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Teacher candidates' views of future SSI instruction: a multiple case study

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Abstract

The instructional approach of incorporating socioscientific issues (SSI) into science teaching has been found to improve critical thinking and problem-solving skills among K-12 students. Preparation for how to facilitate SSI in the classroom, however, is limited, resulting in very few classrooms across the United States providing opportunities for K-12 students to grapple with these real-world problems. In this manuscript we compare the integration of socio-scientific issues (SSI) within two different undergraduate course contexts: a science methods course that is part of an elementary educator preparation program and a science content course designed for secondary future educators. Through this comparison we aim to provide science education researchers and science teacher educators with empirical support related to how the delivery of SSI influences elementary to secondary teacher candidates' views of SSI as they relate to student engagement, teacher effectiveness, and curricula. Leveraging a mixed methods case study approach, data from each course context were collected through Likert-type surveys and open-ended responses. Findings suggest exposure to SSI pedagogies in science methods and content courses influence teacher candidates' views in different ways and we must consider field and course-based work occurring simultaneously while teacher candidates are learning about SSI-based instruction. Implications for this are discussed.

Keywords Socioscientific issues, Preservice teacher preparation, Science methods course, Science content course

International science education scholars are aware of the negative emotions preservice teachers hold concerning their abilities to teach science. This awareness has resulted in a magnitude of studies focused on improving preservice teachers' confidence in teaching science (e.g. Cinici, 2017; Kinskey, 2018; Kinskey & Callahan, 2021; Trauth-Nare, 2015). A recent survey conducted by Horizon's Institute revealed the average time spent teaching elementary science per day was 20 min. This contrasts with a reported 87 min per day spent teaching reading and 58 min per day teaching mathematics. Of the time spent teaching science, teachers self-reported they facilitated instruction using district-provided, text-book driven curricula. Curricula used was of low-cognitive demand, as opposed to incorporating project-based experiences that engage students in critical thinking and problem solving (Plumley, 2019). The low cognitive expectations are visible in secondary science courses that are often designed around confirmatory "cookbook" laboratory activities where students focus on a set procedure while the outcomes are already known, as a method to confirm a concept previously discussed in class (Sampson et al., 2009). Additional research in the context of secondary preservice teacher education has noted similar trends regarding perceived interest and enjoyment in teaching cognitively demanding science lessons (see Büssing et al., 2020). Literature regarding why teachers make specific decisions about their science instruction often includes self-reported low confidence

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with abilities to facilitate science content (Menon & Sadler, 2016), a lack of time to enact complex science lessons (Kinskey & Zeidler, 2021), or the belief that young children are not capable of engaging in cognitive demanding science, despite empirical evidence suggesting otherwise (Roth, 2014).

One proposed solution to concerns about the quality of science is the incorporation of a socioscientific issues (SSI) instructional approach. SSI instruction provides opportunities for students to grapple with open-ended dilemmas through the application of scientific knowledge and moral considerations by focusing instruction around a personally relevant contentious issue. Students are then supported as they weigh the scientific and sociocultural aspects associated with potential solutions to the issue. Despite concerns regarding young children's abilities to engage in complex scientific thinking, there is empirical and practitioner-based evidence of successful SSI in elementary (Dolan & Zeidler, 2009; Kahn, 2019; Kinskey & Zeidler, 2021) and secondary classrooms (see Zeidler et al., 2011, 2014). While evidence is promising for the benefits of implementing SSI in classrooms, approaches to preparing preservice teachers for this approach to teaching is still emerging.

When considering the preparation of elementary and secondary preservice teachers, it is important to consider the different course contexts within undergraduate programs. Within certification pathways in educator preparation programs, it is common that preservice teachers take science content courses prior to enrolling in their teacher preparation program. Specific to the elementary context, teachers are typically considered generalists, where their preparation focuses on pedagogy with a wide range of surface level preparation for content they are expected to teach (Akerson & Bartels, 2023). In secondary preparation, it is common for preservice teachers to immerse themselves in a combination of pedagogy and content courses related to the discipline in which they intend to seek certification (Birmingham et al., 2019). Empirical studies that expose preservice teachers' experiences with these science content-specific courses have revealed they foster negative emotions toward teaching science due to the fact-laden, lecture-based approaches typically associated with science (Birmingham et al., 2019). Other recent works have suggested that preparation programs offer a hybrid approach to science content courses for preservice teachers that emphasize both content and pedagogical approaches, in addition to the methods courses typically taken by preservice teachers (Bergman & Morphew, 2015).

Rationale

Learning environments, which include characteristics of instructional approaches, have historically been identified as influential in student perceptions and learning outcomes of concepts (Fraser, 2023). Understanding how the learning environment influences perceptions has implications for how to improve those perceptions and outcomes. We argue this is also true for the context in which SSI is presented to preservice teachers. In one study Yerdelen et al. (2018) designed and facilitated a course specifically focused on SSI to preservice teachers with science and non-science majors. Using the attitudes toward socioscientific issues scale (ATSIS), they measured the preservice teachers' attitudes toward SSI before and after engaging in the course, which focused on the theoretical underpinnings of SSI as well as student-directed SSI-based activities. Findings indicated the construct related to enjoying SSI was most influenced by the course when compared to the other two constructs of the instrument: usefulness; anxiety toward SSI. In another study focused on presenting SSI through a science methods course, Borgerding and Dagistan (2018) found that preservice teachers were most concerned about teaching SSI topics related to content knowledge in which they were not confident. This finding related to content knowledge is similar to what has been revealed in research focused on SSI with K-12 students.

For instance, Cian (2020) notes that when students have more content knowledge related to a certain issue, they have more confidence with exploring the issue, resulting in more sophisticated reasoning. When considering teacher preparation in pedagogical practices, it has been observed that educators tend to gravitate toward approaches to which they were exposed as K-12 students due to a familiarity and comfort (Russell & Martin, 2023). Therefore, presenting SSI through a pedagogically focused methods course may be met with some apprehension due to the progressive nature of SSI-based instruction (Zeidler & Sadler, 2023). It is argued that when preparing future teachers for science instruction, teacher educators must embrace the reciprocal relationship between content and pedagogy (Russell & Martin, 2023). Thus, in this study we explored how introducing the SSI framework in two different learning environments, (1) a methods course with underpinnings related to content; and (2) a content course with pedagogical underpinnings, influenced teacher candidate (TC) views on facilitating SSI-based instruction, as it relates to curriculum, students, and teacher preparation, in their future classrooms.

Theoretical framework

Socioscientific issues framework

It is important to note a difference between simply discussing controversial issues related to a given science concept and implementing the Socioscientific Issues (SSI) framework. The SSI framework offers a sociocultural approach to the development of functional scientific literacy, which draws from the intersection of science, culture, and character (Zeidler, 2014; Zeidler et al., 2014; Zeidler & Sadler, 2023; Zeidler et al., 2005). In doing so, this framework intentionally attends to the kinds of normative factors, such as moral motivations, personal values, ethic of care, or other social milieu, that are often overlooked in more traditional approaches to science teaching which tend to privilege scientific reasoning devoid of such contextualized considerations. Instead of only providing a context for science content or simply pointing out ethical dilemmas, SSI instruction uses a well-designed theoretical framework to capitalize on the pedagogical power of controversial issues to stimulate emotional growth, as well as moral and ethical development (Sadler et al., 2007; Zeidler & Kahn, 2014; Zeidler et al., 2005). When SSI is well designed, students can address content knowledge, nature of science, and epistemological reasoning while investigating contentious issues (Fowler et al., 2009) through discourse, research, and critical analysis of the problem (Zeidler & Kahn, 2014). This process simulates both how scientific inquiry is conducted and provides opportunities to develop the skills necessary to become a scientifically literate contributor to society.

SSI instruction is situated within relevant, often ill structured, real-world scientific contexts understandable to students through pedagogical facilitation of key strategies from the teacher (Zeidler et al., 2011; Zeidler & Kahn, 2014). SSI instruction includes confronting students with personally meaningful contentious issues and helping them to develop and contemplate multiple sophisticated viewpoints while weighing scientific evidence. Concurrently, students must evaluate normative factors associated with the issue including the social, moral, and ethical implications associated with proposed solutions (Zeidler et al., 2005). Furthermore, students argue, discuss and debate while justifying their reasoning and decision-making regarding the SSI. The proper immersion into an SSI can generate cognitive and moral dissonance as students consider their existing views side-by-side with the perspectives of others regarding those issues (Fowler et al., 2009). To resolve these internal conflicts, students must think reflexively and consider their biases, misconceptions, and emotions. As students engage in the contentious issues, they develop a deeper understanding of the science content, as well as effective communication skills through collaborative problem solving, discussion, and debate (Kahn & Zeidler, 2016). This is accomplished through a series of explicit pedagogical decisions made by the teacher to provide opportunities to consider, analyze, and synthesize various forms of knowledge.

Review of the literature

Socioscientific issues in methods courses

The inclusion of SSI in science methods courses is an area of research that has become more common throughout the last decade. Researchers around the world have found leveraging a methods course to engage future teachers with SSI to be valuable in tackling some of the overarching concerns within science instruction. One approach to utilizing SSI in methods courses is through the analysis, modification, and/or development of curricula. Pre- and in-service teachers in K-12 classrooms are inundated with resources of varying quality, ranging from district-based curricula to lessons available on popular websites such as Teachers Pay Teachers or Pinterest. Developing preservice teachers' ability to think critically about these resources is crucial in their preparation for facilitating high-quality science instruction in their classrooms. In a study with secondary preservice teachers, Borgerding and Dagistan (2018) had participants analyze state and district mandated curricula for opportunities to incorporate controversial and SSI. Through this process the researchers revealed some misperceptions concerning what is considered SSI as well as anxieties concerning how parents and students would respond to the incorporation of controversial and SSI within mandated curricula. In the elementary context Forbes and Davis (2008) provided opportunities for preservice teachers to take a science lesson from existing curricula and modify it to include alignment with the SSI framework. By taking them through the process of analyzing an existing lesson and modifying it, the preservice teachers were not only able to identify the lack of rigor in the existing lesson but were able to develop the skills to build upon an existing foundational lesson to improve the quality. The researchers' found that when the preservice teachers modified the lesson for SSI, the science content was made more relevant to student lives and the real world. In another study by Macalalag et al. (2020), elementary educators enrolled in a STEM methods course were introduced to SSI by learning to engage in scientific discourse through various perspectives. Once they built their understanding of SSI through this lens, the educators were tasks with exploring the Engineering is Elementary (EiE) curricula to identify lessons easily aligned with an SSI. Once they built a collection of appropriate lessons, the teachers designed units and lessons that incorporated the EiE curricula to engage their students with environmental-based SSI. Through this process the participants recognized the value of connecting science content to the lives of their students.

Another approach to modifying lessons within methods courses is the incorporation of multimodal media as it relates to SSI. Aydın et al. (2019) worked with elementary preservice teachers on their abilities to develop infographics for SSI to be used in their future elementary classrooms. After formal preparation in the development of infographics, preservice teachers were assessed on their ability to communicate information about different SSI through their media and data on their views about the process were collected. Findings revealed the preservice teachers struggled with the process at first but ended the experience seeing the usefulness of utilizing infographics for communicating about SSI with students. In another study, media was used to gain an understanding of how primary preservice teachers viewed the controversial issue of mining in the Amazon. In their study, researchers Cebrián-Robles et al. (2021) provided participants with an activist video about the issue. The preservice teachers were then responsible for analyzing the video by annotating where they identified the problem and some possible solutions to the issue presented. Researchers used this data to identify the common problem being linked to environmental concerns as well as the solutions proposed by the preservice teachers leaning more toward creating awareness rather than an actual resolution. In each of these studies, the researchers were able to leverage media to gain an understanding of what their preservice teachers viewed as important concerning SSI. Having knowledge of preservice teachers' views is a critical component to understanding how to prepare them for SSI-based instruction.

Rather than focusing on modifying existing plans, some researchers have provided opportunities for preservice teachers to write their own SSI lesson plans. For instance Kara (2012) had secondary biology education preservice teachers select concepts from mandated curricula and develop SSI-based lessons to microteach to their peers. Through the process of developing and teaching these SSI lessons, the researcher found the participants to have positive feelings toward the importance of modifying curricula to teach SSI. In another study Lee (2022) asked preservice teachers who had majors in specific science disciplines (i.e., biology, chemistry, etc.) to create their own SSI lessons using frameworks identified by Sadler (2011). Through this work Lee identified secondary preservice teachers to struggle with balancing an emphasis on science content and social implications. Alternatively, when Newton and Kinskey (2021) had elementary preservice teachers write SSI lesson plans, the challenge was incorporating science content with a hands-on activity.

Socioscientific issues in content courses

A less studied approach to exposing TCs to SSI instruction is through science content courses. Science content courses differ from science methods courses in that the primary goals for content courses are to develop conceptual understanding of science concepts and practices. In comparison, other science methods courses often focus on pedagogical practices and implementation of learning theories and use sciences concepts as context to demonstrate theories and practices.

While most literature on TCs' exposure to SSI instruction appears to either focus on methods courses, special topics courses intended to introduce novel teaching approaches (see Karışan et al., 2018; Yerdelen et al., 2018), those within the context of a content course often do not explicitly emphasize SSI pedagogical practice. For example Betul-Cebesoy and Chang-Rundgren (2023) exposed TCs to controversial issues after a seven-week unit introducing genetic and biotechnology, instead of embedding the content within the controversial issue, as is considered best practice by prominent SSI researchers (i.e., Sadler, 2011). Additionally, Betul-Cebesoy and Chang-Rundgren (2023) were more interested in how the TCs reasoned about the issue rather than how to use SSI in their future classrooms.

An exception to the practice of separating content from the controversial issue within content course contexts is illustrated in a study of TCs enrolled in an environmental science course that used wolf management in California as an SSI to teach ecology and develop socioscientific perspective taking (SSPT) (Newton & Zeidler, 2020). As part of the intervention, the 33 students engaged in forced perspective reading and writing activities where they were required to read and write about the issue from the perspective of a stakeholder that was randomly assigned. The findings indicated that the TCs demonstrated an etic/emic shift and were able to develop a more advanced understanding of the issue because they were able to consider the perspectives of stakeholders with perspectives different than their own. However, similar to the previously mentioned study, this study did not provide any insight regarding the TCs' ideas about using SSI in their future classrooms. Additionally, Newton et al. (2023) examined the use of immersive virtual reality fieldtrips using virtual reality headsets in a science content course for preservice teachers to consider the mitigation of and resiliency to climate change on the Outer Banks of North Carolina, USA. Analysis of the data indicated that students were highly engaged with the issue and developed a more sophisticated understanding of the issue. What remains unclear is the extent, if any, that engaging in SSI in science content courses influences whether TCs plan to use SSI instruction in their classrooms.

Purpose and research questions

Preparing TCs to facilitate science instruction that is relevant and meaningful to their students' lives is a notion that continues to be communicated in reform documents in the United States (e.g. National Academies of Sciences, Engineering, and Medicine, 2021; National Research Council [NRC], 2012). While SSI-based instruction meets this need, empirical evidence has suggested teachers have a reluctance to enact SSI-based instruction, particularly at the elementary level (Borgerding & Dagistan, 2018). If science education researchers understand how the preparation of SSI-based instruction influences these views, there may be promise to alleviate some concerns regarding the enactment of SSI in the classroom. Therefore, we aimed to further explore the different approaches to exposing preservice teachers to SSI-based instruction through a content course and a methods course. The research questions that guided this study are:

1. How do TCs view SSI-based instruction before and after engaging with SSI during a science methods course?
2. How do TCs view SSI-based instruction before and after engaging with SSI during a science content course?
3. To what extent do the unique attributes of the science methods and content course appear in TCs' views of SSI-based instruction?

Context

Our decision to explore both an elementary undergraduate science methods course and a secondary undergraduate science content course stems from our interest in understanding how views concerning the same pedagogical approach (SSI) are influenced by the nuances of required courses for both elementary and secondary preservice teachers. Researchers who focus their work on preservice teacher development with SSI argue that experience engaging with SSI-based instruction provides opportunities for future teachers to develop the skills necessary to facilitate SSI with their own students (Linhares & Reis, 2018). This approach to teaching science is beneficial due to the nature of scientific literacy skills K-12 students develop while learning science through an SSI approach. While discussed in more detail below, generally, the TC in the methods course first examined the theoretical underpinnings of SSI instruction from a teacher perspective, including how SSI aligns with inquiry instruction and teaching standards, and then engaged with SSI through the student lens as they grappled with content related to the issue of using pesticides on local farms. The Earth science course, on the other hand, first engaged with SSI instruction from a student's perspective where the TC participated in an SSI unit related to climate change and barrier islands. Upon completion of the unit, the instructor explicitly dissected the unit to discuss how it aligned with the SSI Framework and accepted learning theories. Additionally, TC in the methods course had field experiences in classrooms as part of their training, while the TC in the Earth science class did not. The results from this study will inform teacher educators who are seeking to support TCs throughout their teacher preparation program.

Methodology

To answer the research questions, we implemented a multiple case study design in which we were able to gain an in-depth understanding of each course context (Stake, 1995; Thomas, 2021). Quantitative and qualitative data were collected in a pre-post format concurrently (Greene, 2007) and served as a supportive way to triangulate TCs' views concerning SSI-based instruction. The data that were collected informed our understanding of how each case, the science methods and Earth science content course, may have influenced TCs' views of SSI-based instruction.

Data collection

Pre- and post-surveys

TC participants in the study responded to a modified version of Özden's (2015) Likert-type survey, which was organized by three main constructs: SSI and student engagement; SSI and teacher effectiveness; and SSI in the curriculum. Our modified version included 17 statements, both Likert-type and open-ended questions, to which the TCs responded with their level of agreement along with a written response to explain their thinking. Another modification we made to the survey included adding grade level bands: elementary, middle, and high school. The TCs enrolled in the science methods (n = 34) and content (n = 9) courses were all earning a teaching certificate in either early childhood through grade 6 (EC-6) or middle grades/secondary instruction. Therefore, we were interested in their views of SSI-based instruction related to each construct in grade level bands so we could compare how their views changed with consideration to grade level appropriateness and SSI. The survey was used to identify how, if at all, TCs' views of SSI shifted throughout the semester.

The first question in the survey was intended to capture how the TCs felt about the use of controversial issues in science. The second set of statements related to TCs' views related to student engagement. The third set related to TCs' views of SSI and teacher effectiveness. The fourth set was related to SSI and curriculum. The final question was only provided in the post course survey and asked candidates how, if at all, the course influenced their views of SSI-based instruction. When revising the survey, we did make the decision to change the language from "SSI" to "controversial issues" due to the lack of TCs background knowledge about SSI. Since "socioscientific issues" are controversial issues that are facilitated through a specific framework, we use these terms interchangeably throughout the findings section.

Data analysis

The mean for each Likert item was calculated for both the pre- and post-SSI experience. The difference between the means was then calculated and reported in the tables below. Since the scale for the Likert-type responses ranged from 4 = Strongly Agree and 1 = Strongly Disagree, a positive difference in means represents a shift toward agreeing while a negative difference in means represents a shift toward disagreeing. Any items that were negatively worded were reverse scored to accurately reflect students' responses.

The qualitative responses on the survey were coded using a two-coding cycle approach (Saldaña, 2009). Each researcher first engaged in an open coding system in which we individually coded using inductive descriptive codes to identify the general information the TC was communicating. After this initial stage of coding, we met and compared our codes. Due to the concise nature of the responses, we were able to reach 100% agreement on the codes. Once we reached agreement, we divided the data by course context (methods and content) and identified the frequencies of each code. During our data analysis, we used the quantitative data to help make sense of the findings related to the qualitative data. For instance, if we noticed a high frequency of TCs expressing that SSI were not appropriate for elementary children, we went back to the quantitative data to see if the descriptive statistics represented this same trend. Using the quantitative data as a check for the qualitative data allowed us to feel more confident in our findings.

Findings

To capture the essence of our goal for this work, which is to gain an understanding of how the presentation of SSI through different course contexts influences TCs' views of SSI, our findings are organized by each case (science methods course and Earth science content course). Within the presentation of each case, we include details of our course context, including relevant modules and course objectives, as well as a discussion of how the results of our survey data may be informed by how we facilitated SSI in our courses. Since our goal was to emphasize course context, we do not present the data by TC, and instead present trends within our course contexts from pre to post.

Case number 1: science methods course

Background

The science methods course was taught by researcher 1 and held on the main campus at a university in the southwestern region of the United States. The course was a weekly, 3-hour class that met for 15 weeks during the spring semester. All TCs in the course were in their final year of an undergraduate teacher preparation program seeking teacher certification in early childhood through grade 6. While enrolled in the science methods course, the TCs were also enrolled in three other courses and completing a field experience that required them to report to an elementary classroom three full days per week. Prior to enrolling in the science methods course, candidates were expected to have had one science content course as a component of their prerequisite requirements. To the best of the researcher's knowledge, the TCs had not been exposed to the SSI framework or to instruction that included SSI in any capacity. When the TCs completed the pre-course SSI survey, they had not read any assigned material concerning SSI.

Course layout

The learning goals associated with the science methods course were designed to build elementary TCs' pedagogical understanding of how to facilitate science to elementary children in grades K-6 (1. Explores the history and nature of science and identifies the role of science in contemporary classrooms; 2. Manages classroom, field, and laboratory activities to ensure the safety of all students; 3. Uses the correct tools, materials, equipment, and technologies in science instruction; 4. Describes the processes of science inquiry and explains the role of inquiry in science instruction 5. Has theoretical and practical knowledge about teaching science and about how students learn science; 6. Develops varied and appropriate assessments to monitor science learning; and 7. Appreciates how science affects the daily lives of students and how science interacts with and influences the real world). The researcher designed the course in a way they hoped their TCs will approach teaching their own elementary students: First with building foundational understanding of nature of science (NOS) and science process skills, then moving into inquiry-based learning, and ending the course with extending and refining inquiry-based approaches with interdisciplinary science instruction through SSI (ELA and SS) and STEM (Math).

Each module is planned in a way that should help more advanced pedagogical approaches (SSI and STEM/engineering design) come together. NOS is taught first to help TCs see the "messiness" of science. Specifically, the researcher emphasizes that science does not provide absolute proof and has a tentative and subjective nature. The goal for beginning the semester with NOS, as it relates to SSI, is to help TCs feel comfortable with the subjectivity of science and having different opinions, experience the potential discomfort of this to learn that it's okay for students have different opinions, and that it is acceptable to change your opinion or conclusion as new evidence is presented.

From NOS the researcher moves to science process skills, which provides the TCs with experiences for facilitating inquiry-based skills necessary to help their students make sense of scientific investigations they will complete when learning the content related to SSI. Inquiry-based learning processes are next to help the TCs see how to facilitate student-centered science instruction. This is important with SSI-based instruction since students should have control over their views, beliefs, and interpretation of information. Interdisciplinary science modules are included to help TCs see how to include English language arts, social studies, and math into their science instruction. SSI is interdisciplinary by nature (Zeidler & Kahn, 2014) and provides a context for teaching science if allocated science time is not substantial. The explicit SSI module is designed to expose the TCs to each aspect of SSI and allow them to see how this could be enacted in the classroom and what it would look like. After the SSI module the TCs learn about STEM-based pedagogies, with an emphasis on career and real-world contexts, where a controversial issue is related to an engineering design task. This provides another context in which the SSI framework could be facilitated in the elementary or early middle grades classroom.

Explicit SSI module

In this methods course, the 5E inquiry-based model (engage, explore, explain, elaborate, evaluate) was applied to facilitate the SSI-based module. The issue that was used as a model for this pedagogical approach focused on the use of pesticides on crops. Since a major component of the methods course is ensuring the TCs understand how to use state-based science standards to drive instruction, the engage, explore, and explain focused on a fourth-grade standard about food chains and food webs. Through the dissection of an owl pellet, the TCs reviewed science content related to how energy moves through an ecosystem and the implications of changes within that ecosystem on natural food sources. After modeling how to build this foundational knowledge using the first three Es of the 5e model, the researcher introduced the SSI with the following question: Should farmers in our state continue to use pesticides known to contain harmful chemicals?

The elaborate portion opened with having the TCs write their opinion-based response to this question in their science notebook. The researcher then modeled how to incorporate English language arts (ELA) standards aligned with research and writing to have the TCs explore resources that explained political implications related to the issue (what the USDA identifies as harmful chemicals and the house/senate bills related to restricting usage) and provide different perspectives concerning the issue (i.e. farmers who have lost their crops due to invasive pests; farm workers who have gone on strike based on concerns for their health from exposure to pesticides). As the TCs read articles and watched news stories/interviews from the different stakeholders, they were expected to take notes on the common graphic organizer used to compare, a T-Chart: one side in support of farmers continuing the use of pesticides and the other side against farmers continuing the use of pesticides. Once they engaged in research and notetaking, the TCs were assigned a position and divided up into their associated group. The two groups worked together using a provided claim, evidence, and reasoning protocol to prepare for a class debate concerning the issue. They were expected to not only consider the views of the stakeholders, but also demonstrate in their arguments their ability to apply the science content they learned about early in the lesson.

This module lasted two six-hour class periods toward the end of the semester. There was only one module that followed this and that was the STEM module, where candidates were exposed to engineering design activities related to a different SSI: finding a solution to an oil spill that resulted from offshore oil drilling. The two final modules were meant to serve as culminating activities that applied concepts from the entire semester (NOS, inquiry, etc.). Upon completion of the semester, the candidates took the post-course survey, which focused on SSI-based instruction.

TCs' views of general SSI-based instruction

The first question of the survey asked the TCs to consider, in general, their views of controversial issues in science education by asking: *How would you describe controversial issues as they relate to science instruction?*

When exploring the data of the pre- and post-course responses related to general views of controversial issues in science, TCs enrolled in the methods course demonstrated shifts in their ability to respond to the question (the frequency for the code *unsure* decreased from 13 to 5) and to do so from a more sophisticated understanding of how the SSI framework relates to pedagogical approaches taught in the methods course.

In the pre-course survey, the three most frequent codes were: *unsure* (13), *misperceptions of SSI* (9), *and benefits to student learning* (7). Responses associated with the code *unsure* were often self-expressed by the

TC, rather than interpreted by the researchers, as with the following example response from TC #1: "I am not really sure." or TC #9: "I don't know." Responses that were coded as *misperceptions* of SSI revealed the TCs' lack of understanding with foundational SSI concepts, such as with TC #10 and their understanding NOS: "Science is factual until unproven," or when a response identified controversial sociocultural topics, not controversial issues for teaching, such as with TC #33: "Emotional… Ex: How the earth was formed." Candidate responses were diverse in how they expressed a view that aligned with the code *benefits to student learning*. For example, TC #4 stated, "If the controversial issue has to do with the natural world. I believe it should be included in the curriculum for better understanding of the natural world around them." This was coded as benefits to student learning due to the identification that incorporating controversial issues in science could help students gain a deeper understanding of the world around them. Another example comes from TC #38 who considers how controversial issues may help students relate science to the real world: "I can relate real world topics to science topics. In a sense, they go hand in hand. I think teaching both together are important. It will help relate real world matters to students."

In the post-course survey, after the TCs had experienced SSI during the methods course, new descriptive codes emerged: *unbiased/objective*, *perspective taking*, *challenging*, *student engagement/interest*, and *nature of science*. We found it notable to mention these new additions because the codes highlight the candidates' deeper understanding of SSI. An example of a TC whose response demonstrates a nuanced understanding of SSI, is TC #41: "They [controversial issues] should be looked at, as they relate to science they are perfect for scientific inquiry." This response not only identifies that controversial issues should be taught in science, but also includes an understanding of pedagogical implications of teaching SSI through inquiry-based instruction. Additionally, TC #39 expressed, "I feel these are the heart of science, there is nothing better than for students to discuss an issue that has to complete opposite sides and both people have scientific proof to back up their statement." This response suggests a deeper understanding of specific components of the SSI framework, such as perspective taking.

TCs' views related to student abilities

The pre- and post-means for the methods course are presented in Table 1 and organized by grade level bands.

In the Likert-type survey related to student engagement with SSI, the only statement in which the TCs shifted toward disagreeing was the statement "Elementary students are not mature enough to engage with controversial issues in science." This demonstrates a slight change in views related to their overall beliefs related to elementary student abilities to engage with SSI, indicating the TC favored the idea that elementary students were mature enough to engage with controversial issues. The quantitative data also demonstrates that TCs in the methods course consistently agreed with the other statements related to views of elementary, middle, and high school students and how SSI would influence their ability to learn science content and stimulate interest in science.

The qualitative data, which was used to gain a better understanding of the Likert-type responses, requested the TCs explain the reason for ranking the statements the way they did. These short response answers were coded to understand the TCs' views of SSI influences on student interest/engagement. The three most frequent codes that emerged in the pre-course survey were:

Table 1 Candidate views related to student engagement

Survey statement	Pre-course survey mean	Post-course survey mean	Difference in means
Academically successful students would be more interested in controversial issues in science than students who struggle academically	2.37	2.51	0.14
Elementary students are not mature enough to engage with controversial issues in science	2.06	2	−0.06
Middle school students are not mature enough to engage with in controversial issues in science	1.7	1.71	0.01
High school students are not mature enough to engage with controversial issues in science	1.48	1.53	0.05
Elementary students can learn science content better by engaging with controversial issues	2.75	2.88	0.13
Middle grades students can learn science content better by engaging with controversial issues	2.93	3.04	0.11
High school students can learn science content better by engaging with controversial issues	3.11	3.2	0.09
Integrating controversial issues would increase elementary students' interest in science	2.71	2.91	0.2
Integrating controversial issues would increase middle grades students' interest in science	2.88	3.17	0.29
Integrating controversial issues would increase high school students' interest in science	3.02	3.2	0.18

student interest/engagement (9), *unnecessary/difficult* (8), *and appropriateness* (6). The most frequent codes that emerged in the post-course survey were *student interest/engagement* (13), *real-world connections* (8), and *appropriateness* (7). While the code of *student interest/engagement* remained high in the pre and post survey, evidence related to this code was more robust in the post-course survey. For instance, in the pre-course survey, TC #13 stated, "I think controversial issues will make any student more interested. I personally would not be interested if there wasn't something intriguing." In the post course survey, a response that was provided the same code was from TC #7, "I think that integrating controversial issues shows students how the information is relevant to the world and their own lives. Often, they may already have an opinion on some of these issues and may be more engaged in the lesson." The second quote also provides evidence related to another high frequency code in the post-course survey, *real world connections*.

The code *appropriateness* was also high frequency in both pre- and post-course data. The responses that received this code varied from the TC stating SSI-based instruction was appropriate or inappropriate for students in general to referencing specific grade or age level groups for which they viewed SSI-based instruction appropriate for. An example of a TC who explicitly mentions that older students would be more engaged in SSI-based instruction comes from TC #21, "I believe the older students get, these controversial issues will intrigue and drive their learning in science." From this response, we interpret their views to indicate younger children might not be as invested in this pedagogical approach. In contrast, the post-course survey response from TC #8 states,

> I think that students of all ages can benefit from the integration of controversial issues into science instruction. Depending on your classroom, teachers can discern which issues might be more difficult for students to engage in, but I don't believe age should be a factor in whether or not to engage students in those discussions.

It is evidence based on this response that TC#8 views SSI-based instruction appropriate for all students.

The most frequent code in the pre- and post-survey data, *student interest/engagement*, aligns with the results from the quantitative data concerning statements related to increasing student interest in each grade level band. The qualitative data also provided more in-depth understanding of the TCs' views concerning survey statements related to maturity levels of students, as they utilize the short responses to clarify young children grasping the importance of SSI and considerations for the controversial topics taught by the teacher.

TCs' views related to teacher effectiveness

With the questions related to teacher effectiveness, we were interested in gaining an understanding of the TCs views concerning how equipped teachers in elementary, middle, and high school grade levels were to facilitate SSI-based instruction. The pre- and post-survey means and the difference in means for each of the pre-post course survey statements are presented in Table 2.

Trends in the quantitative data indicate the TCs in the science methods course strengthened their views that teachers in all grade levels were unequipped to facilitate SSI in the classroom. When considering teachers' abilities to answer questions about controversial issues, TCs shifted toward a view that middle grades teachers did

Table 2 Means associated with TCs' views of teacher effectiveness

Survey statement	Pre-course survey mean	Post-course survey mean	Difference in means
Elementary teachers do not have the skills necessary to incorporate controversial issues in science	1.86	1.91	0.05
Middle grades teachers do not have the skills necessary to incorporate controversial issues in science	1.77	1.8	0.03
High school teachers do not have the skills necessary to incorporate controversial issues in science	1.73	1.75	0.02
Elementary teachers can easily answer questions about controversial issues in science	2.31	2.4	0.09
Middle grades teachers can easily answer questions about controversial issues in science	2.46	2.35	−0.11
High school teachers can easily answer questions about controversial issues in science	2.51	2.44	0.11
Elementary teachers should be trained in how to incorporate controversial issues in science	3.08	3.28	0.2
Middle grades teachers should be trained in how to incorporate controversial issues in science	3.13	3.35	0.22
High school teachers should be trained in how to incorporate controversial issues in science	3.15	3.37	0.22

not have the abilities to answer questions while elementary and high school teachers did. In the final series of questions, the quantitative data represents a shift that teachers in all grade levels should be trained in how to incorporate controversial issues in science.

In the qualitative data, the difference between the most frequent code, *training necessary* (21) and next frequent code, *pedagogical considerations* (5), was dramatic with overwhelmingly favorable mention of teachers needing training in SSI. This same trend was observed in the post-course survey with the most frequent code being *training necessary* (26) and the next frequent code *pedagogical considerations* (9). From this data, we were able to gain clarification on the trends in the quantitative data related to TCs' views, specifically concerning the stronger shift toward believing teachers of all levels were not capable of engaging students in SSI as we recognized an emphasis on a need for teacher training. For example, TC #44 wrote in the pre-course survey, "The more trained you are to incorporating these issues, the better you will be at teaching it to students" and TC #29 wrote in the post course survey, "I think teachers should be trained on how to discuss things with their students to make all feel comfortable." In both examples, the TCs point to specific reasons for increased training including increased effectiveness and creating an inclusive environment for all learners.

The statements that resulted in a code of pedagogical considerations included curriculum-based considerations or instructional approaches related to SSI. In the pre-course survey, TC #20 explained, "Teachers are expected to deliver an education to students based on topics outlined by [the state], often times controversial topics are not found in the [state standards]; therefore, they should not be taught." An example of a pre-course survey response that focuses on instructional approaches may be found from TC #14's response,

> I feel that as teachers we are taught to avoid controversial topics in the classroom. I think that this avoidance is a large reason for the repetition of these issues and that as educators we should focus more time on trying to learn how to have productive and controversial discussions in our classrooms.

Despite acknowledging obstacles that impede implementing SSI instruction, this TC recognized the value of using SSI instruction when they mentioned leveraging SSI to improve student discussions in the classroom. A post-course survey quote from TC #8 includes the codes for *training* and *pedagogical considerations*:

> Teachers at any level should be well trained to incorporate controversial issues in science. Students need to understand how science relates to their own world and controversial issues is a way teachers can introduce how Science is involved in every part of our lives.

In the methods course, the mention of connecting science to the real world was explicitly emphasized as a benefit to the SSI instructional approach, which is why it was coded as a *pedagogical consideration*.

Within this construct of the survey, there were strong connections between the quantitative and qualitative data. As we look at trends in the quantitative data, we note the overall view that teachers at any level do not have the skills necessary to facilitate SSI. This is consistent with the qualitative data suggesting teachers need additional training in SSI-based pedagogies.

TCs' views related to SSI curriculum

Survey questions related to SSI curriculum provided us an opportunity to understand how the TCs viewed the appropriateness of SSI in various disciplines (Table 3).

In the quantitative data there was a shift toward agreeing with each of the statements. The statements are positively framed toward incorporating SSI in every grade level. We note the largest shift occurred in statements related to the ease with which controversial issues can be incorporated into elementary curriculum.

Table 3 Means associated with TCs' views related to SSI curriculum

Survey statement	Pre-course survey mean	Post-course survey mean	Difference in means
Controversial issues are more appropriate to be incorporated into science than any other subject area	2.17	2.37	0.2
Controversial issues should be incorporated into elementary science curriculum	2.64	2.95	0.31
Controversial issues should be incorporated into middle grades science curriculum	2.84	3.08	0.24
Controversial issues should be incorporated into high school science curriculum	3.04	3.24	0.2
Controversial issues are easy to incorporate into elementary science curriculum	2.15	2.51	0.36
Controversial issues are easy to incorporate into middle grades science curriculum	2.42	2.64	0.22
Controversial issues are easy to incorporate into high school science curriculum	2.55	2.8	0.25

The qualitative data was analyzed to better understand the patterns noticed in the quantitative data related to TCs' views of SSI in the curriculum. The two most frequent codes in the pre-course survey were: *difficult to incorporate* (16) and *discipline specific* (7). In the post-course survey, the two most frequent codes were: *incorporate into any subject* (13) and *difficult to incorporate* (7). The code difficult to incorporate was most frequent in both the pre-and post-course survey, with the number of candidates who mentioned the difficulty incorporating SSI in the curricula slightly decreasing from 16 to 7. In the pre-course survey TC #32 explains why they believe teaching SSI is difficult: "I feel like controversial topics need to be discussed, but it is so hard to because we don't have the proper resources and training." Similarly, in the post-course response, TC #34 references a lack of training as the reason for difficulty incorporating SSI: "I do not think that it would be difficult to incorporate controversial issues in the classroom with teacher that are given the proper knowledge and training to appropriately provide that information in the classroom." It is evident from the student exemplars above that the qualitative data aligns with the quantitative data to indicate the TC more strongly agreed with implementing SSI instruction in any grade level.

Responses that received the second most common code in the pre-course survey, *discipline specific,* were also consistent with the quantitative data as they emphasized how science was the best subject for the incorporation of SSI. TC #14's pre-course response explains how they believe most controversial issues align with science topics, which makes science the best subject for the incorporation of SSI: "I think that science especially is an important subject to talk about controversial issues as most of the issues are society and can fall under the umbrella of science." Alternatively, the most frequent code in the post-course survey included candidate responses that explained how SSI would be *appropriate in all subject areas*. An example of this type of response may be found reading TC #8: "I think controversial issues can be appropriate for any subject because all subjects can have real-world connections. I don't think that integrating controversial issues into science curriculum will be an easy task, but I do think it is possible with some guidance and planning time." The phrases in the survey emphasized SSI in science curriculum, which somewhat limits what we can learn about TC's views related to SSI in the curriculum. The qualitative data provided a venue for the TC's to expand on their thinking and demonstrate how they view SSI to be appropriate for integration into other subject areas.

While we noted the shift in the quantitative data toward agreeing that SSI should be incorporated into each grade level band, we also note the concerns with incorporating SSI expressed within the qualitative data. In the open-ended responses, the TCs further elaborated that while they believed SSI should be incorporated into curricula, it will be difficult to do.

Summary of methods course findings

Overall, the TCs in the methods course demonstrated more nuanced understandings for the facilitation of SSI after engaging with the modules throughout the semester. The data demonstrates a collective shift toward deeper pedagogical considerations related to SSI (i.e., critical thinking, real-world connections) as well as a greater appreciation for leveraging disciplines other than science as the venue for incorporating SSI-based pedagogies, such as controversial issues. Additionally, we noted consistencies regarding concerns or potential difficulties with teaching SSI but acknowledge the reason behind the difficulties demonstrates a deep understanding of practice-based challenges (i.e., access to resources) rather than superficial notes that are non-descriptive.

Case number 2: the science content course

Background

The science content course was taught in-person on campus at a university in the mid-Atlantic region of the United States. The course met twice a week, each session being one hour and 15 minutes, during the spring semester. The TCs were all in their third year of undergraduate coursework and planned to teach secondary science upon graduation; however these TC specialized in a variety of science disciplines none of which included Earth science. There was no internship component to this course, however, it was possible that students were observing teachers as part of other education courses. The TCs' prior course work was focused on science, their exposure to education courses began in their third year. Prior to this course, none of the students had been exposed to SSI.

Course layout

The learning goals of the content course were designed to focus primarily on Earth science content knowledge and, to a lesser extent, teaching pedagogy (1. Use Earth and space science content to plan age-appropriate investigations and experiences for middle and high school students; 2. Develop activities for countering common student misconceptions in Earth and space science; 3. Construct explanations based on evidence for how geoscience processes have changed Earth's surface and for how the geologic time scale is used to organize Earth's history; 4. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of past plate motions; 5. Develop models to describe the cycling of Earth's materials (including but not limited to water) and the flow of energy that drives these processes; 6. Collect and analyze data to predict weather conditions; 7. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates; 8. Explain how the availability of natural resources, occurrence of natural hazards, and changes in climate influence human activity; 9. Identify human impacts on Earth systems, in particular, factors that have caused the rise in global temperature over the past century). The instructor elected to utilize inquiry approaches to teach content, as the state in which the university resides expects science teachers to implement inquiry instruction. Consistent with a social-constructivist approach, TCs first engaged with content as students to develop a shared experience and co-construct knowledge, then deconstructed their experiences with the instructor to discuss the pedagogical approaches and decisions made. The course began with an SSI unit focusing on climate change. To be consistent with the SSI literature and make the content personally relevant to the TCs (Zeidler et al., 2022), the contentious issue focused on the impact and response to climate change on barrier islands near campus. The TCs were introduced to the issue at the beginning of the unit via a series of videos focusing on climate change on the islands that were produced by a local newspaper. After watching the videos, the TCs' initial thoughts were elicited to allow the instructor to identify prior knowledge and misconceptions related to climate change. The instructor then described the culminating event for the unit, a town hall-style meeting where groups of students presented recommendations for the barrier islands from a perspective randomly assigned by the instructor.

The next four weeks were designed to provide the TCs with scaffolded experiences that allowed them to develop the science knowledge and skills, along with the reasoning skills to effectively analyze the issue. This process included laboratory investigations with debriefing sessions to explicitly connect the investigations to the issue. The groups were also given time in class to research the sociocultural aspects of the issue. The instructor met with groups individually to discuss potential resources to facilitate skepticism/potential bias, perspective taking, and generate new questions to explore. Finally, each group of TCs presented their recommendation to the class and group of their peers who acted as a town council. After each group presented and addressed questions from the class, the town council were sequestered and made a recommendation, based on the presentations, for how the state should manage the barrier islands. The week after the town hall consisted of the instructor introducing the SSI Framework and making connections to the TCs' previous SSI experience.

The remainder of the semester consisted of the TCs investigating other earth science concepts using other inquiry-based approaches (e.g., Argument-Driven Inquiry, 5E model). As with the SSI instruction, the TCs first experienced the instruction as students then deconstructed their experiences to examine the pedagogical decisions and implications associated with each approach.

Findings and analysis for case two

What follows is both the quantitative data (i.e., means and changes in means) for each Likert-type statement on the survey, as well as qualitative data. When considering the data, especially the frequencies of the qualitative codes, it should be noted that one student repeatedly stated a concern for the maturity of elementary students to engage with SSI. As a result, the frequencies indicate a stronger sentiment toward young students' ability to engage with SSI that is not reflected in the quantitative data where each TC's response is represented one time per Likert item.

TCs' views of general SSI-based instruction

TC's views on SSI instruction were wide ranging prior to engaging with SSI. The only qualitative code that was repeated at this time was the *prioritization of scientific knowledge when teaching SSI*, meaning that scientific knowledge was privileged compared with other types of knowledge. However, after instruction, the responses clustered around four codes: *perspective taking, sociocultural connections associated with the issue, real-world connections of the content*, and *opportunities to improve decision making*. This change indicates that not only were TCs able to recognize the complexity of SSI that extends beyond scientific content knowledge, but also that the skills SSI can develop the requisite skills to resolve complex issues.

TCs' views related to student abilities

The pre- and post-means for the methods course are presented in Table 4 and organized by grade level bands. The quantitative data indicates a generally positive change in TCs' feelings about students' ability and engaging in SSI. After engaging in SSI first as students, the TCs indicated that they believed all grade level bands and academic ability levels would be positively impacted by engaging in SSI instruction. Prior to the SSI instruction the most frequent qualitative responses focused on the prioritization of science knowledge (2). While after the instruction, TCs discussed the how SSI helped to understand *different viewpoints and perspectives* (2), *made sociocultural connections with the issue* (2),

Table 4 Candidate views related to student engagement

Survey statement	Pre-course survey mean	Post-course survey mean	Difference in means
Academically successful students would be more interested in controversial issues in science than students who struggle academically	2.50	2.44	−0.06
Elementary students are not mature enough to engage with controversial issues in science	1.88	1.78	−0.10
Middle school students are not mature enough to engage with in controversial issues in science	1.63	1.68	0.05
High school students are not mature enough to engage with controversial issues in science	1.50	1.44	−0.06
Elementary students can learn science content better by engaging with controversial issues	2.63	2.67	0.04
Middle grades students can learn science content better by engaging with controversial issues	2.88	3.11	0.23
High school students can learn science content better by engaging with controversial issues	3.25	3.33	0.08
Integrating controversial issues would increase elementary students' interest in science	2.63	2.78	0.15
Integrating controversial issues would increase middle grades students' interest in science	3.25	3.44	0.19
Integrating controversial issues would increase high school students' interest in science	3.38	3.56	0.18

acknowledged the real-world connections between science and the issue (2), and that *SSI instruction facilitated informed decision-making* (2).

The qualitative data provides more insight as to why the TCs in the content course believed that SSI would be beneficial for all students. Specifically, after completing the SSI unit themselves, the TCs reported that SSI gave students real-world connections to the science content being studied as well as to sociocultural aspects of the issue. For example, TC (TC) 53 stated, "I think controversial issues are pertinent to science education. Without controversial issues, students have minimal context for the science content knowledge they learn." Likewise, TC 51 offered, "…these issues have factors outside of science that affect them like economics, government, or social implications…" In both statements the TCs allude to value of personally relevant curriculum as well as the inherent complexity of contentious issues.

Furthermore, TC 57 also discussed the connection between SSI instruction and future decision making when they stated,

> Controversial issues relate to science instruction by being able to be a solid relevant example in the classroom for students to make connections to, as well as gain an understanding of issues they may have to face in the future.

In this example, TC 57 not only recognized the connection between science content knowledge and relevant issues, but they also acknowledged the influence SSI instruction can play on developing functional scientific literacy in citizens to make sustainable decisions in the future.

TCs' views related to teacher effectiveness

With the questions related to teacher effectiveness, we were interested in gaining an understanding of how the TCs viewed how equipped teachers in elementary, middle, and high school grade levels were to facilitate SSI-based instruction. The pre- and post-survey means and the difference in means for each of the pre-post course survey statements are presented in Table 5. The results from the quantitative data indicate TC in the content course were more confident that teachers of all grade level bands had the skills necessary for SSI instruction. Despite the reported increased confidence in teachers' ability to teach SSI, TC reported less confidence in teachers' abilities to answer questions related to controversial issues. Finally, TC more strongly agreed that teachers should be trained in SSI instruction after the TC participated in SSI instruction.

The most frequent qualitative responses prior to SSI instruction focused on the *appropriateness of SSI instruction for all ages* (4) and *the real-world connections of science* (2). After the SSI instruction, teaching candidates commented most frequently on *the real-world connections that SSI provides* (3) and how *SSI instruction increases student engagement* (3). These sentiments were unique to the qualitative data as the Likert items did not focus on these aspects of SSI instruction.

Consistent with the quantitative data, the TCs in the content course increased their belief that teachers of all grade bands have the requisite skills for teaching SSI. The first three Likert items, which are negatively worded, indicate that the TCs held strong beliefs in teachers' abilities after the SSI experience. For example, TC 57 offered the following after engaging with SSI:

Table 5 Means associated with TCs' views of teacher effectiveness

Survey statement	Pre-course survey mean	Post-course survey mean	Difference in means
Elementary teachers do not have the skills necessary to incorporate controversial issues in science	2.00	1.78	−0.22
Middle grades teachers do not have the skills necessary to incorporate controversial issues in science	2.00	1.67	−0.33
High school teachers do not have the skills necessary to incorporate controversial issues in science	1.88	1.67	−0.21
Elementary teachers can easily answer questions about controversial issues in science	2.25	2.00	−0.25
Middle grades teachers can easily answer questions about controversial issues in science	2.13	2.00	−0.13
High school teachers can easily answer questions about controversial issues in science	2.38	2.22	−0.16
Elementary teachers should be trained in how to incorporate controversial issues in science	3.25	3.56	0.31
Middle grades teachers should be trained in how to incorporate controversial issues in science	3.38	3.67	0.29
High school teachers should be trained in how to incorporate controversial issues in science	3.50	3.67	0.17

> I feel instructors of all age groups can effectively create science instruction that incorporates controversial issues. They will always be an opportunity to use an issue because issues are always occurring. With the right amount of effort and scientific knowledge a good instructor can relate science to any real-world event.

This statement clearly indicates that the TC was confident in all teachers' ability to effectively implement SSI instruction. Likewise, the TC alludes to the durability of SSI instruction across time, as real-world events occur regularly.

The TC shared similar support regarding the need for all teachers to be trained to implement SSI instruction as witnessed in the final three Likert items in the table below. The quantitative data indicates an increased belief in the need for teachers of all grade bands to be trained in the use of SSI instruction. This sentiment is exemplified in the qualitative data with TC 55's statement,

> I believe that we as teachers should be trained for these types of conversations in the classroom. I feel that because the teachers now have not been properly trained, they cannot teach to the best of their ability and can answer questions easily when they have never taught the subject before.

Statements like TC 55's were the most frequently coded statements in this section of the post-SSI survey, with six TCs alluding to the need for formal training.

TCs' views related to SSI curriculum

Survey questions related to the SSI curriculum provided us an opportunity to understand how the TCs viewed the appropriateness of SSI in various disciplines (Table 6). TCs' initial qualitative responses focused on the *need for teachers to be trained in SSI* (4). After the SSI unit, the TCs continued to emphasize the *need for training* (6) and commented on the *effectiveness of SSI to fit in both the science and social studies curriculum* (4). Consistent with the qualitative data, the quantitative data indicates increased support for the inclusion of SSI instruction in the curriculum, as the post-SSI means for each Likert item was greater than the pre-SSI survey; however, TCs did not overwhelming feel that science was the most appropriate subject to teach SSI, as the post-SSI mean was a 2.44 on the first Likert item in the table.

Table 6 Means associated with TCs' views related to SSI curriculum

Survey statement	Pre-course survey mean	Post-course survey mean	Difference in means
Controversial issues are more appropriate to be incorporated into science than any other subject area	2.25	2.44	0.19
Controversial issues should be incorporated into elementary science curriculum	2.63	3.22	0.59
Controversial issues should be incorporated into middle grades science curriculum	3.13	3.44	0.31
Controversial issues should be incorporated into high school science curriculum	3.38	3.67	0.29
Controversial issues are easy to incorporate into elementary science curriculum	1.75	2.11	0.36
Controversial issues are easy to incorporate into middle grades science curriculum	2.13	2.44	0.31
Controversial issues are easy to incorporate into high school science curriculum	2.63	2.67	0.04

The qualitative data sheds insight into the TCs' thinking on this subject. For example, TC 53 offered the following, "science is the best subject to incorporate controversial issues. History is a close second, but science gives the opportunity to apply content knowledge, critical thinking skills, and group work skills." TC 53 also addressed another common theme in the qualitative data, namely, a concern for the maturity level of younger students. TC 53 stated,

> I think it would be easiest to incorporate controversial issues into a high school classroom because they are most mature. Elementary schoolers may become frightened or upset or even develop more scientific misconceptions than they had before. Elementary schoolers need to focus on observing the natural world and fostering curiosity. They are not ready to tackle controversy.

In this statement, the TC, who aspires to be a high school Biology teacher, has some concerns about elementary students' ability to comprehend complex issues. There are a multitude of reasons why TC 53 might express this level of concern including a lack of teaching experience, having no elementary preparation, or a lack of familiarity with state and national standards for elementary science. As mentioned previously, this concern was a frequently repeated by TC 53 and did influence the frequencies of the qualitative codes.

Summary of content course findings

Analysis of TCs' responses indicate that after completing an SSI Unit on climate change on the Outer Banks of North Carolina, USA they had a more focused understanding of the usefulness of SSI to develop the skills and knowledge to resolve complex issues. Likewise, they believed that SSI was beneficial for all learners, regardless of age and ability level. Furthermore, the TC demonstrated an increased feeling that teachers have the skills necessary to teach SSI, while also indicating a need for more teacher training on SSI implementation. Interestingly, despite this confidence in teachers' ability, the TC felt more strongly that teachers of each grade level band could not answer questions about controversial issues. Conversely, after completing the SSI unit, the TCs did not feel as strongly about science classes being the best place to engage in SSI instruction, which indicates that the TC recognized the interdisciplinary nature that underlies SSI instruction and that other disciplines could effectively initiate SSI instruction and indicates that TC did not privilege scientific knowledge after the SSI experience as much as they did prior to instruction. Finally, there was a clear concern after the SSI unit that elementary age students may not be mature enough to engage with SSI; however, this can be accounted for by considering that this claim was repeated multiple times by the same TC.

Discussion

Analysis of each case reveals valuable insight regarding TC understanding of SSI instruction after engaging in various exposures to SSI. When considered in conjunction, the findings from the cases provide the foundation for a novel approach to developing elementary to secondary teachers' views related to facilitating SSI instruction. Each learning environment allowed TC to develop unique considerations for future SSI instruction. After completing the SSI experience in the methods course, TC were capable of contextualize SSI in terms of classroom implementation, or put another way, from the perspective of a teacher. The TC demonstrated the ability to connect SSI instruction with important aspects of effective science teaching, namely student engagement, to support learners of all ages and abilities (see Chinn & Iordanou, 2023). Additionally, the TC in the methods course were able to connect the use of SSI instruction with the widely accepted notion that interdisciplinary connections are vital to real word science instruction (Johnson & Czerniak, 2023). Finally, the TC in the methods course recognized the need to appropriate resources to support instruction.

The TC who engaged with SSI in the Earth science course, focused on slightly different aspects of SSI teaching and learning. These TC discussed the value of SSI instruction to teach the reasoning and skills requisite to resolve complex issues, while also recognizing the interdisciplinary nature of the issue. Furthermore, the TC in the Earth science course recognized the inclusive nature of SSI instruction to meet the learning needs of a variety of students (Kahn, 2019). Generally, the TC in the content course seemed to consider the impacts of SSI instruction on student learning. It should be noted that they TC in the content course expressed thoughts on teaching SSI that indicated some concerns; namely a lack of explicit training in SSI and the limits of teacher knowledge a given issue. Both of which are reasonable concerns considering that the TC in content course had never been exposed to SSI instruction before and did not have the content knowledge related to climate change. It is encouraging that the TC in the content course recognized the limitations of the teacher because it has been noted elsewhere in the literature (see Presley et al., 2013) that teacher should situate themselves as co-constructors of knowledge and not experts in the issue when teaching SSI. So, while the TC may have viewed their knowledge limitations a negative, recognizing their limitations prepares them to use SSI instruction more effectively in the future.

The findings from the cases indicate that it would be beneficial for teacher preparation programs to expose TC to SSI in multiple learning contexts to develop teachers with a sophisticated understanding of the intricacies of SSI instruction. It is with this in mind that we advocate for a teacher preparation program that provides opportunities for TC to engage with SSI instruction frequently throughout their teacher preparation programs and in course that focus on both science content as well as pedagogy and theory. The cases shown here demonstrate that engaging with SSI instruction and the SSI Framework in a variety of courses with differing objectives allow TC to prioritize different aspects of teaching and learning. When TC experience SSI first as a student they can recognize the need for and development of the socioscientific reasoning (SSR) skills that SSI scholars have identified as necessary to contemplate and resolve contentious issues (Sadler et al., 2007; Zeidler et al., 2019), while also making interdisciplinary connections and feeling engaged with the content. If this type of experience was followed with a methods course like the one described here, TC would then be able to begin to consider the effective implementation of SSI instructions by not only having a deeper understanding of the theory underpinning SSI, but also consider engaging with issues as a student, thus developing learning experiences that best support students as well as anticipating potential areas that require support.

Conclusion and implications

Understanding how undergraduate TCs view SSI instruction within the context of methods and content courses has implications for how teacher preparation programs develop TC who can effectively implement SSI instruction in their future classrooms. The analysis of TC's survey data indicates that both learning contexts provide unique learning experiences that, when viewed collectively, develop a TC with who has a deeper understanding of effective SSI instruction. For example, tying SSI to pedagogical approaches, such as standards-based instruction or inquiry had implications for how methods course students viewed the appropriateness of SSI (i.e., inappropriate if not in the standards). Furthermore, experiences in the methods course allowed TC to anticipate potential conflicts with families and administrators who may be concerned with the controversial nature some SSI present. Finally, because of the methods course, TC began to anticipate the support and resources requisite for effective SSI instruction. Based on the results from this study, we believe that frequent and varied SSI experiences throughout teacher preparation programs will serve to better prepare TC for developing and implementing effective science instruction that moves towards developing a participatory citizenry capable of resolving complex issues. This type of instruction and learning aligns closely with standards like the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013), which has the stated goal of, "preparing students for college, career, and citizenship" (2013, p. 5), while also contextualizing science within the real world.

We are aware that the small sample size of the content course limits this study. For instance, within our findings we found it interesting to note the difference in the quantitative and qualitative data reflecting the views of TCs from the content course with respect to elementary student abilities and elementary curriculum, as the data demonstrated conflicting results. For example, the quantitative data indicates that the TC in the content course agrees that SSI is appropriate for elementary students, but the qualitative data conflicts with this sentiment. It is possible that one TC who repeatedly stated that SSI is not appropriate for elementary students could artificially inflate the frequency of that code, thus providing a false indication that the content course negatively influenced how the TCs conceptualized SSI instruction. While not within the aims of the current study, for researchers interested in generalizing the findings from this study, future studies should consider collecting more data points as well as increasing the sample size.

From this study, we argue for SSI to be incorporated into both science content and methods courses to provide valuable experiences that complement the pedagogical development of future teachers. Empirical studies that expose preservice teachers to early content courses have revealed they foster negative emotions toward teaching science due to the fact-laden, lecture-based approaches typically associated with science (Birmingham et al., 2019). However, when a content course models best practices for real world, relevant science instruction, such as with SSI, TCs engage with controversial issues in a manner that is personally relevant and improves their confidence with science content teaching (Menon & Sadler, 2016). Similarly, other science education researchers have suggested in addition to the methods courses typically taken by preservice teachers, preparation programs also offer a hybrid approach to science content courses for elementary preservice teachers, which include an emphasis on both content and pedagogical approaches (Bergman & Morphew, 2015), which the researcher of the content course in this current study aimed to do. The current study supports a "best of both worlds" approach to introducing TC to SSI teaching in that various instructional contexts appear to provide TC with unique understandings of specific aspects of SSI instruction. In this regard, TC who are exposed to SSI pedagogy in multiple contexts demonstrate a more sophisticated understanding of the benefits SSI instruction offers to students.

List of abbreviations

ELA	English language arts
NOS	Nature of science
SS	Social studies
SSI	Socioscientific issues
STEM	Science technology engineering mathematics
TC	Teacher candidate

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Author contributions
MK collected data from the methods course. MN collected data from the content course. MK and MN analyzed data from both the methods and content courses. MK wrote the introduction and literature related to methods courses. MN wrote the theoretical framework and literature related to content courses. MK wrote the findings for the methods course. MN wrote the findings for the content course. MK and MN wrote the comparison and conclusion sections collaboratively.

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Data availability
The datasets used during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The Institutional Review Boards (IRBs) at Sam Houston State University approved the study. Approval number is IRB-2021-31. Our study meets the ethics/human subject requirements of IRBs at the time the data was collected.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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