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Teachers' pedagogical content knowledge on socioscientific issues and social justice

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ABSTRACT Reforms in STEM education call for reframing teachers' pedagogical content knowledge (PCK) by focusing on development of students' knowledge and scientific literacy through socioscientific issues (Lee, 2016; Zeidler, 2016; Johnson et al., 2022). We developed a two-year professional development (PD) for 6-12th grade STEM teachers that embedded SSI framework into their teaching. An analysis of survey and interview data from 24 teachers over two years and data from nine focus group interviews and pre/post surveys were used to answer our research questions on the enhancement of teachers' SSI pedagogical practices, and PCK for integrating social justice to their lessons. Our findings suggest that the PD was beneficial to participating teachers and improved their comfortability and experience teaching SSI. Moreover, our teachers developed PCK for teaching STEM through the lens of social justice in several ways, including considering different perspectives and backgrounds, connecting to current events and issues relevant to students' lives and engaging students in decision making and problem solving to make a positive impact in their communities.

Keywords: *Social justice, Socioscientific issues (SSI), STEM education*

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INTRODUCTION

Socioscientific issues (SSI) are ill-defined, debatable problems found in science that necessitate an examination of ethical choices as they cannot be resolved through science alone (Zeidler, 2016). By directly addressing moral and ethical issues (an aspect often left out of traditional STEM education), SSI can offer an authentic immersion into why science can matter to everyone beyond simply academics (Layton et al., 1993). For teachers, this can mean designing curriculum and instruction around the exploration and addressing of SSI to be the driver of student learning (Sadler, 2009). The use of SSI is firmly situated in the landscape of educational reform and has been shown to have the potential to address the important social justice concerns within STEM education (Macalalag et al., 2019). Rudolph and Horibe (2015) indicated the importance for teachers to ensure the alignment of the form, function, and goals of STEM education. STEM education should ideally include the examination of STEM practices for improving personal and societal welfare (Pedretti, 1996). According to Billiar et al., (2014), K-12 STEM teachers strive to provide their students with a deeper understanding of subject matter and problem-solving skills by developing interactive and engaging STEM programs. In the study conducted by Morales-Doyle (2017), students in a chemistry class investigated the lead and mercury levels in local soil samples through nitric acid digestion in collaboration with a local research university to study effects of pollution from coal power facilities and determine if concentrations were within state regulations and environmental guidelines. Moreover, students "demonstrated complex thinking about science and social justice, cultivated their commitment to their communities and cultures, and developed credibility within their community as local youth who were knowledgeable in science" (p. 1054).

SSI could provide contexts for learning STEM concepts in the classroom and an entry point for discussing scientific, cultural, discourse, and case-base issues, which in turn, help develop scientific literacy (Zeidler, 2014). In the classroom, scientific literacy involves students' making decisions, analyzing information, and synthesizing problems in their community, filtered through the lens of their own culture, experiences, and knowledge of STEM disciplines (Zeidler, 2014). Traditional teaching of STEM subjects in classrooms tends to educate students with disciplinary core ideas and practices without engaging in sociocultural factors (Lee et al., 2019). On the other hand, SSI has been used to promote democratic participation in which students are involved in a thought-provoking process seeking deeper understandings of a topic through decision making using real-world contexts relatable to students (Barrue & Albe, 2013). SSI comprises three components: scientific aspects, social aspects, and discursive aspects. Whereas scientific aspects are explorations of phenomena associated with a focal issue applicable to both students' sociocultural contexts and the school curriculum (Minken et al., 2021), social aspects relate to the interconnectedness of students and their community. Discursive aspects involve ways in which students use their research and analysis to formulate an argument and defend their stance on an issue. These connect with the social aspects by allowing students to voice their opinions of large-scale problems through interviews and class discussions. These discursive aspects were also present in the students' work when they evaluated their data and formulated a central argument based on their research.

Teachers face a number of challenges in making STEM subjects engaging for students to learn. Teacher professional development (PD) can support teachers in implementing changes in order to achieve desired student learning outcomes, though challenges still remain (Custer & Daugherty, 2009). According to Ejiwale (2013), there is a lack of quality PD for teachers, poor motivation of students, and weak connection with individual learners. Teachers' overall development is a primary requirement for making the learning process more meaningful for students. Another challenge is a lack of qualified STEM teachers which affects the implementation of innovative teaching methods. Supovitz and Turner (2000) found that science teachers require longer durations of PD to develop a culture of student inquiry and investigation in their classrooms. Moreover, Gomez Zwiep and Benken (2013) demonstrate that PD had a greater impact on the self-perceptions of science teachers compared to mathematics teachers, indicating that teachers in different content areas may have unique needs. Guskey (2002) indicated implementing curriculum changes requires time and energy to learn new practices which adds to teachers' workload which may cause hesitation or anxiety in adopting new practices. The success of

changing teaching practices in STEM classroom initiatives, including authentic assessments and fully integrated programs, depends mainly on teacher attitudes (Laboy-Rush, 2011), which also determines the level of their commitment to actively engaging in STEM classroom practices (Rockland et al., 2010). Therefore, PD for teachers and adequate educational experiences in STEM education is a driving force of STEM education (Sujeewa et al., 2017).

In addition to SSI, the theoretical framework of sociotransformative constructivism (sTc) is another avenue by which to approach multicultural education and social constructivism by examining how equity issues influence subject matter and pedagogy (Rodriguez & Berryman, 2002). sTc comprises dialogic conversation (being conscious of another's values and beliefs as they voice their thoughts), authentic activity, metacognition (student self-reflection on their learning process to gain deeper understanding of content), and reflexivity (consideration of one's own social location, ideological stance, and academic past to identify any implicit and explicit influences in the classroom; Rodriguez, 1998). According to Zozakiewicz and Rodriguez (2007), inquiry-based sTc PD for in-service teachers can result in more inclusive and student-centered instructional practices.

In order to address some of the challenges mentioned and to examine our PD approach, the following research questions guided our study:

1. How did teachers respond to the PD approach in terms of their reactions and experiences with SSI/sTc implementation?
2. How did teachers apply SSI/sTc approaches/practices after attending PD?
3. To what extent did participating in the PD influence secondary STEM teachers' PCK for integrating STEM teaching with social justice?

LITERATURE REVIEW

Professional Development (PD) Programs for STEM Teachers

Teaching SSI with sTc is challenging to do particularly for teachers with limited knowledge and teaching pedagogies in these domains (Johnson et al., 2022). Over the decades, different types of PD programs helped STEM teachers implement reformed-based teaching practices such as science inquiry, the engineering design process (EDP), problem-based learning, and others (Korucu et al., 2019; Macalalag & Parker, 2016). Huang et al (2022) identified several key PD approaches including alignment of theory and practice, observation of role models, reflection, collaboration with peers, higher order thinking, and continuous feedback. In the work of Macalalag et al. (2019), teachers developed and implemented lesson plans in order to teach cultural issues associated with STEM contexts (e.g. renewable energy, sustainability) that are connected to real-life experiences of students. In a study to identify PD activities, Hasim et al (2022) saw engineering-based, computational thinking, inquiry-based learning, problem- or project-based learning (PBL), modeling, interdisciplinary studies, and technology as common workshops provided to STEM teachers. In particular, problem-based learning approaches provide opportunities for teachers to engage their students in problems (e.g. water sources and point source pollution, garbage disposal and management) that could potentially impact their community. Moreover, a specific version of PBL is EDP in which teachers engage students in a systematic way of solving problems such as asking questions, brainstorming, testing and revising prototypes, and analyzing failures. Similarly, in model-based science inquiry (MBI) learning, students engage in model development, testing, and revision by asking questions, engaging in evidence-based reasoning, and analyzing and communicating information (Bolger et al., 2021). The 5Es framework (engage, explore, explain, elaborate, and evaluate) helps teachers plan their lessons in order to engage students in active learning such as PBL, EDP and MBI in classrooms (Bybee et al., 2006). Capps et al. (2012) reviewed empirical studies on inquiry-based PD programs, methods which emphasize students actively constructing knowledge in place of memorization. Inquiry-based instruction engages students in

scientifically oriented questions, emphasizes evidence in developing and justifying an answer and connects the explanation to their scientific knowledge. They concluded that teacher participation in authentic research experiences and support for developing inquiry-based lessons through PD are the most important factors in enacting inquiry-based instruction in their own classrooms .

In terms of PD to promote SSI teaching, Carson and Dawson (2016) provided a three-pronged approach to teach SSI to 75 secondary science teachers in Western Australia incorporating PD, curriculum resources, and classroom support. They noted that instruction from an expert in the field, a geoscientist academic who studies climate change, was particularly valuable to increasing content knowledge and therefore made teachers more willing to teach SSI issues in their classrooms. Cebesoy and Rundgren (2023) explored the PD of Turkish pre-service teachers involving the SSI of abortion in the case of inheritable diseases and found the importance of both scientific content and ethics/morality in the teachers' decision making. Finally, Eidin and Shwartz (2023) provided a 30-hour SSI PD to science teachers in Israel. Questionnaires and interviews indicated that learning to engage students in argumentation and informal logic were fundamental in teachers' SSI implementation. Their PD increased the teachers' positive attitude toward SSI implementation in their classrooms, based on increased awareness of the importance of SSI in facilitating the goals of science teaching, and improved self-efficacy in facilitating discussions and debates, assessing arguments and preparing SSI lessons.

Teaching SSI and Social Justice

Sociostransformative constructivism (sTc) offers a valuable framework for integrating social justice education. By examining how equity issues influence subject matter pedagogy, sTc provides a lens for understanding how to create inclusive and equitable learning environments (Rodriguez and Berryman, 2002). SSI situates STEM concepts in contexts personally meaningful to students and is a method to address disparate goals of STEM education (Johnson et al., 2022). Morales-Doyle (2023) emphasizes the significance of science education in addressing social justice issues while cautioning against overemphasizing its role. By focusing on generative themes that emerge from community contexts rather than disciplinary concepts, science curricula can connect students with the struggles for justice. Social justice is the pursuit of equity and fairness in society by ensuring that all individuals have opportunities to challenge and address inequalities and injustices to create a more just and equitable society for all (Killen et al., 2021). By connecting STEM concepts to personally meaningful contexts, SSI can empower students to consider how STEM-based issues reflect moral principles and elements of virtue in their own lives and the world around them (Zeidler et al. 2005).

SSI has the potential to foster social justice perspectives by: (a) connecting school and lived experiences, (b) promoting critical thinking and civic engagement, (c) developing empathy and understanding, and (d) empowering students to take responsibility and action (Zeidler et al. 2005; Sadler et al., 2007). For example, Lesnefsky et al. (2023b) conducted a study examining how high school students engaged in a social justice SSI unit on viral pandemics. This unit on viral pandemics involved students to study concepts related to viruses, transmission, and public health measures. By engaging students in this topic, students could address systemic inequalities that often exacerbate the impact of pandemics on marginalized communities. The researchers found that this approach increased the students' understanding of complex causal relationships in societal systems and created meaningful connections. In terms of SSI promoting social justice by enhancing critical thinking and civic engagement, SSI encourages students to engage in sociomoral discourse, argumentation, discussion, and debate which can contribute to the development of critical thinking skills and character education (Zeidler & Nichols, 2009). Moreover, teachers can use a variety of news media sources for students to think critically about SSI (Tsai & Jack 2019). For example, a group of French students studying global warming engaged in analysis of media sources and debate, demonstrating increased communication, argumentation and subject knowledge (Albe & Gombert 2012). SSI instruction helps students improve at dealing with complex issues, decision making and position taking, more than learning science, ethics or argumentation alone, as demonstrated in a study involving middle school students in a unit involving pollution and water quality (Sadler et al., 2007).

For SSI promoting social justice by developing empathy and understanding, students demonstrated increased compassion towards environmental and social issues and those affected as well as ongoing pro-environmental actions in a place-based SSI study regarding reintroduction of wolves in Yellowstone National Park (Herman 2018). Moreover, Kinslow et al. (2019) demonstrated, in a field-based ecology class for secondary students incorporating multiple SSI topics such as water quality, improved competencies related to complexity, perspective taking, and inquiry. With regards to empowering students to take responsibility and action, Bailey (2022) studied three social justice focused SSI topics such as health disparities linked to food access inequity, cancer rates linked to living locations, and DNA analysis for exoneration in cases of wrongful incarceration to 9th grade Biology students in America. As evidenced through surveys, work samples, and journal responses, the students could better describe how science connects to social justice issues and the social concerns of the units of study and shifted in their perceptions of equality and needs of citizens in their community. Moreover, Dauer et al. (2021), in an interdisciplinary and introductory undergraduate science course that covered place-based SSI with a focus on decisions regarding society on a policy level, demonstrated increased civic engagement attitudes, though results varied based on specific context due to student-perceived personal or community connection (biofuels, food insecurity and water conservation topics were more effective than prairie dog conservation). Student ideas for actions after course participation emphasized direct action like consumer habits or career choices as opposed to indirect advocacy or political action.

Conceptual Framework

Pedagogical Content Knowledge (PCK) can be helpful in thinking about how to understand and interpret the knowledge teachers have that allows them to be successful teachers in their classroom. The components of PCK include teachers' orientation to teaching, instructional strategies, curriculum, assessments, and understanding of students (Magnusson et al., 1999). This PCK framework was further adapted by Lee (2016) to focus on PCK specific to teaching SSI/sTc, and included an additional component, knowledge of learning contexts. Orientation to teaching SSI/sTc can be thought of as both a teachers' motivation teaching SSI and the way they approach SSI, whether that be for the purpose of improving student achievement, for the belief in the importance of SSI for its own sake, or something in between. Regardless of what a teachers' orientation is, it serves to shape the teachers' attitudes in one way or another with respect to the other components of PCK. A teachers' orientation for teaching SSI/sTc will influence the teaching strategies they choose, the value they place on different aspects of the curriculum and understanding how, when, and which SSI/sTc to incorporate into their lesson planning, the types of assessments they use as well as what they choose to assess, the way they understand and respond to students success, challenges, and misunderstandings related to the SSI, and how they navigate the learning context (classroom, school, and community) in selecting the SSI and facilitating lessons relating to it (Magnusson et al., 1999; Lee, 2016). In our study, we are interested in understanding the ways in which teachers' PCK of SSI/sTc support their: (a) abilities to engage students in learning STEM subjects, (b) reactions and experiences with SSI and sTc implementation, (c) attitudes about the effects schools can have on social inequities, and (d) how one's background affects one's teaching practices.

While PD involving STEM is not uncommon, there are not many programs to support in-service teachers' development of PCK for SSI/sTc, and few quality PD programs, workshops, or other opportunities around social justice are available to most educators due to cost (Basile & Acevedo, 2022). Some examples of related PD and its influence on teachers' PCK have been documented by a small number of researchers. For example, Watkins and Manz (2022) describe the ways in which teachers navigate uncertainty regarding scientific demonstrations to successfully facilitate classroom discussions. Their analysis unearths the myriad of decisions teachers must consider in what may otherwise appear to be a straightforward learning activity, such as decisions relating to when and how to engage with students' uncertainty about phenomena, how to generalize the uncertainty of one student to create a question or problem for the larger group, deciding what freedoms and constraints to provide for students engaged in making sense of scientific phenomena. Knight-Bardsely and McNeill (2016) found that reflecting on new instructional practices after initial implementation strengthened teacher

PCK and skill relating to scientific argumentation. This was seen as teacher belief and practice shifted from valuing explanation-based student arguments toward a more sophisticated emphasis on the role of evidence and reasoning in students' arguments. However, some teachers chose not to try new instructional strategies presented during PD workshops, and instead reused and renamed existing activities; in these instances, teacher PCK did not change. At the same time, development of teachers' PCK in science is not always straightforward. As an example, Barendsen and Henze (2019) found that a veteran chemistry teacher developed general, albeit minimal, PCK regarding the integration of context into science instruction, as opposed to PCK specific to the topic of the lesson under consideration. This may suggest the importance of developing topic-specific PCK prior to implementing new, reform-oriented classroom practices.

METHODOLOGY

SSI With sTc PD Program

Our SSI-sTc project is a four-year, NSF-funded PD program designed for in-service, secondary (grades 6-12) STEM teachers to teach STEM for social justice. Participants engaged in about 100 hours of PD content beginning with a summer institute which introduced teachers to the SSI/sTc framework through a mixture of presentations, guest speakers, and hands-on activities. Additionally, teachers were supported in developing an SSI/sTc unit of study aligned to their content area and district curriculum, which they were expected to refine and ultimately teach later in the school year. Teachers were also assigned a coach who would work with the teachers on an individual basis through meetings and classroom observations to review and refine their lesson ideas. Teachers also engaged in workshops and field trips which were often facilitated by guest speakers and participants sometimes traveled to a different location where they learned about place-based resources and various strategies for incorporating SSI/sTc into their teaching.

Our PD included four domains: social, scientific, discussive, and social justice. The social domain of the PD focused on issues that are relevant and interesting STEM topics and connect to students' lives and school curriculum. It encourages students to evaluate information from various viewpoints and to study systems associated with a particular issue (Zeidler et al., 2005). Participants engaged in activities such as analyzing mortgage plans, debating housing justice, and simulating resource allocation. For example, in the "Who Controls Housing?" workshop, participants examined mortgage plans to understand the financial implications of homeownership, connecting mathematical concepts to a real-world issue. Debating housing justice fostered critical thinking and empathy, while the "Chain Game" simulated unequal resource distribution, providing a hands-on experience of the challenges faced by individuals in different socioeconomic circumstances. These examples demonstrate how the social domain effectively connected STEM topics to real-world issues, fostering a more engaging and meaningful learning experience for participants. The scientific domain provided participants opportunities to study disciplinary core ideas, STEM practices, and/or cross cutting concepts (NGSS Lead States, 2013) that are relevant to a particular issue. For example, in the "Need for Speed" workshop, participants investigated the friction of surfaces to understand the factors affecting car stopping distances. This activity allowed participants to explore the scientific concept of friction, engage in the STEM practice of scientific inquiry, and connect their learning to a real-world issue that impacts road safety.

The discursive domain encouraged scientific skepticism by asking participants to critically assess information by considering potential biases, credibility of sources, methodology, and author's expertise. SSI also educates participants to use evidence to support their claims, provide rationale, and acknowledge their own biases and limitations (Johnson et al., 2020). For example, teachers in the "Need for Speed" workshop used data available online to develop recommendations for improving road safety. This activity required participants to analyze information critically, consider potential biases in data,

and use evidence to support their conclusions. By engaging in these discursive practices, participants were able to develop the skills necessary to evaluate information critically and communicate their findings effectively. The social justice domain challenged participants to utilize authentic activities that are socio-culturally relevant and tied to everyday life of students. It also provided opportunities for them to voice their own reasons, while using their learning experiences to transform (actions) themselves and others (Rodriguez, 2002). For example, the "Who Controls Housing?" workshop included a simulation activity that exposed participants to the challenges of poverty and homelessness. This activity provided participants with a firsthand experience of the systemic issues that contribute to inequality and the personal impact of these challenges. Moreover, participants investigated local speed limits to address community concerns, demonstrating the potential for STEM education to be applied to real-world issues and contribute to social change. The activities were deemed suitable for the STEM approach due to their focus on interdisciplinary learning, problem-solving, and real-world applications. This was checked through review of STEM facilitators in our team and alignment with STEM education frameworks/standards. Expert opinions were sought from STEM educators and researchers to assess the activities' suitability and provide feedback on their design and implementation. The activities were aligned with social justice and SSI by addressing issues such as housing inequality and resource distribution. They also incorporated STEM concepts, such as mathematical modeling and scientific inquiry, to promote critical thinking and problem-solving skills.

At the end of each year, the program hosted an end-of-year conference to showcase teachers' work. The conference was open to the public and involved a keynote speaker and breakout sessions where our teachers ran workshops, which they had developed, relating to a component of the SSI/sTc framework that would be of interest for in-service and pre-service teachers, teacher educators, and other educational professionals. For each of the first three years of the project, a new cohort of approximately 25 teachers is enrolled, such that teachers in their second year of the program are able to serve as mentors to teachers in their first year of the program while continuing to develop their practice.

Methods

We measured the merit of the PD in fostering growth in the teachers' PCK on SSI/sTC, teachers' experiences, and teachers' pedagogical practices on social justice, using multiple approaches. First, using the survey and focus group interview guide described momentarily, a pair of external evaluators measured teachers' self-reported knowledge and insights about the PD, respectively. Second, a team of higher education and K-12 educational collaborators conducted interviews with teachers to better understand their pedagogical practices on social justice in classrooms. Evaluators and researchers used the methods below to address the following questions: (1) How did teachers respond to the PD approach? (For example, what were their reactions and experiences with SSI/sTc implementation?) (2) How did teachers apply SSI/sTc approaches/practices after attending PD? and (3) To what extent did participating in the PD affect secondary STEM teachers' PCK for integrating STEM teaching with social justice?

The 10-minute, confidential survey that evaluators administered to teachers online at the end of each school year included items adapted from the Social Justice subscale of Whitaker and Valtierra's (2018) Culturally Responsive Pedagogy Scale. For example, using a 7-point Likert response scale ranging from "minimal" to "very good," evaluators asked teachers to rate their understanding before and after the year's PD of (1) how one's cultural background, (2) socio-economic status, and (3) belief systems influenced one's teaching. Using a 7-point response scale ranging from "strongly disagree" to "strongly agree," teachers also rated their level of agreement with four statements reflecting different attitudes about schools, such as "hot-topic conversations (e.g., race, gender, sexuality, religion, etc.) should be had in class when necessary and/or relevant" and "I value equity (giving each student what they individually need) over equality (giving each student the same thing)." Instructions on the questionnaire asked respondents to consider their level of agreement with the statements before the PD initiative, compared with how they felt now (at the end of the school year).

The evaluators' survey contained 31 questions total and took 10 minutes to complete. (See Appendix 1

for the end-of-year teacher survey.) Although the survey provided valuable information used to gauge teachers' experiences and the overall merit of the program, we have not tested the tool's psychometric properties on our small teacher sample. Adapting items from the Whitaker and Valtierra (2018) scale precluded our ability to consider the survey tool valid or reliable; however, the data generated can be used to do so in the future. In all, the total number of participants was 27 Cohort 1 participants in Year 1 and 14 in Year 2; 18 Cohort 2 participants in their Year 1 and 14 in Year 2; and 23 Cohort 3 participants in their first year. Teachers in Cohort 1 first completed the survey at the end of Year 1 (April 2022) and those in Cohorts 1 and 2 completed it also at the end of Year 2 (April 2023). Fourteen Cohort 1 teachers completed the Year 1 survey, and 12 Cohort 1 teachers and 10 Cohort 2 teachers completed the Year 2 survey. The consent form, which teachers signed at the PD's outset, informed respondents of their rights and explained the voluntary nature of participating in evaluation activities, such as the questionnaire and focus group interview. Evaluators' annual hourlong focus group interviews with teachers also occurred online. The interviews offered an opportunity to gain deeper insights into teachers' reactions to and satisfaction with SSI/sTc principles and strategies, and their experiences with implementation. They asked about the extent to which teachers: participated in various PD activities (e.g., professional learning communities, summer institute, field trips); experienced challenges in the PD; felt to share their opinions; felt sufficiently prepared to integrate concepts into their instruction (and then did so); and noted any effects of integration on students. They also asked if teachers would recommend the PD to others, had suggestions for improvement, and could identify benefits and drawbacks of participation.

In all, the evaluators conducted nine total focus group interviews: (1) three groups (n = 16) of Cohort 1 teachers in December 2021; (2) two groups (n = 14) of Cohort 1 teachers in April 2022; (3) two groups (n = 13) of Cohort 2 teachers in December 2022; and (4) two groups (n = 12) of Cohort 1 teachers in January 2023. Each virtual interview lasted about one hour and was audio-recorded and transcribed for analysis. Respondents discussed their reasons for enrolling in the PD, perspectives about program quality, feelings of preparation to integrate SSI/sTc concepts into their classroom, suggestions for improvement, and benefits and drawbacks of participating. In analyses of the qualitative data from the interviews, the analysts summarized themes that emerged naturally from the data. See Appendix 2 for the teacher focus group questions.

In addition to the data that program evaluators collected, the collaborative team of higher education and K-12 research team analyzed responses from interviews that they conducted with teachers. Specifically, after completing the first year and second years of our PD program, nine teachers of the 27 teachers (13 teachers in Cohort 1 and 14 teachers in Cohort 2) responded to the following questions: (a) from the beginning of the project to now, in what ways has your knowledge of social justice evolved? and (b) from the beginning of the project to now, in what ways have your teaching practices for integrating STEM teaching with social justice evolved? These teachers were selected for the study because they demonstrated sophistication in creating SSI Unit Plans. Of the nine teachers, two taught math subjects (honors Precalculus, honors Geometry, learning support math, and Algebra), while the remaining seven taught science (middle school science, Chemistry, Physics, Physical Science, Environmental Science, Biology, and Computer Science). The range of teaching experience of the study participants spanned from 2 - 32 years. One teacher had less than five years of teaching experience, three had between five to 15 years, and five teachers had greater than 15 years of experience. Our analyses of these individual interviews followed quantitative analysis of qualitative data as described by Chi (1997). Our coding proceeded through an iterative process of application to the data set and refinement of the codes to capture relevant emerging themes in the data (Merriam, 1998). The initial codes were developed and examples were identified by the researchers. The coders independently analyzed the data before discussing the final codes together and reaching agreement. Teacher names are presented as pseudonyms in this paper to preserve anonymity.

We submitted and received an initial approval from the ethics committee of the primary institution on November 2, 2021. Subsequent modifications of our original proposal were also given an exempt status in October 2022 and in July 2023. All of the compliance data is kept confidential in accordance with a plan approved by the ethics committee.

FINDINGS

Finding 1: Teachers' Experiences with SSI and sTc PD Program

Cohort 1 and 2 teachers expressed strong praise for the strategies and PD, which some said they described as "very enriching," "inspirational," and a "reframing" of their prior approaches. One 12th grade teacher, who had not used the approach previously, characterized the teaching strategies as "all great ideas" and stated, "We're new [at this]. This is totally like… a shift in educational pedagogy." Another teacher who described the PD content as "different from a lot of other teaching styles" appreciated the high degree of modeling, reflection, and "organic discussions" in the PD. He had felt comfortable during PD conversations about "controversial SSI issues" because teachers could choose whether to share their opinions, listen to others without sharing one, or simply withhold support from a position with which they disagreed. "I never felt like someone [was] going to really come at me," he said. A peer said that discussing controversial issues productively together was possible because developers had created a sense of community during the first week of the PD. Another called the PD content "inspirational," and it helped that students enjoyed teachers' application of content. For example, one teacher stated,

> *"Being able to connect the social justice aspect to concepts in science, it really has challenged me as an educator to really look at how I can take core content and then make it authentic and make it real for the kids, and the kids love it."*

Another teacher, who chose food deserts as her SSI topic, took students to a local Save-a-Lot grocery store for an educational field trip that served as an opportunity to be outside, while a third teacher had been incorporating SSI issues into lessons "all year on the DL" (secretly) because the strategies were motivating to students. As a result of strategy use, the teacher said "Not once have I heard [students say] 'when are we going to use this in real life?' I have not heard it!"

For some teachers, PD content was not necessarily new, but use of SSI/sTc strategies either "reframed" their practice or provided a better framework for their teaching than they had used in the past. Three teachers in a different focus group expressed strong satisfaction with the strategies they learned, and shared the following:

> *Respondent #1: "I feel like I learned a lot, but it's reframing... I don't think there's been one activity that I don't actually do as a lab in some sterile form, but it's framed now, so there's more meaning and connectivity to it…At the beginning of the unit, I frame the social issue that goes with it and every couple of days bring it back up and say, '...Next week I'm going to be doing a lab and an article review on this.' So it connects my topics better to their lives… it makes it so much more relevant to the kids."*

> *Respondent #2: "I feel like that's the beauty of it though. For me, I felt like I was teaching science for the first time, in a good way. It finally made sense and purposeful… you could take whatever activity you were doing and just reframe it. And now it's like, Oh, that's what it was missing. That's how I feel."*

Asked for specific examples of what the teachers were reframing or thinking about differently, two responded,

> *Respondent #1: "For my seventh grade physical science class… I remember one question was the force [that a] tornado would put on a door frame… I was trying to think of what they could do that [was] socially relevant… Last year, we did have the tornado touch down in [nearby town], which all the kids knew about. And I drove through it and [it was a] war zone….So we studied tornadoes and tied it to global warming. And then we did a little lab that I think I found on [a website]. And*

> *they built little houses out of cardboard, and I had hair dryers and tr(ied) to blow their houses down. And then they got worse, reinforce(d) it, and then propose(d) whether all houses in this region should be built sturdier so the roofs don't blow off from the pressure difference. And they loved it!... It went through the whole unit and showed the footage of the tornado and [nearby town] and we talked about remembering that day. You had friends in that area."*

> *Respondent #3: I think for me, just simply put, it gives me the, 'why are we learning this?' Because it makes my students more socially conscious of what's going on. And for them looking at what's happening in their own neighborhoods and how they can be responsible citizens and how they can look at the situation and look at all the sides of the situation and then make a decision on what might be best for their community and is there anybody else out there really looking for the best interest of their communities. So it gives them a reason to know why we're doing certain things in our classes."*

Finding 2: Knowledge, Understanding, and Comfortability with SSI and sTc Teaching Approaches

Analyses of teachers' reported changes in knowledge and understanding of SSI issues and comfortability with its application showed promise, despite the quantitative survey data violating assumptions of normality, statistically speaking. (For example, Wilcoxon signed rank tests showed the data violated the assumptions of normality for paired t tests. Evaluators ran histograms and statistics to check for skewness and used the Shapiro-Wilk test which showed data in 8 out of 11 items were not normally distributed (due largely to small sample size and one or two outliers.) An exact sign test compared attitudes, knowledge, and comfort level before and after PD participation; in the end, participants showed a statistically significant median increase at post compared to pre ($p<.05$).

That notwithstanding, Table 1 summarizes the teachers' pre- and post-mean survey responses for various items, the results from the paired *t*-tests, and level of statistical significance. The change in mean responses from pre- to post- was statistically significant for each item measured. In particular, their attitudes about SSI/sTc implementation significantly changed from the beginning to end of the school year. There was a significant difference in the mean level of agreement with a statement that schools can reproduce inequalities between pre- ($M = 5.83$, $SD = 1.30$) and post- ($M = 6.57$, $SD = 3.01$); $t(22) = -3.01$, $p = 0.006$. The reported understanding of SSI/sTc also significantly changed from pre- to post-survey. For instance, teachers' mean level of agreement with a statement that one's cultural background influences one's teaching increased from 4.83 ($SD = 1.70$) points to 6.22 ($SD = 0.80$) points over time. Moreover, teachers' reported comfortability with teaching SSI and sTc concepts after being exposed to the PD rose significantly.

Table 1.
Paired t-Test Results for Attitudinal, Understanding, and Comfort Level Items for Cohort 1 and 2 Teachers

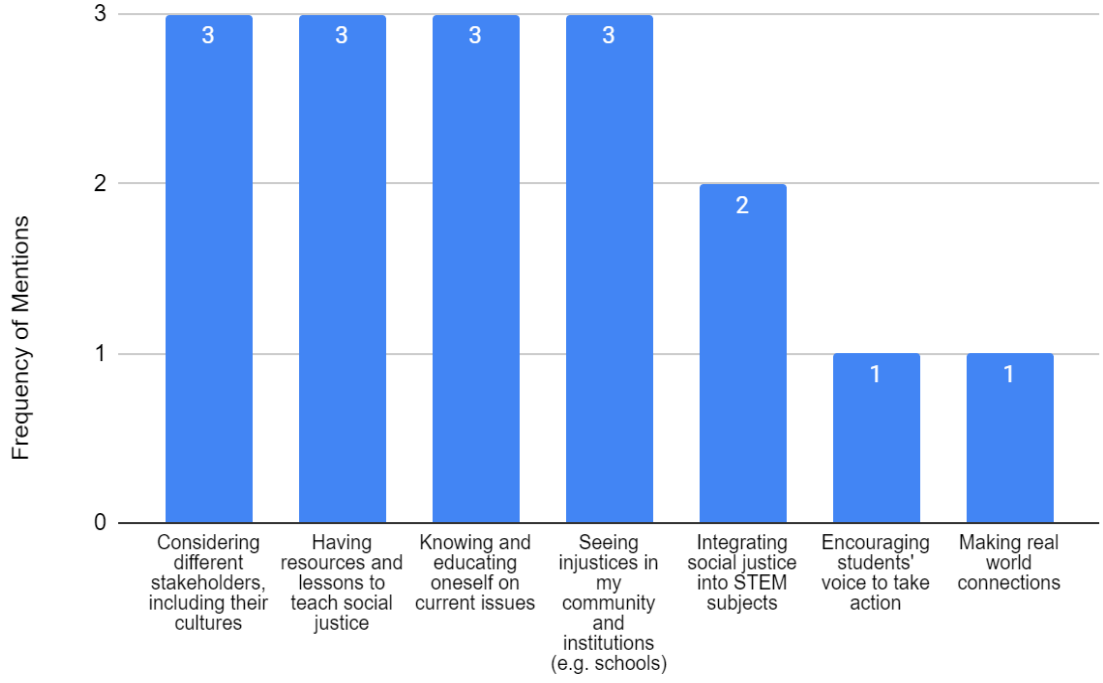
	n	*Mean (SD)* Beginning of First Year	End of First Year	*t* (df)	*p*-value
Attitudes about:					
Hot-topic conversations... should be had in class when necessary/relevant.	24	4.92 (1.72)	6.42 (0.72)	-5.20 (23)	0.000
Schools can reproduce inequities.	23	5.83 (1.30)	6.57 (0.51)	-3.01 (22)	0.006
It is important to acknowledge how issues of power are enacted in schools.	23	5.43 (1.44)	6.52 (0.51)	-3.98 (22)	0.001
I value equity [defined] over equality (giving each student the same thing).	24	6.42 (0.88)	6.88 (0.34)	-2.70 (23)	0.013
Understanding of:					
SSI	24	2.54 (1.64)	6.04 (0.81)	-10.8 (23)	0.000
sTc	24	2.17 (1.58)	5.17 (1.27)	-8.95 (23)	0.000
What it means to engage civically	24	4.08 (1.50)	5.46 (1.06)	-4.59 (23)	0.000
How one's cultural background influences one's teaching	23	4.83 (1.70)	6.22 (0.80)	-3.87 (22)	0.001
How one's socio-economic status influences one's teaching	23	4.87 (1.87)	6.04 (0.93)	-3.00 (22)	0.007
How one's belief systems influence one's teaching	24	4.96 (1.65)	5.92 (1.02)	-3.29 (23)	0.003
Comfort with:					
Teaching SSI	24	2.63 (1.74)	5.71 (0.86)	-9.21 (23)	0.000
Teaching sTc	24	2.33 (1.63)	5.17 (1.34)	-9.12 (23)	0.000

Note: Attitudinal, understanding, and comfort scales ranged from 1 to 7, where "1" reflected negative responses and "7" reflected positive scale responses. Source: End-of-year surveys, April 2022 and April 2023.

Finding 3: Teachers' Knowledge of Social Justice After Attending PD

Researchers asked teachers how their knowledge of social justice evolved from the beginning of the project to now. Figure 1 shows the frequency with which teachers' responses contained various themes. Overall, teachers changed by considering different stakeholders and including their cultures (*n* = 3), having resources and lessons to teach social justice (*n* = 3), knowing and educating oneself on current issues (*n* = 3), and seeing injustices in their community and institutions (e.g. schools) (*n* = 3). Teachers provided examples of how their knowledge of social justice evolved.

Figure 1.
Evolution of Social Justice Knowledge



Ms. Davis started to consider different stakeholders, including their different cultures. She mentioned that "one of the most important takeaways for me was considering different stakeholders. So for me whenever I'm approaching the social justice topic, I'm trying to insert some points of view that maybe my students didn't consider." Ms. Smith realized that having the resources and lessons to teach about social justice can "... get students involved in learning the information and … applying it to their life." She previously believed these topics were too confrontational for science classes.

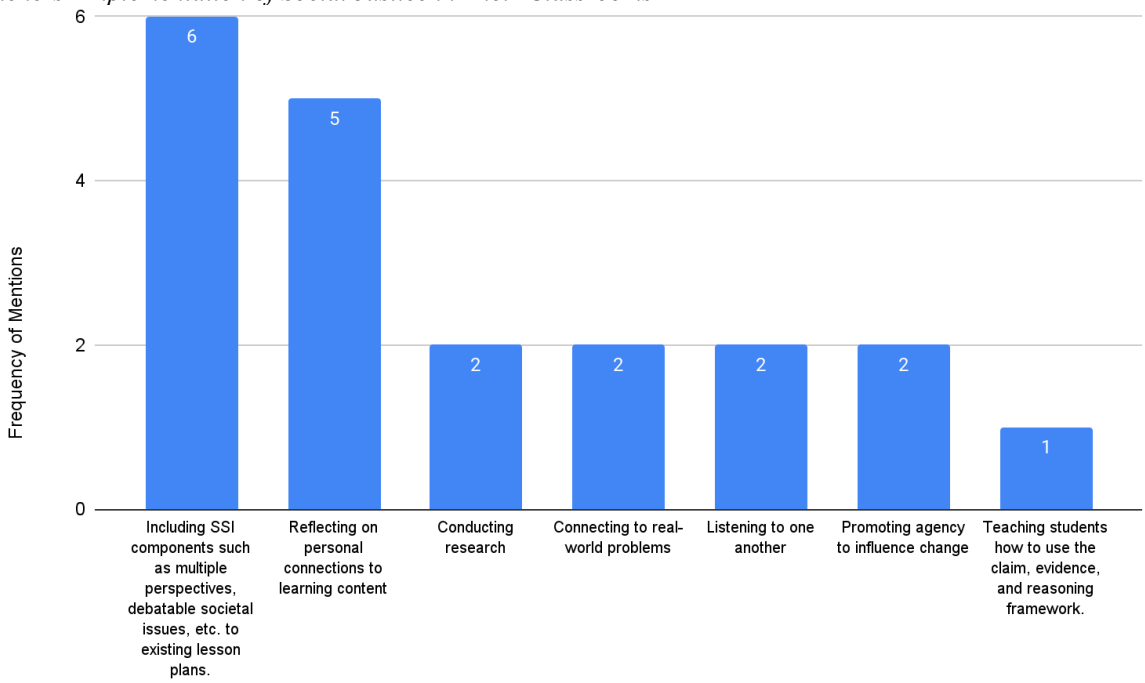
Building upon applying this information to their lives, Mr. Lopez expressed the need to further educate oneself, specifically stating that "what I had to do was to really teach myself about issues, concepts that would affect my students and apply it to match my unit of study and find out the needs of my students to get them interested." Continuing the theme of needing to become more informed, Ms. Lee, shed further light on personal experiences. For her, seeing injustices in her community and institutions helped evolve her practice to "just being able to talk about 'hey, where are these things coming from?' And maybe opening eyes, showing kids things that they haven't noticed before and just trying to get some of that outrage on things I think was awesome." Ms. Lee highlighted experiences in her own community, while other teachers explored the integration of social justice in their classrooms.

Ms. Johnson was one teacher who learned how to integrate social justice into STEM subjects "because [she] never really contemplated 'maybe I should have integrating social justice issues into the curriculum that is required by the school district.'" Transitioning to a related aspect, Ms. Robinson explored the connection in this social justice integration. Ms. Robinson encouraged students' voices to take action. Through the project, she realized that, "the idea of social justice is all about student voice, and partnerships. So it's not just me giving them, 'Hey, I think this relates to your life, let's look at it.' But having the students choose and say, 'I think this relates to my life and here's what I wanna do it'" Ms. Robinson also engaged her students in making real world connections. She used "social justice as a tool to show that the concept that we're learning in our classes relates to everyday life. So that way the students realize that the issues that they're seeing every day in their own lives in the world can be brought back and reflected into their classrooms." The examples explored offer a glimpse of the participants' evolution in understanding social justice and their expansion of knowledge in integrating social justice into their own classrooms.

Finding 4: Teachers' Teaching Practices for Integrating STEM Teaching with Social Justice After Attending PD

Researchers asked interviewees to reflect on the ways their teaching practices for integrating STEM teaching with social justice goals had evolved. Figure 2 shows the frequency of mentions for pedagogical changes they had made. Teachers mentioned SSI components such as multiple perspectives, debating societal issues, etc. to existing lesson plans (n = 6) as their most common pedagogical change. This was followed closely by reflecting on personal connections to the learning content (n = 5).

Figure 2.
Teachers' Implementation of Social Justice in Their Classrooms



Each of the teachers gave examples of the pedagogical changes they made to integrate STEM with social justice. Ms. Davis was more intentional with integrating the framework of SSI into existing lessons to connect them to social justice issues. She said "I'm trying to be more intentional with infusing some SSI. Last year, I did a unit on renewable and nonrenewable energy resources. This year, I introduced that in the fall so that I could do a second unit on whether or not funding should be used to design, or engineer, the perfect pet and then recently in the news when the water in [city] was contaminated, I was able to introduce a little bit of SSI for my students that time, too." Ms. Johnson found another way to change her pedagogy, by letting students reflect on how the content relates to them and their lives, thereby making personal connections to the learning content. Her perspective was that "it's a perfect opportunity to actually make sure students are aware of what the impact is specifically for just social justice issues and to them." In order to make personal connections to the content, students need to be able to properly analyze the information that they are given.

Conducting research (n = 2), connecting to real world problems (n = 2), listening to one another (n = 2), promoting agency to influence change (n = 2), and teaching students to use claim, evidence, reasoning framework (n = 1) are additional pedagogical changes mentioned. For example, Ms. Lee began to stress the importance of conducting research, by teaching students to properly read and analyze data and articles, which was one of the things she enjoyed most about changing her pedagogy. She said that "I think one of the really good things about [PD program] was that I really pushed scientific reading and journal reading and article reading at the beginning." Mr. Lopez began to search for issues that have personal relevance to the students so they can visualize the SSI, for example, by showing them "exactly where our drinking water comes from and how the water is polluted in our watershed. How do we turn that around?" Mr. Lopez prioritized making real world connections, but Ms. Brown found creating a classroom environment where her students feel safe to share their own experiences was integral to teaching STEM with social justice by providing a safe space that allowed her students to actively engage with each other and her in a way that values all of their contributions. She motivated them to "not to be afraid to have those difficult conversations. I think making sure that the space is set up to be safe for students to have the dialogues and to be willing to do the work and push themselves." Building upon students feeling safe and able to express their thoughts encouraged students to actively use their knowledge. Other teachers began to encourage students to use their knowledge and perspective to make a change in the world. Ms. Rodriguez wanted to get her students to think about social justice and the

societal change that they personally can bring about. She wrote "now I try to sprinkle social justice into those projects so students can really think about debatable issues and really think about how they can change society when it pertains to social justice." To be able to use their knowledge to change the world around them the students have to be able to make well structured arguments, something that Ms Smith focused on. As a final example, Ms. Smith mentioned the importance of teaching students how to use claim, evidence, and reasoning framework. She said, "The claim evidence reasoning is… getting [students] to look at the evidence for climate change… and then coming up with the reasoning for it." All of these examples demonstrate pedagogical changes that the participating teachers found helpful in integrating STEM into social justice topics.

CONCLUSION AND DISCUSSION

The SSI contexts can help students become problem solvers as they engage in complex issues, consider multiple perspectives, and examine ethical dilemmas while learning STEM concepts (Sadler et al., 2007). Moreover, SSI can foster discussions on social justice such as health disparities linked to food access and inequity and DNA analysis for exoneration in cases of wrongful incarceration (Bailey, 2022). However, teachers face a number of challenges in implementing SSI in their classrooms as perceived time constraints, difficulties in implementing SSI discussion activities, and school curriculum as a rigid list of topics to follow (Reis, 2013). In our PD program, we engaged our teachers for about 100 hours for two consecutive years to help them develop their PCK towards teaching SSI and sTc. We immersed them in discussions, hands-on activities, unit development, reflections, and field explorations as they learned the different components of SSI and sTc.

We administered and analyzed survey questionnaires and focus group discussions in order to answer our first research question: "How did teachers respond to the PD approach? What were their reactions and experiences with SSI/sTc implementation?" Our findings suggest that our Cohort 1 and Cohort 2 teachers expressed strong praise for the strategies in our PD. They described our PD components as "very enriching," "inspirational," and a "reframing." This research finding complements the results of Eidin and Shwartz (2023) in which they found that their teachers increased their awareness of the importance of SSI in learning science by improving their ability to facilitate discussions and debates, assessing arguments and preparing SSI lessons. Capps et al. (2012) suggested teachers develop their own inquiry-based lessons designed around incorporating authentic research experiences to help teachers execute inquiry-based instruction in their classrooms, similarly our findings point to a shift in educational pedagogy in our PD. In particular, one of our teachers described the PD content as "different from a lot of other teaching styles" and appreciated the high degree of modeling, reflection, and "organic discussions" in the PD. One teacher described feeling comfortable during PD conversations about "controversial SSI issues." Our research findings also agree with Cebesoy and Rundgren (2023) that both scientific content and ethics/morality are key in developing teachers' decision making strategy as part of their PD conversations about controversial SSI issues. We followed Bybee et al. (2006) suggestion of utilizing the 5Es framework to help teachers plan their lessons in order to engage students in active learning. Finally, our analysis of data points to the importance of developing a sense of community during the first week of PD, which helped teachers discuss controversial issues productively together.

Our data analysis also shed light on our second research question: "How did teachers apply SSI/sTc approaches/practices after attending PD?" Our findings suggest that teachers apply SSI/sTc by considering different stakeholders and including their cultures, having resources and lessons to teach social justice, knowing and educating oneself on current issues, and seeing injustices in their community and institutions. These findings extend the results of Doğanay and Öztürk (2017), which reported that students could use SSI to engage different stakeholders through role playing, access resources and educate oneself through the topic of human rights, and identify injustice in the community through discussions, media reports analysis, and cooperation-based learning. In particular, Ms. Davis, who is

one of the teachers in our study, put emphasis on the importance of considering different perspectives from stakeholders, including their different cultural backgrounds, as part of approaching a social justice topic. Ms. Smith highlighted how teaching about social justice focused SSIs can engage students in both the content and real-world relevance, similar to Zeidler et al.'s (2005) assertion that students reflect the morals and social world around them when considering SSI topics. In an example of application of SSI/sTc approaches/practices after attending PD, Mr. Lopez emphasized that teaching himself about current issues and concepts that are relevant in his students' lives meant he could apply them to his units of study and increase their interest. The increased interest Mr. Lopez mentioned expands on the research by Johnson et al (2020) in which teachers were able to adapt teaching strategies based on the relevance of different SSI cases to their students' lives by building scientific knowledge and providing meaningful contexts. An additional component of approaching social justice in the classroom is through the study of injustices in one's community and institutions. In particular, Ms. Lee said that engaging students in difficult discussions on what is happening in their communities and why helped her students to open their eyes and call for action.

Our findings also extend what Dauer et al. (2021) saw in their introductory undergraduate science course in which SSI helped their students to increase civic engagement through student-perceived personal or community connection; such student ideas for actions could lead to active community involvement and positive changes in habits and career choices. Ms. Johnson learned how to integrate social justice into STEM subjects, mentioning that because it is not a topic required in the school curriculum she had not considered including it before. According to the research of Bailey (2022), including social justice in STEM leads to students being more able to depict how science connects to social justice issues and the social concerns involved and shifts their perception of equality and the needs of their own community. Ms. Robinson gave more power to student voices to encourage social justice integration within her SSI lessons. This contrasts with the results of Kinslow et al. (2019) who demonstrated that their ecology-based SSI topics resulted primarily in increased scientific and environmental literacy skills as opposed to student engagement or social justice understandings. Finally, engaging students in making real-world connections is an important component of applying SSI/sTc approaches/practices after attending PD. In particular, Ms. Robinson mentioned that "social justice [is] a tool to show that the concept that we're learning in our classes relates to everyday life. So that way the students realize that the issues that they're seeing every day in their own lives in the world can be brought back and reflected into their classrooms." Our findings support Dolan et al. (2009), that teachers can use SSI to engage students in constructive sociomoral discourse by exposing them in real-world scenarios to bolster their social development while enhancing scientific knowledge.

In terms of our third research question, "To what extent did participating in the PD affect secondary STEM teachers' PCK for integrating STEM teaching with social justice?", our findings suggest that our teachers' PCK includes orientation to teaching social justice after attending our PD. For instance, a teacher in our study conducted a physical science lesson on tornadoes and global warming that helped emphasize social inequities in students' nearby region. This teacher was able to use an SSI context to incorporate the engineering design process and to increase the understanding of social inequalities through personal connections. This concept is highlighted in Lesnefsky et al. (2023b) in which high school students demonstrated how a social justice SSI unit (viral pandemics) can increase the understanding of complex causal relationships in societal systems as well as create meaningful personal connections. Moreover, our analysis suggests positive changes in our teachers' PCK towards understanding of how to encourage students to study social justice or injustice in their communities. For example, a teacher in our study expressed the need to educate himself on current issues to help his students apply what they learned to the unit of study. In this example, he is motivated to learn in order to become a better teacher for his students. According to Eidin and Shwartz (2023), learning to engage students in argumentation and informal logic was fundamental in their SSI implementation. This teacher identified the learning needs of his students to help them gain interest in the lessons. Finally, one of our teachers indicated that SSI implementation is the perfect opportunity to help students understand how social justice can impact them.

In summary, our analysis of data suggests that our PD provides teachers with learning opportunities on SSI and sTc, which in turn develops their knowledge, understanding and comfortability in teaching them. Moreover, our PD enhances teachers' PCK for integrating STEM teaching with social justice such as considering different perspectives and cultural backgrounds, thinking about current issues and concepts that are relevant to students' lives, and engaging in problem solving and decision making that can make a positive difference in the community.

Implications on Teacher Education

The findings of this study provide valuable insights into STEM learning and how SSI instruction can be used to enhance science and mathematics secondary in-service teachers classroom practices. Our PD enhanced teachers PCK, which in turn adds to their comfortability and willingness to teach SSI and sTc in their classrooms. In particular, SSI can contribute to meaningful application of STEM concepts in and outside the classrooms, while engaging in actions that can potentially reduce injustices in our community. Incorporating social justice within the classroom can serve to further engage students by connecting them to issues that are important and relevant to their lives outside the classroom, demonstrating the importance of STEM education as lifelong skills.

Challenges and Limitations

Pandemic constraints created recruitment and meeting challenges. We used a hybrid model incorporating both in-person and virtual workshops in year one and switched to a two-week in-person summer institute in August followed by hybrid PLC meetings and field trips in year two. Another challenge was the development of teacher units required more time than the PD facilitators initially planned. Thus, the workshop schedule was adjusted to allow teachers additional time to develop their units of study, directed toward addressing specific needs that the teachers identified in their feedback. Moreover, teachers felt unprepared to teach their lessons and requested additional support from PD facilitators and coaches. To accommodate teachers, we offered more coaching time, modeled SSI lessons during PD workshops, and provided timely feedback on lessons and included additional math-based support.

Our study contains several limitations. Our participants volunteered to participate in a SSI and social justice PD program for secondary education STEM teachers from a geographically concentrated region, which limits generalizability of our results. Our data was based on teachers' interviews and focus groups, which may not represent students' experiences with SSI.

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APPENDICES

Appendix 1: End-of-Year Teacher Survey

1. How *USEFUL* did you find the following program activities OVER THE PAST YEAR?

(If you didn't attend any of the events/activities in a given category, check "n/a.")

	Not at All Useful	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful	
Fall Tuesday Evening Institute Sessions	O	O	O	O	O	n/a
Spring PLC Sessions	O	O	O	O	O	n/a
Spring Workshops	O	O	O	O	O	n/a
Field Trips	O	O	O	O	O	n/a
Pre-Visit Coaching	O	O	O	O	O	n/a
Classroom Support Visits	O	O	O	O	O	n/a
Debriefs after Classroom Support Visits	O	O	O	O	O	n/a

2. Please indicate your level agreement with these statements about the PD this past year:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
This professional development has been a good experience overall.	O	O	O	O	O	n/a
I understood what was expected of me.	O	O	O	O	O	n/a
My comfort level with the topics grew over time.	O	O	O	O	O	n/a
I was satisfied with the program.	O	O	O	O	O	n/a
I am confident in my ability to lead future "SSI" and "sTc" instruction.	O	O	O	O	O	n/a

3. Below are statements reflecting different attitudes about schools. Please rate your level of agreement with the statements BEFORE the PD initiative compared with how you feel NOW.

BEFORE								**NOW**							
Strongly Disagree						**Strongly Agree**								**Strongly Agree**	
1	2	3	4	5	6	7	Hot-topic conversations (e.g., race, gender, sexuality, religion, etc.) should be had in class when necessary and/or relevant.	1	2	3	4	5	6	7
1	2	3	4	5	6	7	Schools can reproduce inequities.	1	2	3	4	5	6	7
1	2	3	4	5	6	7	It is important to acknowledge how issues of power are enacted in schools.	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I value equity (giving each student what they individually need) over equality (giving each student the same thing).	1	2	3	4	5	6	7

4. How would you rate your understanding of the following BEFORE your participation in the PD compared with your understanding now? (1 = "Minimal Understanding" to 7 = "Very Good Understanding.")

BEFORE								**NOW**							
Minimal						**Very Good**								**Very Good**	
1	2	3	4	5	6	7	Socio-scientific issues (SSI)	1	2	3	4	5	6	7
1	2	3	4	5	6	7	Sociotransformative constructivism (sTc)	1	2	3	4	5	6	7
1	2	3	4	5	6	7	What it means to engage civically	1	2	3	4	5	6	7
1	2	3	4	5	6	7	How one's cultural background influences one's teaching	1	2	3	4	5	6	7
1	2	3	4	5	6	7	How one's socio-economic status influences one's teaching	1	2	3	4	5	6	7
1	2	3	4	5	6	7	How one's belief systems influences one's teaching	1	2	3	4	5	6	7

5. How would you rate your COMFORT LEVEL with the following?

BEFORE								**NOW**							
Very Uncomfortable						**Very Comfortable**		**Very Uncomfortable**						**Very Comfortable**	
1	2	3	4	5	6	7	Teaching SSI	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	Teaching sTc	1	2	3	4	5	6	7	

6. Do you think your instruction facilitated civic engagement among your students?
O YES **O** NO

7. Were you provided useful feedback about your implementation of SSI and sTc instruction?
O YES **O** NO

8. Would you say your SSI and sTc lessons were implemented successfully this year? Why do you say? (Is there any evidence of success and if so, what might that be?)

9. What did you find MOST and LEAST helpful about the professional development activities?

*Most helpful:*_____

*Least helpful:*_____

10. What do you still need to do/know to advance your SSI and sTc instruction?

11. What might you do differently in the coming school year to advance your SSI and sTc instructional practices?

Appendix 2: Teacher Focus Group Interview Guide

Hello, I'm from _____. The _____University has hired us to evaluate the grant funded by the National Science Foundation. As part of this evaluation, we are seeking to gather information from you as someone who participates in the professional development offered.

This interview should take **approximately 50 minutes**. Please answer the questions as best as you can. Although we will audiotape this conversation, your identity will never be revealed to anyone outside the evaluation team. While we may report quotes collected during this interview, at no time will we connect comments with any individual. You are free to stop participating or withdraw at any time. Let me know if you would like to skip a question because you don't feel comfortable responding to it or prefer not to answer the question.

We'll talk about what you think about professional development (PD) and then your suggestions for improvement. By PD I mean the PLCs, institute workshops, field trips, and classroom visits. Sometimes I will ask about the whole experience taken altogether, and other times I'll ask you specifically about the PLCs this past spring.

1. First, can you tell me a little about your background, such as the grade/subject you teach?

2. To what extent were you able to participate in spring PD activities (i.e., workshops, PLCs, field trips, class visits and coaching)? What, if anything, affected your ability to participate?

3. What did you think of the spring PD activities overall (i.e., workshops, PLCs, field trips, class visits and coaching)? Were they of high quality?

    a. Which component was the most relevant or useful to you? Why?

    b. Which component was the least relevant or useful? Why?

    c. What challenges, if any, did you experience during your PD participation?

4. What do you think about the quality of the PLC sessions overall?

    a. What do you think of the format of the PLCs?

    b. Did you feel free to share your opinions? What, if anything, did the facilitators do (or not do) to create a safe space for you to voice your opinions? How successful were they in creating a safe space?

5. Let's talk about integrating the PD concepts into your instruction.

    a. Did you feel sufficiently well prepared to integrate SSI/StC lessons? Did you feel supported to integrate SSI/sTc lessons into your practice?

    b. Have you used any of the project resources (specify examples)? How so? If no, why not? Would they be more useful to you if modified in some way?

    c. To what extent have you integrated what you covered in the PD overall this year (PLC, institute, and field trips) into your instruction?

    d. How well has that gone?

e. What would you say has been successful? What did not go as well as you hoped?

f. How challenging was it to integrate the concepts?

g. How did students respond to the lesson/s?

6. Related, let's discuss any effects of integration on you and your students.

a. To what extent has there been any effect of classroom integration on your students?

b. How, if at all, have you been affected? (Probe, if needed: on your confidence, comfortability in discussing hard topics or introducing "debates" in lessons?)

7. What would you say have been the benefits and drawbacks of participating (if not already addressed)?

8. Let's talk about suggestions for improvement.

a. How might the program be improved? What would be helpful to you?

Thank you!