire life needing to know those, whether it be through healthcare, or just day-to-day experiences. They need to know science as functioning citizens in our world.” (B₂)</p>	<p><i>Should help students make real-world sense of science</i></p>	<p>“Learning conservation of energy in physics is great, but it’d be cool if you could teach it in a setting where we’re seeing a real world application. Say we use renewable energy as a theme. Then we’re seeing how one energy gets connected to another energy, and also [asking], ‘How could we actually use this? How could we make this useful?’ (E₁)</p>
	Roles of Students and Teachers in K-12 Science Teaching and Learning	<p><i>A classroom is a learning community with teacher as responsive facilitator and students as social learners</i> “...the whole science community aspect of teaching is something that’s really important to my personal philosophy.” (A₁)</p>	<p><i>Teacher is expert authority, with active responsibility to give knowledge to students</i></p>	<p>Teachers are, “kind of teaching, or creating--not teaching or creating; they’re not empty vessels!--but, um, helping inform students of scientific practices.” (B₁)</p>	<p><i>Teachers facilitate authentic and meaningful learning experiences for students to apply science to daily life</i></p>	<p>“You can kind of guide them in how to use information ... to make a decision or opinion on something that’s actually happening.” (E₁)</p>

Table 4. Selections from Analysis of PSTs' Beliefs about SSI-TL

	Descriptive Codes	Interpretive Codes with Data Exemplars		
	Adam	Bethany	Ethan	Henry
Essential Elements & Characteristics of SSI-TL	<i>SSI integrates science into complex, authentic issues</i> “[SSI] is a strategy of instruction that establishes a framework for content to be entirely wrapped around a focal issue, something that is complex, that has multiple angles to attack it with.” (A ₃)	<i>SSI weaves an issue throughout a unit</i> “...issue first and then issue integrated throughout the unit...” (B ₃)	<i>SSI uses an issue to give meaning to science</i> “[SSI-TL] is a unit, or a series of lessons, that is always focusing on teaching content while using a social issue to back it up.” (E ₃)	<i>SSI deemphasizes science</i> “[SSI-TL] means putting the issue before the science.” (H ₂)
Aims & Purposes of SSI-TL	<i>SSI is meaningful learning through contextualized science, for all students</i> “Its purpose is to connect the abstract concepts that you have taught in a science classroom to something that is relatable, so that you have something for the students to grasp onto at first, to where then you can add the content knowledge, too.” (A ₁)	<i>SSI is engaging to students</i> “It's meant to draw students in, engage them, kind of hook them first with the issue, and then use that issue to build skills and build content knowledge.” (B ₂) “The point of SSI is to choose an issue that is engaging to all learners.” (B ₂)	<i>SSI helps students integrate science into real life</i> “[SSI] brings the world outside the classroom to the world inside of the classroom.” (EMPR)	<i>SSI could be useful to non-science students</i> “[SSI-TL] is good for students that struggle with abstract thinking. [SSI-TL] devalues that, and provides a lot of context to the learning that's going on. And for some students that's a huge benefit. They can engage with and retain the content better, in that setting.” (H ₃)
Costs & Benefits of SSI-TL	<i>SSI presents science in an authentic way</i> “What can we do with science? What does science do?” This is the framework for every scientific conversation, discovery, experiment.... I think [SSI] does a really good job of what makes science, science....” (A ₂)	<i>SSI is an effective way to teach science</i> “[SSI-TL] is a great way to teach skills in addition to content, and it's a way to give that content a context for students to make sense of it, and to make it meaningful so that it is more memorable to them.” (B ₃)	<i>SSI makes science useful, meaningful, and memorable</i> “Look at a car wreck. What caused it? We look at that all the time with forces and motion. Newton's 2nd Law is basically a giant cause and effect. And you're now using a relevant issue to show where this concept comes in. It just gives ground to a lot more stuff that we know we do in science when we go outside the classroom.” (E ₃)	<i>SSI interferes with science</i> “I think [SSI] is an effective method to get [students] participating in science, but not necessarily to learn science, in and of itself. [SSI] means putting the issue before the science, and that's not necessarily something that I would value in my classroom.” (H ₂)

time. For example, one of our typological coded was *focal SSI is foregrounded in the unit*. In each unit we looked for evidence of this typological code, and then summarized the results for each PST. We carried out this process for each of our 12 *a priori* typological codes, as well as for any additional curricular elements or characteristics that emerged. An example of an emergent code was *criteria for issue selection*, a characteristic that was evident in each PSTs' curricular unit.

Next, we looked for patterns, relationships, and themes within typologies. For example, related to the foregrounding of the focal issue, we found that while all PSTs introduced the focal issue in the first lesson of their unit, there was variation in the extent to which the issue was revisited in subsequent lessons. We corroborated findings with secondary sources, which included reflective writings, field notes, and interview data, to ensure trustworthiness of our interpretations of the curricular materials. We rewrote findings as one-sentence generalizations. For example, "While the focal issue was the focus of the first lesson of every PST's unit, their interpretations of *introduction* and *exploration* varied." We then conducted cross-participant analysis to construct a broad characterization of each PSTs' unit, supporting findings with data excerpts and examples. Throughout the typological analysis the first author again shared findings frequently with the second and third authors to ensure trustworthiness of findings (See Table 5).

Findings

Pre-service teachers' beliefs about SSI teaching and learning.

The analyses are organized around three salient themes that emerged from the data related to PSTs' beliefs about SSI teaching and learning. First, PSTs' beliefs about SSI-TL were mediated by their existing K-12 science teaching and learning beliefs.

Table 5. Curricular Analyses: Selected Findings & Supporting Data

Elements/Features of SSI-TL	Patterns as One-Sentence Generalizations Supporting Data
Focal Socioscientific Issue	
Focal Issue Foregrounded	<p>While the focal issue was the focus of the first lesson of every PST's unit, their interpretations of <i>introduction</i> and <i>exploration</i> varied.</p> <ul style="list-style-type: none"> • Adam, Bethany, and Ethan designed <i>explorations</i> of their respective focal SSI. Each used relevant external resources (PBS video, local news stories, Mythbusters episode) to contextualize both societal implications and related science within the issue • Henry designed a Socratic seminar intended to compel students toward whole-class consensus about the issue, and specified in his lesson plan, “Neglect to mention the physics material which will be covered. As this is the introduction of the focal issue, the teacher will introduce the topic and refrain from making direct statements regarding the issue. Instead, the teacher will use questioning techniques to steer the conversation toward what science needs to be covered in the coming weeks.”
Focal Issue Woven Thru Unit	<p>Units varied in extent of integration, as well as in sequencing of explicitly SSI-focused lessons.</p> <ul style="list-style-type: none"> • Adam made deliberate and explicit connections to the focal issue as a representative of the broader issue of invasive species, and related it to the science topic of balance in ecological systems, in nearly every lesson. • Bethany’s issue appeared in nearly every lesson, although it is important to note that this issue is extremely broad as written, and connections would have been arguably more difficult if the issue had been more specifically defined. Presenting the issue as a science topic throughout the unit may have led to the limited focus on societal dimensions. • Ethan introduced the issue, then followed up in the very next lesson with a focused exploration of social dimensions, a design that set up the subsequent science lessons. Ethan’s unit explicitly revisited the “essential question” (related to the focal issue) in multiple lessons, requiring use of evidence from current and previous lessons, as repeated formative assessment. • As described previously Henry introduced the issue separately from science, and then reintroduced it again only once in the unit, except as required in the “social connections” lesson and synthesis project. Instead of a focus on the issue, Henry’s lessons included these recurring questions related to science, “What is the relationship between position and velocity?” and “What information about the world can one measure directly?”
Societal Dimensions	
Societal Dimensions Explicated	<p>Curricular units revealed wide variation in PSTs’ interpretations of societal dimensions.</p> <ul style="list-style-type: none"> • Adam’s unit clearly and cohesively highlighted both the societal implications and the social and economic policies that could serve as solutions for the featured SSI. • Bethany’s unit included no structured exploration or explicit identification of stakeholders, perspectives, issue complexity, etc., at all prior to the culminating project. The only mention of societal dimensions is in the project description, to be completed on an individual basis. • Ethan described societal dimensions multiple times throughout the unit, and was careful to connect them to relevant science ideas within the context of the issue. However, he described the construct in his “social connections” lesson plan as, “social aspects of the issue. What are the statistics? What does current research on the topic say? What safety measures are currently

	<p>in place? Has this been done before?" In his post-unit reflection Ethan explained, "For the social aspects lesson I picked 4 topics for the students to look at; pros of reducing the speed limit, cons of reducing the speed limit, safety features commonly found in cars, safety features commonly found on highways. I chose to have more than just pros and cons because it just does not feel like the whole issue is covered there. What happens in a car wreck is not just determined by how fast you are going, but also the car you are driving and the road you are on (e.g., safety features and highway barriers)."</p> <ul style="list-style-type: none"> Henry's only mention of societal dimensions was, "students will present an opinion about a rule," in the introduction to the curricular materials, and again in the culminating project description. He listed a lesson titled, "Connection to Focal Issue," but did not describe it, and made no explicit mention of societal dimensions of the issue anywhere in the unit.
Connections and Synthesis	<p>Variation in PSTs' interpretation of "synthesis," in this context reflected disparity in the inclusion of societal dimensions, as well as some variation in the amount of scaffolding through explicit task requirements of science.</p> <ul style="list-style-type: none"> Adam's project followed a tightly integrated sequence of activities linking science and societal dimensions, and a science-specific summative assessment. Culmination of the unit assigned a specific act of social activism to demonstrate student understanding of links between science and societal dimensions by recommending a specific action in response to the SSI. Bethany's task requirements for a "policy proposal" explicitly required some attention to science and some attention to societal dimensions, although the societal dimensions were not explored within the unit's learning activities. Students were required to explicate a position, support with scientific evidence or models, summarize reasoning, identify possible societal implications, and identify potential supporters and opponents of the proposal. The task seemed less an assessment of learning throughout the unit and more an add-on. [Ethan] – clearly specified three components students were required to include in their papers: "social aspects" of the issue (as previously defined), science aspects of the issue, and (scaffolded in instructions) connection of the two in project description. [Henry] – placed no explicit emphasis on societal dimensions, as these did not appear at all throughout the unit. The issue was a context for science, but other than students' "argumentative essay" culminating projects the unit placed no emphasis on economic, political, ethical, historical, or other societal implications of the issue. Henry seemed to not differentiate between focal issue and its societal dimensions. Henry's view of the SSI was that it was nebulous, but distinct from science.
Emergent Elements	<p>PSTs' units demonstrated variation in the location of issue controversy.</p> <ul style="list-style-type: none"> Adam viewed science ideas as being clear and well understood, with controversy of the issue existing within society, apparent in the multiple stakeholders with competing perspectives: "Invasive species disrupt the ecological stability of an ecosystem. An understanding of the factors influencing an ecosystem serves as a learning goal that to be understood <i>requires students to first learn the basics of ecology...</i> Socioscientific issues by the nature have <i>sides and actions associated with them.</i>" Ethan described controversy existing within science in early interviews, but ultimately presented controversy <i>in the solution.</i> Bethany expressed a belief (also confirmed in interviews) that controversy is located <i>within</i> science as she explained why a particular issue did <i>not</i> meet criteria for an SSI: "I think the social application of natural selection is intriguing and students would be engaged, but it is not a true 'issue' that has multiple ethical sides nor is it debated in the scientific community." Henry saw controversy outside the science, in the "social studies" of SSI.

Second, PSTs' beliefs about SSI-TL were reflected in their perceptions of its relative costs and benefits. Finally, as PSTs' beliefs about SSI-TL developed, they experienced and resolved distinct struggles.

Mediation of SSI-TL beliefs by K-12 science teaching and learning beliefs.

As PSTs made personal sense of SSI teaching and learning, they did so through the lenses of their existing beliefs about the broader topic of K-12 science teaching and learning, as evidenced by their consistent framing of ideas about SSI-TL in terms of their more general beliefs. Of note, PSTs' repeated and consistent descriptions of K-12 science teaching and learning demonstrated that these particular beliefs remained unchanged during the project. As PSTs' beliefs about the features and characteristics of SSI-TL developed, they were mediated by existing beliefs about K-12 science teaching and learning, such as: beliefs about science in K-12 science teaching and learning, goals and purposes of K-12 science teaching and learning, and roles of teachers and students in K-12 science teaching and learning.

Beliefs about science in K-12 science teaching and learning.

As Henry made sense of SSI-TL, his ideas were influenced by the traditional beliefs he expressed about science and its portrayal in the K-12 science classroom, leading to a belief that SSI-TL failed to portray science authentically. Henry viewed science as a collection of facts, a "body of knowledge which scientific practices have proved true" (H_{MPR}), and believed that science teaching and learning should therefore serve as a context for dissemination of these facts. Henry also believed science to be a decontextualized and discrete field of study, entirely distinct from, and "much more intense" (H_{FG}) than disciplines such as reading, writing, or history. Accordingly, Henry

expressed a belief that SSI-TL's explicit focus on issues, a defining characteristic of the approach, meant, "the amount of science is drastically reduced" (H₂). Describing his interpretation of the approach, Henry said, "I can take this scientific fact, though there are few of those, and connect that to a social fact and a political fact and historical one" (H₂), a characteristic of SSI-TL he described as, "putting the issue before the science" (H₂). Henry argued that scientific facts were "independent of human affairs, and it should be that body of knowledge which is the focus of the science classroom" (H_{MPR}). Through Henry's lens of traditional beliefs about science in K-12 teaching and learning, SSI-TL did not present science authentically, and was thus incompatible with "real" (H₁) science teaching and learning.

Like Henry, Ethan expressed a distinct belief of science as he described his ideas about SSI-TL. Specifically, Ethan believed science to be a collection of phenomena and processes in the natural world that were practically applicable to students' daily lives in any number of ways. A consequence of this, in Ethan's view, was that science teaching and learning should consist of using various methods to experience and make sense of natural phenomena, and to link those experiences to daily life. Ethan believed, "Science isn't one single method. It's a lot of finding research and support, and there's really no clear-cut, correct way to do it, just that you can do it and make something meaningful out of it" (E₃). Filtered through these beliefs, Ethan saw SSI-TL as a classroom approach by which to present science in "real-world" (E₁) contexts. To Ethan, an SSI was "something that gives the underlying concept you're trying to teach a little more meaning, because you also have this tangible thing that a lot of students can experience just by walking out their front door" (E₁). Consequently, Ethan told us, "[SSI-TL] gives them a practical

instance where their learning could actually be used” (E₁). Ethan saw SSI-TL as a means of presenting science as he believed it to be; that is, integrated with real life.

Bethany and Adam expressed a belief that science far surpassed a canon of knowledge or collection of phenomena. Instead, these PSTs viewed science as a conglomeration of scientific ideas, practices, decision-making, and communication methods, to be utilized authentically in K-12 science classrooms through immersive, problematized scientific scenarios. Bethany described science as, “concepts and the nature of science, and all of those aspects” (B₁), explaining, “science can be messy, and controversial” (B₁). Adam told us, “Science is this huge body of knowledge, but the methods of how we got to the body of knowledge are just as important to be taught in high school” (A₁). Adam also believed science classrooms should explicitly emphasize limitations of science, about which he said, “[S]cience alone does not make decisions for society, but rather, by using science can social, political, and economic decisions be made” (APP_R). Through their beliefs about science teaching and learning, Adam and Bethany interpreted SSI-TL to be an authentic representation of what they considered science to be. To Bethany, SSI-TL was, “an approach to teaching science standards that also incorporates ethics, argumentation, reasoning skills, and current issues” (B₁). Bethany’s position was, “Life is messy, life does not have clear cut answers. [SSI-TL] is a great context for students to explore that discomfort” (B₂). Adam interpreted SSI-TL as “a strategy of instruction that establishes a framework for content to be entirely wrapped around” (A₃). Expanding this idea, he said, “What can we *do* with science? What does science *do*? This is the framework for every scientific conversation, discovery,

experiment.... It's what makes science, science. [SSI-TL] does a really good job of that”
(A₂).

Beliefs about goal/s and purpose/s of K-12 science teaching and learning.

Henry’s beliefs about the goals and purposes of K-12 science teaching and learning reflected two distinct purposes, arising from both a need for non-scientists to develop adequate science understanding, and the need for a select group of students to be rigorously prepared for science careers. To Henry, science learning was knowledge reproduction, and the extent to which this outcome should be realized depended on students’ future paths. Henry explained, “Society has a need to inform students *about* science, but we also have the need to educate people *in* science so that they can go on with science.” (H₃). Filtered through these beliefs, Henry saw SSI-TL as an ineffective strategy for science teaching and learning. Toward these dual purposes, Henry told us that the use of issues inherent in SSI-TL might justify it as an appropriate approach in the case of “students who struggle with abstract thinking” (B₃), because SSI-TL “devalues that” (B₃). Similarly, SSI-TL might increase the motivation of this population of students by getting them “moving around more” (H_{FG}). However, Henry argued that SSI-TL, by virtue of its focus on an authentic issue, could be “an effective method to get [students] participating in science, but not necessarily learn science, *in and of itself*” (H₃). SSI-TL was at odds with Henry’s beliefs about goals and purposes of K-12 science teaching and learning, and therefore, was simply not appropriate for achievement of these goals for serious students of science.

Ethan believed the primary goal of science teaching and learning was to help students appreciate the impact of a potentially boring discipline on daily life, to

encourage the application of science lessons to personal decisions. “Science can be seen as a dull subject” (E2), Ethan told us. yet, “when people can make sense of it and apply it to their worlds, they can see it’s useful” (E2). Explaining his dilemma in terms of his familiarity with standards and common activities of his discipline, Ethan said, “It’s not waves, I’m not making gummy bear wave contraptions. I’m not sending hovercrafts down the hallway. [Uniform motion] us usually a unit where it’s hard to find flashy things” (E₃). Interpreted through these beliefs, Ethan saw utility in an SSI-TL approach, “a series of lessons … using this controversial issue to teach the content” (E₃). This interpretation was well aligned with Ethan’s beliefs about the purpose of science education. Explaining the value of SSI-TL toward achieving this aim, Ethan reasoned, “They learn the content you needed them to learn, and they learn the life lesson part at the same time” (E₃).

The beliefs Adam and Bethany expressed were once again similar as they described goals and purposes of K-12 science teaching and learning. For them, science classrooms were a place to help students become skilled at using evidence and reasoning to substantiate communication and decision-making, toward the broader aim of producing an informed populace. Bethany described preparing a scientifically literate citizenry as a primary goal of science teaching and learning. “They need to know science as functioning citizens in our world” (B₁). Of her aim to equip students as “high achieving, contributing citizens,” Bethany said, “that should be the point of school, right?” (B₂). Adam expressed a similar sentiment, explaining, “An important part of my own education philosophy is improvement of scientific literacy and understanding of science as a school of thought” (A_{PPR}). He told us, “My teaching philosophy is teaching the skills of how to do science and what is science, not just what content do we use in

science” (A₃). Filtered through these beliefs, Bethany and Adam saw SSI-TL as a means to promote citizenship through scientific literacy. Bethany described SSI-TL as “a framework for dealing with issues personally, when [students] are dealt them later in life” (B₂), calling the approach “a really great way to shape your students into good citizens” (B₃). To Bethany, SSI-TL would serve this aim, “because they're gonna go through their entire life needing to know those [skills], whether through healthcare, or just day-to-day experiences” (B₁). “You want kids to have an exposure to these issues so that they can be functional citizens on issues related to science” (B₂). Adam saw multiple affordances of SSI-TL, serving as not only “something for the students to grasp onto at first,” (A₁) by way of a focal issue, but also, providing an emphasis on “the content knowledge. And it emphasizes skills practice, like all of your critical thinking, designing solutions, defending arguments, using evidence, within the context of your issue” (A₁). Adam’s belief was that SSI-TL, “address[ed] the learning of some really important social and cultural things, like how people talk through issues, how you can communicate with other people who have varying opinions. Those are very teachable things” (A₂). Both Bethany and Adam believed SSI-TL to offer students opportunities to develop important skills of citizenship, in preparation for making informed decisions of measurable public consequence about science issues, consistent with their beliefs about the goals and purposes of K-12 science teaching and learning.

Beliefs about roles of teachers and students in K-12 science teaching and learning.

Henry described his beliefs about the roles of teacher and students in the K-12 classroom in very traditional terms. To Henry, teachers of science were experts who

possessed scientific knowledge whose role was disseminating it to students through the use of tools and templates. Students were to play the role of knowledge recipient, reproducing relevant ideas and mastering mathematical problem solving. Henry described his ideal instructional method: “So there's *front-loading*, which is, you take more scientific content in the beginning, give it to them, and then after that, they spend time digesting it.” (H₂) In Henry's view, the teacher would distribute information by traditional didactic methods, and then oversee and evaluate students' mastery of this information. He explained students' role further: “I like to use [the term] ‘digesting,’ and that, to me, means you're taking things that are not being introduced — you already have it in your hands — and you're manipulating it, processing it, getting farther with it” (H₂). Students were to confirm the information distributed by their teacher, via activities such as practice of mathematical problem solving. On multiple occasions Henry used terms such as “vectors,” “unit cancelling,” and “graphing” as examples of these “content”-based activities (H₁, H_{MPR}, H₃). Henry exhibited difficulty as he tried to reconcile his understanding of SSI-TL with his beliefs about teacher and student roles and their dependence on algorithms, tools, and templates: “They can do the work if you set it up for them, and they can get the answer, but reading the question, or interpreting a scenario and saying, ”How is this applicable? What do I know? What's in my toolbox that I can use? That is one of the biggest hurdles that students encounter” (H₁). In light of his beliefs that students were to take up knowledge disseminated by the teacher, Henry saw SSI-TL as a challenge to these traditional roles and a distraction in the science classroom. “The issue detracts from the content itself” (H₁), he told us, and even though he had seen that an SSI “garnered much of the class' attention” in the methods course” (H_{MPR}), an SSI

meant “starting with the issue first, having students engage with the issue, and being assessed on their comprehension of the issue. And working backwards, as a secondary goal, from the issue towards science that is relevant to that issue. (H₃). Through the lens of his beliefs about teacher and student roles, SSI-TL required too much deviation from teachers’ need to disseminate science facts, and students’ need to confirm and practice using them.

Ethan demonstrated familiarity and fluency with learning standards, which were salient in his beliefs regarding roles of teacher and students in K-12 science teaching and learning. Ethan viewed teachers’ primary role as preparing students for their futures through “life lessons” (E₃) in a science context. Part of teachers’ role was to know, interpret, and use relevant science learning standards, which Ethan considered to be “the things that the state says they need to know,” (E₃). However, because “standards only tell us where we’re going, not how to get there” (E₂, E₃), Ethan believed teachers to wield considerable freedom in the design of K-12 science teaching and learning activities that could be most applicable to students’ experiences. Consistent with this belief, Ethan interpreted SSI-TL to be a valuable approach, reasoning, “You’re dealing with people that are gonna become adults, at most, four years from when you see them. And there’s a lot of life lessons you learn in [SSI-TL]” (E₃). Filtered through Ethan’s beliefs about teacher and student roles, SSI-TL could enable teachers to not only teach students science lessons, but also mentor students regarding their futures. Ethan explained, “Depending on the issue you pick, [SSI-TL] can present a platform where the teacher can guide students through facing and tackling some of those [life lessons], where the students might not have a guide, otherwise, to help them through” (E₃). Students, in turn, were expected to

make sense of the science and life lessons presented by teachers. “[SSI-TL] is more than just memorizing an answer and regurgitating; you're using the science concepts you learned as well as the research techniques you learned, to formulate a response to this question. It's more critical thinking around the issue” (E₂). Inherent in the use of SSI, Ethan told us, is a challenging role for students: “You would hope to be able to, as a student, form an answer at the end of [an SSI-TL unit], but that answer's not gonna be yes or no” (E₂).

Adam expressed his belief that science teachers should play the role of skilled master, planner, and expert facilitator of meaningful science learning experiences; and students should play the role of actively engaged constructors of new science knowledge. Both roles would leverage students' prior understandings. A teacher's role included purposeful design of classroom activities, while remaining adaptable to students' needs. Adam reflected that a teacher's curricular design should be “created organically around an idea and a framework, but is constantly evolving around student expectations [and] actions. A flexible unit plan can accommodate the direction of student discussions while still staying true to the content requirements” (APPR) For Adam, an SSI-TL approach was an ideal complement to these roles. SSI-TL could foster teachers' design and facilitation of meaningful K-12 science learning experiences by enabling them to, “make their science classroom real to life,” (A₁), while also accommodating flexible decision-making in response to students' thinking about science ideas. With SSI-TL, it was “a good thing that they're coming in with their own knowledge, because then you can shape that to what your goal is with the lesson” (A₁). In this way, SSI-TL, a “structure [to] connect science

to kids” (A₁), could engage all students as active learners by “garner[ing] student motivation to get involved with the content” (A₃).

Bethany’s beliefs about the roles of teachers and students in K-12 science teaching and learning demonstrated a level of inconsistency with her other beliefs that illustrated a conflict she seemed to experience throughout the project. Again and again, Bethany described broad, theoretical ideas about science teaching and learning that were consistent with progressive pedagogies (e.g., her beliefs about science and about goals and purposes of K-12 science teaching and learning); yet she seemed to contradict these beliefs when expressing her beliefs in terms of practice (i.e., what students and teacher would *do* in the K-12 science classroom). Her practical beliefs, most evident in her description of student and teacher roles, tended to be far more traditional in nature. For example, Bethany spoke about the role of teachers to “craft learning” (B₁). In the same interview she corrected herself when describing the teachers’ role as “kind of teaching, or kind of creating, I guess—wait, not teaching or creating; they’re not empty vessels! But, um, helping inform students” (B₁). Still, she spoke of her plan to “become more comfortable... teaching the content to the students” (B₁). Bethany viewed students as “soon-to-vote citizens” (B_{MPR}), an idea that was well aligned to the pedagogical philosophy of SSI-TL; yet even as she described and defined SSI-TL, her explanation of student and teacher roles was vague and underdeveloped. She thought of SSI-TL in terms of larger theoretical and conceptual ideas, but had not yet reconciled her ideas about classroom context to align with them. Bethany described SSI-TL with uncertainty, as “starting with and threading a ... um ... social, political, economic issue throughout a science content unit, with a heavy focus on using skills and developing skills, to ... use

science to approach a complicated, um ... unanswered question” (B₂), and in the same interview, lamented an SSI-based learning experience of her own that had failed to be “taught to us as a student which is more like what we expect” (B₂). She refuted her own idea in the next sentence, with, “Well, this [SSI-TL] is, you know, better obviously, but ...” (B₂). Consistent with her competing beliefs about K-12 science teaching and learning, Bethany seemed to champion SSI-TL as an ideal instructional approach, while simultaneously wishing for more traditional roles, both as a teacher and a student.

PST perceptions of costs and benefits as reflection of SSI-TL beliefs.

As their beliefs about SSI-TL developed, PSTs perceived costs and benefits of the approach to teachers and students. When talking about SSI-TL, PSTs shared multiple examples of potential costs and benefits they expected of the approach. The summative cost/benefit ratios at which PSTs arrived reflected whether they believed SSI-TL to offer adequate benefits to outweigh its required costs, and therefore to be a justifiable method for K-12 science teaching and learning.

Potential costs of SSI-TL identified by PSTs were related to increased time demands, less focus on science ideas, and challenges related to assessment of learning. Bethany highlighted time demands inside the classroom, telling us, “It does take more time. I think that you have to cut something, and you might have to cut content” (B₃). For Henry this was problematic. He said, “I think the drawback would be that it detracts from the focus on the science. In [SSI-TL] there is lots of time dedicated to history” (H_{FG}). Later Henry described his concern this way, “because you start off with, ‘Here's the focal issue,’ that is what they retain as the core message. The science is secondary, so the student [may] walk out of there with only the core message of [the issue]” (H₃). Some

PSTs described increased time demands outside of class. Ethan said, “I would think it would probably take way more time to put together lessons based on an issue, and to interweave everything, as opposed to just teaching the concept in some way” (E₁). Some PSTs described increased demands regarding assessment. Henry’s perception was, “SSI would have a large portion of subjective grading challenges,” (H₃), while Bethany shared, “I think it’s harder to grade, because you’re looking at, you know, having students take different perspectives. It’s—at least what we’ve seen—very writing centered, project centered, so I think it takes more time for the teacher” (B₂). Adam agreed but did not view the time issue as a deal breaker, arguing, “If the content and the issue are meshed from the beginning, you can have time for all of it” (A₂).

PSTs spoke extensively of their ideas about potential benefits of SSI-TL, such as science learning, learning that exceeded academic requirements, and increased enjoyment and student motivation as compared to other methods. Regarding NGSS-aligned learning opportunities, Adam shared his perception that SSI-TL, “explicitly expects some of the larger action words that NGSS uses, the expectations for students above content. [SSI-TL] just seamlessly fits [for example], into using mathematical models … cause and effect … to me those just fit right together” (A₃). Bethany saw potential for meeting standards for science learning in the types of learning activities she associated with SSI-TL:

“There’s a lot of writing, the whole idea of writing to learn. Students learn and explore a lot through their writing, through being able to draft and develop ideas. I think [SSI-TL] is a great way to provide a context for that, with the information that you have to meet in the standards” (B1).

Ethan agreed: “the engineering design, the crosscutting concepts, the disciplinary core ideas, you see those happen a lot. [SSI-TL] gives a more organic environment to use

them, as opposed to feeling kind of forced” (E₃). More than an opportunity for expected science learning, Bethany argued, “[SSI-TL] can go above and beyond the minimal that the standards require” (B₂). When asked about the potential for students to learn reasoning and decision making skills with SSI-TL, Bethany responded, “And then some! Because you have to understand the issue well, give evidence, and create a strong thesis statement to get your point across. That is an important life skill and a way to make navigating issues more comfortable” (B₂). Ethan said this regarding SSI-TL’s potential to promote more than science learning: “You bring teaching into the classroom on issues that may not formally be taught in any [other] classroom” (E₃). Likewise, Adam explained the benefit of teaching about important life skills beyond science, “that maybe are not explicitly addressed in your district's content that you're required to teach, but if you broke those things down into activities and expectations, it can all be fit into, ‘This is practice on how to build evidence.’” (A₂).

Several times PSTs described SSI-TL’s potential benefit of increased meaning and enjoyment. Ethan explained, “If you bring in an issue, all of a sudden, ‘This is something I see out my front door!’ It matters more, and they kind of have a bit more buy-in. It kind of motivates them more” (E₂). Adam shared his own learner perspective: “I would’ve loved this in high school!” (A₂), while advocating for his future students, as well: “[SSI-TL] also helps those who need only basic understanding of science concepts, to communicate about science issues important to them (A₁). Henry acknowledged this potential benefit, too, telling us that because of its "activities based" nature, SSI-TL would get “people moving around more,” and could therefore be expected to promote student engagement (H_{FG}). Bethany acknowledged the enjoyment SSI-TL would offer

students, while happily telling us, “I mean, it's more interesting for the teacher, too [laughs]” (B₃).

As each of our PSTs considered the requirements, characteristics, and essential elements of SSI teaching and learning, the potential costs and benefits that they identified led them to arrive at a summative cost/benefit ratio. PSTs seemed to ask themselves whether the benefit of SSI-TL was worth the cost. In many cases, PSTs mentioned a cost or benefit they assumed others might describe, while simultaneously presenting corresponding benefits or costs that might mitigate the impact, as if to offer a preemptive rebuttal to opposing views. For example, Henry told us, “I would anticipate that somebody argues, ‘Well one of the benefits is that the students have a more realistic approach to science.’ But what I've seen [is] they don't really get a real world understanding” (H₁). For Henry, any benefit of motivation or learning was overshadowed by his perception that the learning was not representative of authentic science: “In my view, [SSI-TL] selects a discussion topic prior to selecting the content the topic contains. Doing so creates a more engaging environment but concedes that the [science] learning is secondary and passive” (H_{MPR}). Henry perceived the benefits of SSI-TL as inadequate to offset the costs.

Conversely, three PSTs, when acknowledging potential costs of teaching with SSI-TL, justified them by identifying benefits they believed would outweigh the costs. Adam addressed the cost of increased time demands in SSI-TL like this, “I think the content going to the side is not a bad thing” (A₂). In Adam's view, even though SSI-TL would require more time, both in and out of class, it was worth the cost, and teachers of science “should use it, and as much as possible” (A₂). Bethany's view was similar.

Regarding increased time demands she reasoned, “Is that gonna hurt students in the long run? I don't think so, because they're still meeting the standards with a general understanding, and it's going to be more memorable with the issue, a context to remember it in” (B₁). Bethany summarized the combination of benefits that she perceived to outweigh costs in SSI-TL: “I think it is a great way to teach skills in addition to content, and to give that content a context for students to make sense of it, and make it meaningful so that it is more memorable to them” (B₃). Ethan described a similar sentiment regarding relative costs and benefits of SSI-TL.

“I say you can teach [science ideas and social dimensions] within the same lesson, and that means they're learning content through the window of this issue, and at the same time, looking at the issue through content. If you put time into writing the lesson, to marry the two things together, you really can learn them at the same time.” (E₃)

Ultimately, Ethan believed the benefits of SSI-TL to outweigh its potential costs. “Using [SSI-TL], you just get more teaching and learning experiences for students that they would never otherwise get in your class. It makes your class more meaningful” (E₃). As these PSTs reflected on potential costs and benefits of SSI-TL they determined its benefits to outweigh its costs.

Struggles and resolutions during SSI-TL beliefs development, shaped by alignment of PST beliefs about K-12 science teaching and learning to SSI-TL pedagogical philosophy.

Each PST identified a unique struggle during their development of beliefs about SSI-TL, and also reported how they resolved their struggles, as they engaged in each phase of the SSI-focused methods course. Each PST introduced their struggle early in the project, shared the nature of the struggle throughout the project with regard to their

existing K-12 beliefs, and reported at the end of the project their path to resolution. Each PST described a single struggle and resolution, unique to him or her, that could be explained by the extent to which their existing beliefs aligned to the pedagogical philosophy of SSI-focused teaching and learning.

Ethan's Struggle: Selecting a Focal Issue for SSI-TL.

The very practical struggle Ethan described during the project was selection of an SSI for an SSI-TL unit in his discipline. At the beginning of the project Ethan shared his interpretation of an SSI as simply, “a real-world issue, something that's real, something that students see on a daily basis” (E₁), with explicit emphasis on the characteristics of authenticity and applicability to real life, but with no mention of societal implications or controversy. By mid-project Ethan had begun to associate SSI with politics, and subsequently expressed concern about whether suitable issues even existed in his discipline. He shared in his mid-project interview, “I would need help identifying an actual issue. I had some ideas, but fitting this, kind of, political issue with some of the stuff I'm supposed to teach is kinda hard” (E₂). Believing his challenge was discipline-specific, Ethan said, “I think a lot of people in physics struggle finding social issues” (E₂). Ethan reasoned, “People in biology would be like, ‘Oh, GMOs,’ something that's very prevalent. Even Chemistry and Earth Science, there's a lot of things that are very readily prevalent. In physics, there's not as much that jumps out, so far” (E₂). Later Ethan expanded on his concern: “One of the other physics majors pointed out, a lot of stuff we see as controversy in physics was either settled 200 years ago, or we can't even understand it ourselves, it's so ‘out there’” (E₂).

At the end of the project Ethan described his path toward resolution of the challenge of issue selection. Consistent with his beliefs about science as an intersection between phenomena and real life, and K-12 science teaching and learning as the practical application of phenomena to life lessons, Ethan determined that he had been thinking about issues on too large a scale. As the project progressed, Ethan began considering everyday issues that might be framed to highlight science ideas about phenomena in the natural world, the everyday dilemmas they sometimes posed, and possible solutions to these dilemmas. “I think what has changed is what could be a possible issue” (E₃), Ethan said. “It doesn't have to be some huge controversial issue; it could be something small. My final issue ended up being something with speed limits” (E₃). This also enabled Ethan to present a meaningful life lesson alongside relevant science learning, a personal goal he had described throughout the project. Drawing upon his familiarity with discipline-specific standards, and his beliefs about the goals and purposes of K-12 science teaching and learning, at the end of the project Ethan enthusiastically explained his choice of SSI, “Especially [for] freshmen, [graphing] is a really weird thing at first. This kinda abstract thing [they're] learning in math all of a sudden has three thousand meanings [in physics]. Well if you [clarify], ‘We've all ridden in cars at some point, that's what this graph is really showing you,’ it not only gives more meaning to the graph, but maybe it keeps them [safe] when they start driving. That's why that [SSI] caught my eye. I had never really thought about applying it to physics.” (E₃)

In the end, Ethan described his conception of an SSI as, “an issue that comes up a lot ... something that they'll be dealing with in their lives right then” (E₃). Ethan had resolved his struggle by identifying criteria that were most closely aligned with his K-12 science teaching and learning beliefs. True to his views about making science practical and applicable, Ethan emphasized authenticity and immediate applicability to students' lives

when selecting an issue. "It doesn't have to be something like, 'Should we do stem cell research?' or this huge political controversy. It can just be an issue that could come up in your students' everyday lives" (E₃), he decided.

Henry's Struggle: Justifying SSI-TL.

Henry found SSI-TL to be an affront to his beliefs throughout the project, and reconciling that fact was the unique challenge he faced. Prior to any experience with SSI-TL, Henry expressed resistance, tempered by a cautious willingness to consider the approach. At the beginning of the project Henry described SSI-TL as, "not something that I have initially planned for" (H₁), and "not the way that I've pictured my classroom looking" (H₁). Henry was hesitant to "do [an SSI] as the focus" (H₁) of learning, because, he explained, "I don't want to get students too invested in that particular topic," (H₁). However, Henry assured us, "It's not that I'm actively against it, it's that I've not been introduced, so, perhaps, just an introduction might persuade me that it is a good method. Perhaps it's one I'll use as my go-to" (H₁). By mid-project Henry had not been persuaded. Instead, his resistance to SSI-TL had become stronger, even as he conceded one circumstance in which the approach might be appropriate. Henry told us, "I've taken a hostile stance against it" (H₂), and "[SSI-TL] is not necessarily something that I would value in my classroom" (H₂). However, he saw the approach as "activities based" (H₂) and "relaxing for the brain" (H₂), due to its "focus on history" (H₂), which might render it appropriate to compel student involvement if needed. Henry reflected, "Student engagement is a major benefit to [SSI-TL]" (H_{MPR}). However, he cautioned, most SSI were, "a 'non-issue issue,' [because] the issue does not have very impactful consequences" (H_{MPR}).

Similar to the beliefs Henry had expressed about science being set apart from all non-science disciplines, the resolution to Henry's struggle came from defining a dichotomy of student populations: those who would become scientists and those who would not.

"If you look at high school as a whole, there's a portion of students who are going to be going to the science courses, who are going to be going on throughout their entire high school career with science, and some of them are going to be going just for the preliminary portions of it, and there is background to be covered that satisfies a different need." (H₃)

Consistent with the beliefs he had expressed throughout the project, this idea was based on Henry's underlying assumption that SSI-TL was not a means of educating people in science. Instead, SSI-TL was an option for younger students and those less inclined to pursue science careers: "If it were a middle school thing, I'd say do it all day long. If it were a high school thing, I would say you could probably do it once or twice in a science course, up until tenth grade (H₃). Ultimately, however, Henry was unable to justify SSI-TL as an appropriate instructional approach for his ideal science course. For that he would depend on his "front-loading" (H₂) strategy and practice of mathematical problem solving skills.

Adam's Struggle: Doing Justice to SSI-TL.

Adam's beliefs about K-12 science teaching and learning were exceptionally well aligned with the pedagogical philosophy of SSI-TL even as the project began. Consequently, his uptake of SSI-TL seemed to be a quick and natural process. From our first conversation with Adam, he was thinking about the logistics of implementation. With no need for convincing about the merits of SSI-TL, his struggle revolved around identifying and defining the systemic supports a teacher would need to do the approach

justice. Initially Adam was focused on the characteristics of the teacher necessary for SSI-TL: “I think it requires a very high quality teacher. I don’t think that it’s a method for everybody” (A₁). In addition, he argued, “It’s something that has to be implemented well, something that can’t be half-assed. You have to really be engaged as the teacher to get your goals out of it” (A₁). Throughout the project Adam’s belief about the inherent value of SSI-TL was clear, even as he acknowledged its demands. In his mid-project interview Adam argued, “[SSI-TL] has a lot of requirements for it to be successful. I think that if you meet some of those requirements, then it should definitely be a part of your high school classroom. And in as many units as you possibly can” (A₂). For example, “There are some content areas where the breadth is much larger than your issue can contain. You’re better off just getting the content out of the way. When it can be worked in, I think it’s a really valuable strategy” (A₂). Yet, in the same interview Adam demonstrated he was still wrestling with the practical demands of operationalizing the approach. “I think this would be difficult to do in the general biology classroom. You can’t do this kind of stuff without it a certain level of basic content knowledge. Otherwise you really get lost...[and students wonder], ‘where is the content?’” (A₂). In addition, “I don’t think that [SSI-TL] can work at all, unless you’re one hundred percent into framing all of your [relevant] content within this issue” (A₂). By this point in the project, Adam had moved beyond characteristics of the teacher, to characteristics of the content team. “I think having a quality professional team is a requirement” (A₂). Adam was convinced, “A biology teacher can’t go rogue and just do their own [SSI-TL] unit. There’s too much prep time, too much that needs to be discussed at the teacher level, for the teacher to do their job correctly with the students.” (A₂).

As the project progressed, Adam's beliefs about SSI-TL became more sophisticated and nuanced. By our final interview, Adam shared this vision for scaffolding his future students' engagement in an SSI-focused biology classroom:

"I hope that [SSI] can be used explicitly and often in the first semester. Optimally you could get students to work on these skills in the explicit model of [SSI-TL], and later in the year, many of those things could become students' own work. You could present an issue, and skip a bunch of the steps to get the final product, if the students already understand where they're going. I think that's a possibility." (A₃)

Adam shared this about his SSI-TL unit regarding his commitment to promote scientific literacy: "A scientific discussion based unit, where students are required to first predict and explore principles of ecology within the context of the focal issue, [and then] use evidence to support any conclusions, builds these skills." (APP_R). Reiterating his view of SSI-TL, Adam explained, "I've worked on those types of skills, those discussion skills, and how to bring in multiple perspectives, what the issue means within the context of science. So I was already sold on [SSI-TL]" (A₃). Ultimately, Adam's resolution of his struggle with knowing how to use SSI-TL *well* depended on his willingness to simply take up the approach, starting exactly where he was and putting a figurative flag in the ground, expecting to continue toward mastery. Reflecting on the "exhausting process" (APP_R) of SSI-TL curriculum design, Adam wrote candidly, "Even if I continued to work for another 40 hours, I feel I still wouldn't be finished" (APP_R). Mastery of SSI-TL design and implementation, Adam told us, was, "a lofty goal" (APP_R) toward which he planned to strive.

Bethany's Struggle: Teaching SSI-TL as a "Beginning Teacher."

Throughout the project, Bethany's beliefs about self in K-12 science teaching and learning were striking. In three interviews she volunteered the phrases "beginning

teacher” or “new teacher” 21 times while describing her beliefs. Perceiving herself in this way was clearly Bethany’s struggle. Nearly every idea Bethany expressed regarding her philosophical views of K-12 science teaching and learning seemed to be an ideal to which Bethany aspired. Consistent with those ideals, Bethany repeatedly expressed her strong support for SSI-TL. Even so, her own beliefs about K-12 science teaching and learning, and about SSI-TL, seemed to evoke anxiety and fear as they intersected with her beliefs about self. Early in the project Bethany shared, “if you can make content pertinent to students, they’re much more likely to learn it, and remember it, and perform well” (B₁), justifying SSI-TL as an approach that “should play a role in every unit” (B₁) in science classrooms. However, within the same conversation Bethany expressed multiple concerns about herself and others’ perceptions of her, as both a beginning teacher and a teacher of SSI-TL. Of her future colleagues and supervisors she told us, “Everyone says that you can get pushback [about SSI-TL] from your coworkers if you’re teaching in a PLT, or from administration, saying, ‘No, that’s not the most efficient way to teach the science concepts’” (B₁). Bethany described anxiety about SSI-TL with regard to student and teacher roles: “As a beginning teacher, it’s gonna be hard to let go of control in your classroom, and not always have the answer, especially in issues, something ethical. Navigating that could be difficult as a beginning teacher” (B₁). At this phase Bethany looked to evidence and reasoning to resolve her struggle. Bethany’s rebuttal to any resistance she feared from others was, “Here’s the evidence. Here’s the research on this. It worked really successfully” (B₁). Later she maintained, “It’s becoming an evidence-based practice. You can do socioscientific learning” (B₁).

At the mid-project interview, as Bethany's anxiety continued, she introduced a new strategy to deal with it: buying time. Bethany described the prospect of student teaching as "terrifying" (B₂), despite extensive experience in local high school classrooms; and she shared her fears of possible student reactions to SSI-TL: "Getting others on board is hard, especially when you have really high achieving students who might be saying, 'I need to be learning more content, I wish this was lecture based.'" (B₂). For Bethany, SSI-TL remained an ideal approach, consistent with her broader beliefs about K-12 science teaching and learning. She told us, "I still plan for sure on using it." (B₂). However, as Bethany accounted for her beliefs about self, she said, "As a beginning teacher I am not sure how successful I will be at [SSI-TL]. It might be... not technically SSI in the beginning" (B₂), but rather, "kind of exploring for myself how to navigate student responses throughout what is more, I guess, content units when I first start" (B₂). She reiterated, "I hope to be able to slowly make [SSI-TL] a focus. Unit by unit" (B₂).

By project end Bethany's resolution of her struggle was to commit to *not* using the approach even as she explained how she valued SSI-TL. Of her participation in the project she told us, "Designing my own unit, I think it's been really helpful to kind of make rubber meet the road. It's been a little harder to think about implementing it" (B₃). While Bethany's commitment to the philosophy of SSI-TL remained strong, committing to an SSI-TL practice seemed less certain: "I will definitely be an advocate for teaching in a way that's meaningful—and I think this is probably the only way I've been exposed to that is a really meaningful way to teach science, I should commit to that!" (B₃). She also shared, "It resonates for me, because I'm concerned with engaging my students, and I think this could be a really good way to kind of engage all learners" (B₃). However,

Bethany reasoned, “I might have to talk my whole PLC into it” (B₃), and students “might be frustrated, too, with this ‘new teacher’ who won’t just give them the answers” (B₃). Ultimately, Bethany told us, “While I still plan on using current issues, it wouldn’t really be considered an [SSI-TL] unit, you know, strictly issue throughout and upfront. Over time … melding curriculum into that, maybe.” (B₃). Although she had previously described herself as “gung ho” (B₁) about incorporating SSI-TL into her future classroom, she decided by the end of the project, “it’s probably not realistic for my first few years” (B₃). Instead, we could expect Bethany’s practice to be aligned with her more traditional views of teacher and student roles, revolving around the “content units” (B₂) with which she was more comfortable, because, as she had explained, “I am that way sometimes too, sometimes you just want information” (B₂).

Pre-service teachers’ curricular unit designs for SSI teaching and learning.

As we analyzed PSTs’ SSI-TL curricular designs we saw evidence that they were able to create high quality curricular units that met the requirements of the design task, and that varied with regard to alignment to the SSI-TL framework. Data analysis revealed one significant finding, which was that the sophistication with which PSTs integrated SSI into their curricular unit designs was influenced by the level of alignment of their general beliefs about K-12 science teaching and learning to the SSI pedagogical philosophy (See Tables 6 and 7).

Relationship between sophistication of SSI unit design and alignment of PST beliefs about K-12 science teaching and learning to SSI pedagogical philosophy.

Throughout the project, PSTs demonstrated variation in their belief systems about K-12 science teaching and learning, which in turn varied with regard to alignment to the

pedagogical philosophy that underlies SSI teaching and learning. As described in the findings for our first research question, Adam expressed beliefs about science teaching and learning that were very highly aligned with SSI pedagogical philosophy, while Henry's beliefs revealed a very low alignment with the philosophy of SSI. Ethan's beliefs were moderately aligned, and Bethany demonstrated conflicting alignment, in that her broader theoretical beliefs (e.g., the purposes and aims of K-12 science education, science and its presentation in K-12 science education) were highly aligned, while her beliefs about practice (e.g., student and teacher roles) were not. These belief systems influenced each PSTs' interpretation and uptake of SSI-TL, substantially and consistently, in every phase of their participation in the project. Ultimately, we found that the alignment of PSTs' existing belief systems about K-12 science teaching and learning to SSI pedagogical philosophy impacted the sophistication of the SSI-TL curricular units they created.

Each of our PSTs developed an SSI curricular unit that featured a focal socioscientific issue, appropriately related to selected science ideas and practices, with explicit connections between the SSI and the science ideas. In each unit, placement of the issue as an introduction to the unit was consistent with the SSI-TL framework. Three of the four PSTs' units featured the issue prominently by including activities that explicitly revisited the issue, consistent with SSI-TL. One unit did not reintroduce the issue until the culminating activity. All units also integrated the focal SSI into a culminating assessment project at the end of their unit that closely connected the SSI and relevant science ideas. Our analyses revealed variation in the scale of the focal SSI selected by

Table 6. PSTs' Curricular Unit Designs: General Requirements

	Adam	Bethany	Ethan	Henry
Unit Overview	7, 90-minute lessons, logically sequenced to progress from trophic levels and biological diversity to ecosystems, factors, and nutrient cycling	9 lessons requiring 15, 45-minute class periods, varied and logically sequenced from pesticide resistance through adaptation and natural selection	9 lessons of varying lengths, with varied learning activities related to topic, sequenced to build on prior knowledge about uniform and accelerated motion.	12 lessons over 10, 84-minute class periods, with a variety of logically sequenced learning activities closely related to unit
Science Topic	ecological change	microevolution	Newton's laws of motion	uniform and accelerated motion, Newton's 2 nd Law
Big Idea (Wiggins)	"Various factors work together to maintain an ecosystem's balance, and when these factors are changed the ecosystem changes." (A _U)	"When an environment changes & experiences shifts in its resources or physical/ biological challenges, individuals with reproductive advantage from morphological, physiological, or behavioral traits allow species to adapt by natural selection." (B _U)	"Newton's Laws allow us to predict how motion can change and what causes a change in motion." (E _U)	"...to promote perceptive mathematical insight through a student's analysis of a graph's shape" (H _U)
Essential Question	"How can I present living and non-living influences on ecosystem balance and the impacts of change within an environment?" (A _U)	"How are population genetics affected by a changing environment?" & "Why do pesticides stop working?" (B _U)	"Should speed limits be lowered to lessen negative effects of car collisions? If so how much do the speed limits be lowered?" (E _U)	"What is the relationship between position and velocity?" (H _U)
Connections in Gapless Explanation (Windschitl/ Thompson)	<ul style="list-style-type: none"> • roles and relationships of producers and consumers • reciprocal processes: cell respiration & photosynthesis • ecosystem abiotic factors • ecological diversity, change 	<ul style="list-style-type: none"> • individual genetic variation • natural selection • selective pressures and species adaptation • environmental change 	car collisions in relation to: <ul style="list-style-type: none"> • velocity • acceleration • Newton's three laws of motion 	<ul style="list-style-type: none"> • features of Cartesian graphs as representations of motion • velocity in uniform motion • accelerated motion as an extension of uniform motion • Newton's 2nd Law of Motion
NGSS PE	HS-LS2-(1, 2, 6, 7, 8), HS-LS4-6	HS-LS4-(2, 3, 4)	HS-PS2-(1, 3)	HS-PS2-1
NGSS: SEP	<ul style="list-style-type: none"> • developing & using models 	<ul style="list-style-type: none"> • developing & using models • engaging in argument from evidence 	<ul style="list-style-type: none"> • analyzing & interpreting data • constructing explanations & designing solutions 	<ul style="list-style-type: none"> • "graphing" • planning & carrying out investigations
NGSS: CCC	<ul style="list-style-type: none"> • stability and change • scale, proportion & quantity 	<ul style="list-style-type: none"> • cause and effect • stability and change 	<ul style="list-style-type: none"> • cause and effect 	(not identified)
Assessment	multiple formative assessment activities; two forms of concept-specific summative assessments	multiple formative and summative assessments incorporated throughout the unit	multiple formative and summative assessments incorporated throughout the unit	formative and summative and assessment activities for use at multiple points within the unit.

Table 7. PSTs' Curricular Unit Designs: Elements, Features, & Characteristics of SSI-TL

	Adam	Bethany	Ethan	Henry
Focal Socioscientific Issue				
Focal Issue	Invasive Species and “Eat MO Carp” Initiative	Pesticide Resistance	Lowering speed limits to reduce car crash impacts	Policies for Cell Phone Use to Prevent Collisions
Focal Issue Prominence	presented first and revisited every lesson	presented first and revisited multiple times	presented first and revisited multiple times	presented first and reintroduced in culminating project
Focal Issue Framing and Scale	Regional SSI as an <i>authentic solution</i> to an <i>authentic problem</i> created by a science phenomenon with negative societal impacts	National SSI as a <i>broad science phenomenon</i> to be modeled and defined, with vaguely defined societal implications	Local SSI as <i>hypothetical regulations</i> to mitigate <i>hypothetical societal implications</i> of authentic science phenomenon	School-wide SSI as a <i>hypothetical rule</i> , to mitigate <i>hypothetical implications</i> of human behaviors, as illustration of a broad science topic
Criteria for Focal Issue selection	complex, with multiple social sides; relevant due to prevalence in local news: “a focus of media attention for almost five years now, [and] many players who each support a different solution to the issue, allow students to find resources to support perspectives easily” (APPR)	relevant to students as citizens and consumers; an ethical dilemma: “something ethical” (B ₁); “Regardless of the student’s engagement with agriculture, they should be interested [in this issue] as food consumers and soon-to-vote citizens” (BPPR)	directly applicable to students’ personal lives as a context for life lessons and science: “It could really be something a student might just encounter in their everyday life” (E ₃) & “something they’ll be dealing with in their lives right then” (E ₃)	a context for science, relevant and of direct personal interest to students: “I hesitated to select cell phone use simply because it is very small in scale. However, it is very close to the student’s hearts, as they have limited opportunity to text during school hours” (HPPR).
Location of Issue Controversy	in society: “SSI by their nature have sides and actions associated with them...[and involve] making decisions for society” [A ₃].	in science: having “multiple ethical sides or [being] debated in the scientific community” (BPPR)	in the solution to an agreed-upon problem: “what happens between two cars during a collision isn’t much of a question that concerns society, but how to prevent these collisions is” (EPPR).	(not addressed)
Connections and Synthesis				
SSI Connected to Sci Ideas	“Understanding factors influencing an ecosystem serves as a learning goal that requires students to first learn basics of ecology. The ecology unit will be taught under the context of an invasive species impact, specifically Asian carp” (APPR).	pesticide resistance framed as one of multiple issues related to microevolution science topic (BPPR)	focal SSI was chosen for its relationship to “a common Newton’s 3rd law example” (EPPR); connection of science ideas to issue occurs in one lesson prior to culminating synthesis project	focal SSI connected to science ideas related to uniform motion and forces topics (HPPR)

Societal Dimensions Explicated	<p>contained explicit reference to socioscientific reasoning, including a lesson in which students were to consider the focal issue with regard to issue complexity, analysis of multiple stakeholder perspectives, and identification of areas of uncertainty and the affordances and limitations of science in addressing the problem.</p>	<p>no structured exploration or explicit identification of societal dimensions included prior to the end of the unit; perspectives of stakeholders were introduced as a task requirement in the form of scaffolded instructions in the culminating project</p>	<p>referenced “social connections” frequently, but underdeveloped: “4 topics for students to look at: pros & cons of reducing speed limit, safety features commonly found in cars and on highways. ...What happens in a car wreck is not just determined by how fast you are going, but also the car you are driving and the road you are on” (EPPR).</p>	<p>alluded to societal dimensions in the unit introduction: “students will present an opinion about a rule” (Hu); no explicit mention of societal dimensions of the issue</p>
SSI Connected to Societal Dimensions	<p>unit learning goals include, “Incorporate multiple perspectives on an issue and evaluate the solutions presented by multiple parties to assess the current and future impacts of the invasive species Asian carp” (Au), and this is explicitly addressed in a 90-minute lesson and the culminating project</p>	<p>connection in culminating activity only: students asked to propose a policy and identify:</p> <ul style="list-style-type: none"> • “Who will be affected by this policy? How?” • Which groups might oppose [be in favor of] your proposal? Why?” • Are there groups interested in the issue of pesticide resistance but not affected by your proposal?” (Bu) 	<p>issue reintroduced, and students asked to revise their position in the issue, after explicit attention to societal dimensions in two separate lessons</p>	<p>not present; lack of societal dimensions anywhere in the unit rendered this impossible</p>
Synthesis of Science Ideas & Societal Dimensions in Culminating Project	<p>required students to demonstrate their learning regarding relevant science ideas and societal dimensions, by recommending a specific action in response to the issue, as the culmination of the unit’s sequence of activities linking science and societal dimensions to the broader issue in every lesson</p>	<p>required students to explicate a policy position, support it with scientific evidence or models, summarize reasoning, identify possible societal implications, and identify potential supporters and opponents of the proposal; explicit attention to some science and some societal dimensions was required, although both superficially and with no explicit integration of the two.</p>	<p>required students to write a persuasive paper and clearly specified three components to include: social aspects (as previously defined), science aspects, and connection between the two, scaffolded in task instructions</p>	<p>required students to propose and explain a solution to a problem, a context for science ideas; no differentiation between SSI and its ethical, political, economic, or historical dimensions: “I always wanted the focal issue to include a car’s stopping time but also knew the synthesis project was going to pertain specifically to students in a hallway. I decided to provide options on the project to reconcile the two” (HPPR).</p>

PSTs, as well as the ways they were framed. The units demonstrated that PSTs prioritized relevance to students, connections to science, and controversy as important criteria when selecting their SSI. All of the focus PSTs' represented the potential controversy of their focal SSI by presenting it as a dilemma to be solved or a decision to be made, though notably, PSTs' interpretation of the *location* of that controversy varied.

Curriculum analyses revealed notable differences in PSTs' interpretation of the meaning and integration of societal dimensions of SSI. This was evidenced by the variations in the ways societal dimensions were presented, their prominence, and their integration with the focal issue within the unit. Finally, each of the PSTs' curricular units contained an appropriate culminating project, directly related to the focal SSI. However, analysis of this element again revealed variation in PSTs' interpretations of SSI-TL, as PSTs' requirement for *synthesis* in culminating projects reflected disparity regarding societal dimensions. This variation seemed largely an extension of the varied ways PSTs had represented societal dimensions within their units. These themes in variation are illustrated in the individual cases discussed next.

Adam design of an SSI-TL unit about ecological systems in the context of a regional invasive species illustrated the beliefs he expressed throughout the project. Adam had described sophisticated ideas about SSI-TL in his writing and in our conversations with him, identifying his essential considerations. For example, although Adam expressed strong support for SSI-TL, he warned, “I don't think that [SSI-TL] can work at all, really, unless you're one hundred percent into framing all of your content [in a unit] within this issue” (A₂). Likewise, Adam emphasized the importance of incorporating science, societal dimensions, and issue together “from the beginning” (A₂)

of a unit. Consistent with these beliefs, as Adam engaged in the practice of unit design, he crafted deliberate connections between science ideas and societal dimensions, within a current and prominent issue relevant to the local area. In turn, the SSI was woven throughout the unit by way of recurrent and deliberate references and tasks to ensure that it remained prominent. Adam linked his issue to science in *every* lesson of the unit, and placed explicit focus on societal dimensions and socioscientific reasoning where appropriate, resulting in a seamless integration of the issue into the unit. Consequently, the focal issue served as a compelling and relevant context in which to facilitate sensemaking about the selected science ideas. Adam's highly aligned and sophisticated beliefs about K-12 science teaching and learning were clearly reflected in his sophisticated SSI-TL unit design.

Bethany created an SSI-TL unit around a very large-scale issue in which important science ideas could be explored and applied. However, as practical connections to the issue were underdeveloped, some characteristics of SSI-TL remained underdeveloped, as well. As previously described, Bethany's beliefs were conflicted. That is, Bethany's broad beliefs about the theoretical ideas in K-12 science teaching and learning, such as its goals and purposes, and its portrayal of science, were well aligned with the progressive pedagogical philosophy of SSI, while her beliefs about practice, such as student and teacher roles and responsibilities, were much better aligned with a traditional pedagogical philosophy. These beliefs were easily inferred from Bethany's curriculum design, which clearly explicated a big idea and gapless explanation, and selected the broad focal issue in which to contextualize science learning activities. However, integration of the focal issue, its societal dimensions, and the related science

were simplistic, when they were present at all. Notably, the conflict within Bethany's belief system, reflected in her curricular unit, again seemed to magnify Bethany's beliefs about self and her anxieties about SSI-TL. At the same time that Bethany pronounced, "I could definitely see myself using this unit in a classroom" (B_{PPR}), she also reiterated her plan not to do so. Referring again to herself as a new teacher, Bethany explained.

"[Students] may not be comfortable taking risks, especially if I am a new teacher figuring out how to create the best safe learning environment" (B_{PPR}). Consistent with this plan, Bethany said of her experience with SSI-TL unit design, "While I am not sure what curriculum I will be able to fulfill in a 'true [SSI-TL] unit,' I feel more equipped to link standards and content with applied science and social issues" (B_{PPR}).

True to Ethan's beliefs about K-12 science teaching and learning as a context for life lessons and an application of science to everyday experiences, the unit he designed included a well-scaffolded sequence of lessons with a characteristically practical application of scientific principles. Ethan's unit featured an authentic issue he expected all his future students to face within the same time frame as their participation in his course, and Ethan wove the components of SSI-TL together into a cohesive curricular unit. Ethan's unit lacked some depth of connection to societal dimensions, in that it failed to explicitly feature realistic ethical, historical, or economic considerations; or the issue's complexity, stakeholders, and multiple perspectives. Indeed, as previously described, Ethan defined his perception of "social connections" to his selected focal issue as consisting merely of "pros and cons" and "safety features" (E_{PPR}). Describing his unit design, Ethan told us of a lesson that "allows students to start thinking about the forces involved within the context of the focal issue" (E_{PPR}), one "meant to provide the students

with some concrete experience ... as well as provide them with some extension problems where they apply [it] to other situations" (E_{PPR}), and "a chance to display knowledge and use of Newton's laws through a hands on engineering task that the NGSS standards are such a big proponent of" (E_{PPR}). In each case, Ethan designed learning experiences that would both draw from, and be applicable to, students real lives. Consistent with Ethan's beliefs about K-12 science teaching and learning, teachers would serve as facilitators of life lessons, and students would be fully engaged in sense-making about science in the real world, as applied to their lives.

Henry's cohesive sequence of lessons focused on ideas about uniform motion and the practice of essential physics skills related to data collection and analysis, graphing, and mathematical problem solving. Henry's unit was contextualized in a real-life scenario of practical significance to students, but featured almost no exploration of, or connection to, the issue's societal implications. Consistent with Henry's beliefs about science as a discipline isolated from all others, his interpretation of SSI-TL was that it was a very nebulous approach to teaching, distinct from science. Henry's unit reflected this belief. In a presumably good-faith attempt to satisfy requirements of the unit design task, Henry represented his focal issue as little more than a context in which to insert science ideas, omitting entirely the SSI-TL component of societal dimensions. Just as Henry had expressed a dichotomous view of the world as *science* or *not-science*, he seemed to design his unit with *science* or *not-science* lessons. Notably, Henry specified in his introductory lesson, the first (and only) representation of his selected focal SSI prior to the culminating event, that the teacher was to "introduce the focal issue" (H_U) and "Specifically mention the culminating project" (H_U), but also, "Neglect to mention the

physics material which will be covered” (Hu). Henry’s belief that science and SSI were not compatible or overlapping in any way was reflected in his unit design in which lessons featured only science or the focal issue, but never both.

Discussion

K-12 science teachers have demonstrated resistance to teaching with SSI, even when they support such an approach and recognize its many benefits to learners (Bossér, Lundin, Lindahl, & Linder, 2015; Saunders & Rennie, 2013; Tidemand & Nielsen, 2017). Lack of familiarity with the practical aspects of integrating SSI into their classrooms, misalignment between beliefs and SSI pedagogical philosophy, and limited access to materials may inhibit teachers’ uptake of SSI teaching and learning (Lee et al., 2006; Sadler et al., 2006; Saunders & Rennie, 2013). The relationship between PSTs’ beliefs and their uptake of SSI-based practices is often overlooked in the literature, even as research points to the relative readiness of this population to adopt reform-oriented beliefs that can, in turn, support their uptake of reform-oriented practice (Crawford, 2007; Fletcher & Luft, 2011). Our research suggests that familiarizing PSTs with SSI-TL and supporting their engagement in the practice of SSI-TL curricular design in a teacher education context may be a way to challenge their existing beliefs about K-12 science teaching and learning, as well as to mitigate barriers to their adoption of reform-oriented beliefs and practice.

Consistent with studies that have found interactive and mutually constitutive relationships among different dimension of teachers’ belief systems (Crawford, 2007; Forbes & Davis, 2010a; Hutchins & Friedrichsen, 2012; Hutner & Markman, 2016; Jones & Carter, 2007; Jones & Leagon, 2014; Lee et al., 2006), we found PSTs’ existing beliefs

about K-12 science teaching and learning consistently served as filters for their interpretations of SSI-TL and associated beliefs. PSTs' personal struggles during their development of SSI-related beliefs were also influenced by their existing K-12 science teaching and learning beliefs. Those whose personal views were more closely aligned to the philosophy underlying SSI-based pedagogy looked for ways to adopt SSI-TL, and their struggles revolved around how SSI might help them achieve teaching and learning goals. Those whose views were less well aligned gave fair consideration to SSI-TL, but struggled with the ways they perceived it to interfere with their goals.

A small number of studies have indicated interaction between beliefs and SSI teaching practices, also clearly indicated in our findings. However, few of these studies focused specifically on this relationship. Hancock and colleagues (2019) looked at in-service teachers' identities in an experience of SSI curriculum design, apart from implementation. Zangori and colleagues (2018) explored in-service teachers' perceptions about SSI while teaching a unit that they had contributed to developing, but had not designed themselves. Both studies found that teachers drew from personal passions while designing or teaching with SSI. By contrast to these findings, our results contribute to the literature by revealing that PSTs did not draw from personal passions for their issue selection and unit designs, but rather, from their deeply held philosophical positions about science in the K-12 classroom and the purposes of K-12 science education, as well as their beliefs about roles of students and teachers. This could be related to PSTs' limited professional experiences, leading them to draw from the theoretical perspectives commonly emphasized in teacher education, as opposed to the expertise in-service teachers may leverage (Meijer et al., 1999).

Curriculum design is an essential practice of teaching (Craig, 2010, 2012; Remillard, 1999; Wallace & Priestley, 2017) that can also promote teachers' professional growth (Coenders, 2010; Coenders & Terlouw, 2015; Coenders et al., 2010). Several studies in which in-service teachers created SSI curricular materials did not explicitly investigate the process of designing SSI curricula, yet suggested its potential to transform teachers' ideas about teaching (Eilks & Markic, 2011; Feierabend et al., 2011; Hancock et al., 2019; Zeidler et al., 2011). While some studies investigated PSTs' critique, evaluation, or adaptation of curricular materials for SSI or inquiry (Forbes, 2013; Forbes & Davis, 2008; Forbes & Davis, 2010a, 2010b); beliefs in relation to lesson plan design (Rojas-Perilla, 2018); or perceptions and plans for teaching with SSI and other contentious issues (Borgerding & Dagistan, 2018); none of these studies linked PST beliefs to the practice of SSI-focused curriculum design or PSTs' experiences as designers of SSI curriculum. By contrast, our work not only linked all of these constructs, but also revealed a relationship between PSTs' beliefs about K-12 science teaching and learning and the development of their beliefs about SSI teaching and learning.

PSTs in our study experienced opportunities to wrestle with both the philosophy and the practical elements of SSI-TL, and each participant described the approach in terms of their philosophical and practical beliefs about K-12 science teaching and learning. The SSI teaching module afforded PSTs multiple and varied opportunities to engage with SSI-TL, to make sense of its underlying pedagogical philosophy, and to envision ways they may or may not use this approach in their own future classrooms. As PSTs worked toward the primary goal of our methods course, learning to design coherent curricular units, they did so in the context of the innovation of SSI-TL. Our study

revealed that PSTs were not only able to design high quality units, but were also able to integrate the SSI-TL framework and many of its principles into their curricular designs. As Hutner and Markman (2016) described in their proposal of an operational definition of teacher beliefs, the ideas PSTs used and drew from as they engaged in the practice of curriculum design were activated, as the SSI teaching module was structured to compel PSTs' reflection and articulation of beliefs. These salient beliefs then anchored PSTs' formation of beliefs regarding SSI-TL and informed their processes of curriculum design.

Our findings support the notion that awareness of SSI-TL may be inadequate to inspire teachers' complete uptake of the approach (Lee et al., 2006). While each of the PSTs expressed familiarity and well-developed interpretations with regard to SSI teaching and learning, variations in their beliefs, in the alignment of their beliefs to the pedagogical philosophy of the approach, and in the consistency between their beliefs and their uptake of the approach, varied notably. Had PSTs' beliefs been more explicitly attended to, regularly and intentionally, throughout the entirety of their science methods coursework sequence, perhaps our data would have indicated meaningful change in some PSTs' beliefs and resulted in closer alignment between general beliefs and SSI-TL beliefs, and/or more complete and consistent uptake of the innovation of SSI-TL.

Perhaps more frequent, detailed, and explicit discussion about student and teacher roles in SSI-TL would be helpful to challenge the beliefs of PSTs who hold traditional expectations about these roles. This could be particularly true in cases such as Bethany's, in which broad theoretical beliefs might be consistent with progressive pedagogies (Zeidler, 2014), but beliefs about practice may be less well-aligned. Greater attention to characteristics of an issue could be helpful for PSTs who express benefits of integrating

SSI, but struggle to identify appropriate options for their science disciplines, such as in Ethan's case.

Implications and Conclusion

Though our study explored the SSI-related beliefs and curricular designs of only a small number of PST participants, the depth of examination and the findings revealed give us cause to believe teacher education is an appropriate context in which to challenge teachers to articulate their beliefs while considering reform-oriented alternatives, as well as to practice SSI-based curriculum design in a supportive environment.

Implications of our study, for research and teacher education, include the need for more explicit attention to PSTs' elicitation of their beliefs, as well as a systematic comparison to the pedagogical philosophy of SSI-TL, in order to challenge inconsistencies within PSTs' beliefs or between their beliefs and SI-TL. If such explications and comparisons were to happen earlier and more frequently in PSTs' methods coursework than occurred in our study, perhaps those PSTs whose beliefs conflict with SSI-TL would recognize disparities that would compel evaluation and revision of their ideas. Another implication for research and teacher education is PSTs' need for greater clarity and support around SSI-TL, specifically regarding issue selection, the hallmark of SSI, and the more practical aspects of student and teacher roles.

Supporting K-12 science teachers in the uptake of socioscientific teaching and learning is an important cause for both research and teacher education, if science teaching and learning is to promote scientific literacy and the types of learning experiences conceptualized by NGSS. Facilitating immersive experiences in SSI teaching and learning in a teacher education context, as teachers learn to engage in practices around

high quality curriculum design, can support PSTs' uptake of the SSI-TL approach through meaningful engagement with a clear framework. Combining these experiences with activities designed to promote PSTs' articulation of their beliefs about teaching and learning can serve to challenge PSTs to consider reform-oriented beliefs, and offers the potential to support their uptake of corresponding reform-oriented practice (Fletcher & Luft, 2011). Our study serves as an early exploration of the ways such experiences might be leveraged to support PSTs' development of SSI-related beliefs, the capacity of PSTs for SSI-based curricular design, and the significance of making PSTs' beliefs visible, toward alignment with SSI-focused practice.

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Appendix

BEAI Survey

Name:
Date Completed:

<i>Please circle a letter to the right of each statement to indicate the degree to which you agree or disagree.</i>		
SD = Strongly Disagree D = Disagree UN = Uncertain A = Agree SA = Strongly Agree		
1.	I will be able to design a science curriculum unit around a compelling social issue for my future classroom.	SA A UN D SD
2.	I will be able to design a curriculum unit that presents a compelling social issue first, before introducing relevant science concepts.	SA A UN D SD
3.	I feel well equipped to facilitate conversations about controversial issues in the science classroom.	SA A UN D SD
4.	I am not sure whether I know enough about controversial issues related to my science discipline to build instruction around them.	SA A UN D SD
5.	I feel comfortable about asking potentially contentious questions in the classroom that might challenge my future students' core beliefs.	SA A UN D SD
6.	I will be able to scaffold my future students' reasoning about compelling social issues related to the science content in my courses.	SA A UN D SD
7.	I will feel comfortable being a learner as I allow my students to contribute to the body of knowledge in my future science classroom.	SA A UN D SD
8.	I am confident that I will be able to assess my future students' individual understanding of science concepts in a unit designed around a compelling social issue.	SA A UN D SD
9.	I feel well equipped to assess my future students' participation in activities such as debates and group presentations, as part of a science unit based upon a compelling social issue.	SA A UN D SD
10.	I will be able to design end-of-unit experiences for my future students to connect their understanding of science concepts to a specific, compelling social issue.	SA A UN D SD
11.	I will be able to assess my future science students' individual reasoning and decision making related to a controversial social issue.	SA A UN D SD
12.	I expect to find support from my future colleagues and supervisors if I choose to teach science units built around compelling social issues.	SA A UN D SD
13.	I will be able to negotiate community members' and parents' concerns about using potentially controversial social issues to teach science concepts in my future career.	SA A UN D SD
14.	Science instruction built around a controversial social issue that students might hear about in the news can help students develop valuable reasoning and decision-making skills.	SA A UN D SD
15.	Centering science instruction on compelling social issues is an effective way to meet state and national curriculum goals.	SA A UN D SD
16.	An important objective of science education is preparing citizens to reason and make informed decisions about science-related social issues.	SA A UN D SD
17.	Helping students to learn reasoning and decision-making in the context of social and ethical dimensions of complex issues is an appropriate goal of science education.	SA A UN D SD
18.	When students learn about science in the context of controversial social issues, they will develop valuable experience in authentic science practices such as collecting and analyzing data.	SA A UN D SD

19.	When students learn about science in the context of controversial social issues, they will develop valuable experience in authentic science practices such as <u>constructing explanations from evidence</u> .	SA A UN D SD
20.	When students learn about science in the context of controversial social issues, they will develop valuable experience in authentic science practices such as <u>identifying and communicating their own positions on the issue</u> .	SA A UN D SD
21.	Students will be able to develop science reasoning and decision making skills if the teacher is willing to act as a knowledge contributor rather than the knowledge authority in the classroom.	SA A UN D SD
22.	Students will be able to effectively learn about science concepts if they learn about them in the context of a controversial social issue.	SA A UN D SD
23.	Science teachers should adapt instruction to help students connect their prior knowledge and current learning about science concepts to current social issues on local, state, national, and global levels.	SA A UN D SD
24.	Instructional objectives in science classrooms should focus not only on students' understanding of science concepts, but also on students' reasoning about complex dimensions of real-life issues that relate to those science concepts.	SA A UN D SD

<i>Please circle a number to the right of each description, to represent your interest in the corresponding topic.</i>			
<p>1 = Very Uninterested 2 = Somewhat Uninterested 3 = Uncertain 4 = Somewhat Interested 5 = Very Interested</p>			
<i>How interested are you in ... ?</i>			
25.	designing science instruction around a compelling social issue	1 2 3 4 5	
26.	challenging students' core beliefs with contentious questions about social issues that relate to science	1 2 3 4 5	
27.	creating instructional activities in which students learn about science concepts through engagement in higher order practices as they sort through controversial social issues that relate to science	1 2 3 4 5	
28.	taking the position of knowledge contributor rather than knowledge authority in the classroom	1 2 3 4 5	
29.	facilitating conversations in the classroom about social and ethical dimensions of controversial issues that relate to science	1 2 3 4 5	
30.	establishing a collaborative and interactive classroom environment that prioritizes exploration of controversial social issues that relate to science	1 2 3 4 5	
31.	negotiating potentially difficult responses of colleagues to an unorthodox and controversial style of teaching	1 2 3 4 5	
32.	negotiating potentially difficult responses of administrators to an unorthodox and controversial style of teaching	1 2 3 4 5	
33.	negotiating potentially difficult responses of students to an unorthodox and controversial style of teaching	1 2 3 4 5	
34.	negotiating potentially difficult responses of parents to an unorthodox and controversial style of teaching	1 2 3 4 5	
35.	adapting science curriculum materials to address controversial current events.	1 2 3 4 5	

Semi-Structured Interview Protocol

1. What does *issues-based instruction* mean to you?
2. What role might *issues-based instruction* play in high school classrooms?
3. What might be benefits and/or drawbacks to *issues-based instruction* in high school classrooms?
4. To what extent do you intend to use *issues-based instruction* in your future classroom?
5. Describe your response to the following statements:
 - a. Issues-based instruction is a viable method to meet state and national education standards.
 - b. Issues-based instruction is an effective method for students to learn science concepts.
 - c. Issues-based instruction can help students learn valuable reasoning and decision-making skills.
 - d. I feel equipped to use and assess issues-based instruction in my future classroom.

SSI Curriculum Unit 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**

CHAPTER FIVE

In this dissertation I explored pre-service teachers' beliefs about teaching and learning with SSI, in the context of a methods course focused on principles of curriculum design and the SSI Teaching and Learning (SSI-TL) framework (Sadler et al., 2017). The project drew from a body of research that clearly indicates the essential nature of beliefs in teachers' uptake of educational reforms (Bryan, 2012; Fletcher & Luft, 2011; Haney & McArthur, 2002; Hutner & Markman, 2016; Jones & Carter, 2007; Jones & Leagon, 2014; Nespor, 1987; Richardson, 2003; Wallace, 2014; Zint, 2002), as well as research that has highlighted the power of teachers' engagement in reform-oriented curriculum design to transform both their beliefs and their teaching practices (Craig, 2012; Coenders & Terlouw, 2015; Coenders et al., 2010; Eilks and Markic, 2011; Zeidler et al., 2011). In addition, SSI Teaching and Learning served as a tool to help PSTs operationalize this progressive pedagogical innovation (Sadler et al., 2017; Zeidler, 2014).

Broadly, I was interested in PSTs' beliefs about SSI, as representations of ways they might think about SSI or any similar reform-oriented innovation in science teaching and learning; as well as the capacity PSTs might demonstrate for uptake of SSI teaching practices, including curriculum design. I proposed three specific purposes:

1. To disseminate to a teacher education audience a design for a methods course that could support PSTs' uptake of SSI as a reform-oriented innovation.
2. To disseminate to a K-12 audience a tool designed to support K-12 teachers' adoption of SSI.

3. To collect and analyze data, and to share with the teacher education research community, the research methods and findings of this exploration of PSTs' SSI-related beliefs and curricular design products.

Chapter Two was a detailed description, written for teacher educators, of the methods course designed and taught in the project to introduce PSTs to the SSI-TL framework and to support their uptake of the practice of SSI-TL curricular design. Written after the fact, the description was historical in nature. However, through enactment of the course design, the experiences of teaching and learning in an SSI-focused methods course revealed key takeaways for SSI teacher education, especially regarding characteristics of the course that might be preserved or changed, as well as additions that might further scaffold PSTs' uptake of SSI-oriented teaching practice.

One consideration for improving the methods course design arose from recognizing the varied ways PSTs interpreted societal dimensions of a focal issue, a critical component of the SSI-TL framework. In future iterations of SSI teacher education, this could be addressed with addition of scaffolds for uptake of this element of SSI-TL. While retaining the general structure of the SSI Teaching Module, the addition of learner tools to support engagement in socioscientific reasoning and clear explication of societal dimensions of the issue could serve this purpose. For example, in Phase 1, offering a tool that requires learners to explicitly identify stakeholders and their perspectives on the issue, while providing evidence to support their claims, would serve to highlight societal dimensions. Facilitating teachers' attention to these scaffolds in the unit would further emphasize this feature of SSI-TL, and could support PSTs' clarity in interpreting it. For example, in Phase 2, as PSTs are introduced to the framework and

example SSI curricular materials, they could be asked to identify activities in the example unit in which societal dimensions were emphasized, and to describe specific ways that those activities serve to represent features or elements of the SSI-TL framework.

A second consideration is the importance of peer review and curriculum design in the SSI-focused methods course. Participants expressed specific ways that the experience of engaging in this teaching practice helped them to refine both their beliefs about SSI and their preparation to engage in associated teaching practices. Participants described their perceptions of the benefit of reviewing peers' ideas and providing them feedback; changes to their self-efficacy beliefs regarding SSI-TL; and new perspectives about how SSI might look in their future classrooms. Consistent with descriptions provided by in-service teachers about their own similar experiences with SSI curriculum design (e.g., Zeidler et al., 2011) the participant PSTs' feedback supports the curriculum design project as an integral component of the SSI Teaching Module, toward PSTs' preparation for uptake of both curriculum design and SSI-TL teaching practices.

Finally, a broad consideration of the course is to seek an answer to the questions, *Where does this learning experience belong on the teaching continuum? Is teacher education a reasonable place to situate such an experience?* In reflecting on the project, I acknowledge the rarity of the context in which it took place. The SSI Teaching Module occurred in the third of three science methods courses, a rarity in itself, and with a well-established learning community, a cohort of learners with whom I was working for the third consecutive semester. In addition, a majority of PSTs enrolled in the class were completing dual degrees in both education and their content area. Admittedly, this is simply not a typical scenario in teacher education, and as a result, the opportunity to

incorporate this particular reform-oriented Teaching Module cannot be presumed to be an option for every teacher education program. However, in light of research that indicates the significance of reform-oriented beliefs in teachers' adoption of reform-oriented practice (Fletcher & Luft, 2011; Wallace, 2014); early career teachers' openness to adopting reform-oriented beliefs (Crawford, 2007); and the findings from this study (Chapter Four); I hold strongly to teacher education as a suitable context for a learning experience of this type. Supporting PSTs in a teaching practice as essential as curriculum design (Remillard, 1999; Wallace & Priestley, 2017) is a natural extension of their learning to design lesson plans and engaging meaningfully with state and national educational standards, two examples of curricular goals in many methods courses. Contextualizing this learning in an educational innovation, when time allows, can serve to address the barriers (Hansen & Olson, 1996; Lee et al., 2006; Sadler et al., 2006) that might otherwise prevent teachers' later uptake of such innovations. Although it may represent an idealistic position, I support the idea of incorporating reform-oriented curriculum design into teacher education coursework if circumstances allow.

In Chapter Three I described an activity, featured in the SSI Teaching Module in the methods course and intended for use in secondary science classrooms, which has been met with enthusiasm by both the PSTs in this project and in-service teachers in subsequent SSI-focused PD. This chapter was a narrow look at one activity intended to support teachers' incorporation of (and by extension, learners' engagement with) the societal dimensions of SSI in science classrooms. Reviewers' comments of the original submission highlighted the very challenges that the work was intended to address; namely, that focusing on societal dimensions of an issue, in order to make authentic

connections between societal and scientific ideas related to the focal SSI, can seem unnatural and out of place to those expecting to teach science in isolation from other disciplines. In responding to reviewers concerns about the apparent absence of science ideas from the activity, I made a lengthy response to explain the pedagogical basis of the activity, and provided an overview of the unit to situate the single societal dimensions lesson in a broader, clearly scientific context. Subsequent feedback was positive.

In Chapter Four I presented empirical findings related to PST beliefs that emerged with their participation in the SSI-focused methods course and curriculum design experience. Some important implications for future research emerge from this study. First, I acknowledge limitations of the design, a study of four focus participants over one 16-week semester. If time and access allowed I would suggest modification of the study design to capture a longer view than the snapshot this project afforded. Rather than a semester-long look at the focus participants, following them into student teaching, their first year of teaching, and possibly beyond would be ideal. Capturing similar data during and after each of these time periods could offer a glimpse into how PSTs' beliefs about SSI teaching and learning continued to develop during their classroom experiences; whether the struggles around SSI-TL beliefs that they experienced and resolved during methods coursework continued to influence their ideas about teaching; whether they faced new experiences of practice that influenced further developments in their reform-oriented beliefs; and how their beliefs played out beyond the practice of curriculum design, into the practices of curriculum enactment. This longitudinal view could lead to clearer understanding of teachers' needs, as well as development of better supports, in their uptake of reform-oriented innovations such as SSI-TL.

Second, the design of the project necessarily restricted access to data until the collection phase was complete. Analysis of data to characterize beliefs took place after the course had ended and grades were submitted. This was the result of my dual roles as researcher and course instructor, and served to protect participants from bias in course grading. For this reason, I was unaware of participant beliefs as they emerged throughout the project. Given my findings, it is clear that research tools designed to explicate & challenge PSTs' beliefs could strengthen the study. Ideally, research tools would address the influence of PSTs' existing beliefs about K-12 science teaching and learning on the development of their beliefs about the innovation of SSI-TL. For example, reflective activities that focused specifically on those existing beliefs could be embedded in the methods course activities. Although the methods course featured in this project was designed to include frequent reflection about SSI, PSTs' beliefs about the portrayal of science, roles of students and teachers, and aims and purposes of science teaching and learning, in general, were not explicitly addressed in course activities. A broader focus on belief systems, both with regard to data collection and to the design of course activities, toward better representation and support of PSTs' developing beliefs, may have rendered the course more impactful and the research more insightful.

A final implication from the findings described in Chapter Four is that SSI can seem nebulous to learners of this reform-oriented approach, and supporting their uptake should include concrete elements and characteristics demonstrated by a variety of examples. Doing so could allow those in teacher education to avoid an overly prescriptive presentation of the framework, while also ensuring its essential features are clear to potential adoptees as they try to make sense of the innovation. As described previously,

unfamiliarity with an SSI approach to teaching and learning is a reasonable barrier to uptake (Lee et al., 2006; Sadler et al., 2006; Saunders & Rennie, 2013). Teaching teachers about the approach requires clarity, and teaching early career teachers about a reform in the midst of their learning about a fundamental teaching practice, could be presumed to require an even more fine-grained level of support.

Research indicates the propensity of early career teachers to adopt reform-oriented beliefs, as previously described, yet methods coursework may not allow pre-service teachers adequate time for exploration of reform-oriented innovations in the midst of other teacher education curricular requirements. Teachers in the induction phase of their careers may find themselves juggling challenges of transition, as they learn how to manage their classrooms, attend to student behaviors, negotiate collaborations with colleagues, build relationships with students, communicate with parents, and myriad other responsibilities teachers juggle. On the other hand, research has indicated that veteran teachers are less likely to change their beliefs, and therefore, their practices (Crawford, 2007; Fletcher & Luft, 2011). Questions remain about the ideal phase of teaching in which to learn reform-oriented practice. It may be productive to consider that the uptake of a complex innovation in teaching in learning such as SSI-TL is itself a complex process. We know that beliefs change slowly, if at all (Jones & Carter, 2007; Jones & Leagon, 2014). However, research suggests that changes in practice and changes in beliefs may be mutually constitutive. That is, transformation of beliefs have been shown to follow changes in practice (Coenders & Terlouw, 2015; Coenders et al., 2010; Eilks and Markic, 2011; Zeidler et al., 2011), just as changes in practice have been shown to be inspired by changes in beliefs (Lee & Witz, 2009). Barriers to teachers' uptake of

innovations such as SSI-TL may be related to unfamiliarity and misalignment of beliefs (Hansen & Olson, 1996; Lee et al., 2006; Sadler et al., 2006; Saunders & Rennie, 2013).

In light of these ideas, when taken in combination, it may be important to begin the complex process of uptake of reforms in the pre-service context, while allowing for teachers' variation in readiness to adopt reform-oriented practice. Just as our participants demonstrated, teachers should be expected to bring their existing beliefs about science teaching and learning from their "apprenticeship of observation" (Lortie & Clement, 1975) to teacher education, and those beliefs will undoubtedly vary. By experiencing teacher education, at any phase of the continuum, contextualized in progressive pedagogies (Zeidler, 2014), the barriers to educational innovations can begin to be mitigated, and teachers' exposure to new ways of teaching and learning may allow them to think about—and ultimately, to practice—new ways of representing science teaching and learning in their classrooms. Those whose beliefs are already well-aligned to pedagogical philosophies that underlie innovations such as SSI-TL may be prepared to take up the approach quickly. Others may continue to wrestle with innovations, yet consider ways to adapt and adopt them. Those whose beliefs conflict with progressive innovations may not take them up, but may still benefit from better defining their ideas about science teaching and learning, and may find other ways to innovate as a result of having their beliefs challenged in a learning experience such as the SSI Teaching Module featured in this project.

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VITA

Jaimie Foulk learned to read and write at a young age by looking and listening over an older sibling's shoulder. Learning and teaching have been drivers in her life ever since. She was fortunate to experience a multitude of rich learning opportunities as an elementary student, from music and dance to creative writing and math. A middle school teacher taught her to cook and sew. A high school teacher encouraged her to learn about exercise physiology and teach fitness classes. College opened her world by exposing her to professional readings and communities and a diversity of worldviews, and led to her early career as a clinical dietitian/nutritionist and nutrition educator. When she turned her attention to full-time mothering, she viewed it as a long-term exercise in differentiated instruction for two uniquely gifted individuals. After both her children were in school Jaimie turned her attention to her next career field, secondary science teaching. For 18 years Jaimie has learned and taught in her career as an educator in her state public education system. After ten years in her own high school classroom she became a peer educator and professional development facilitator for secondary science teachers throughout her state. During her doctoral work she experiences good fortune again, as she taught or co-taught multiple undergraduate and graduate level courses for students in a top notch teacher education program. When she's not learning about teaching or teaching about learning, Jaimie takes pleasure in pursuing physical challenges, travel, and meaningful time with her family, preferably all three at once.