We Strive: Initial Explorations of STEM Teachers' Successes and Challenges in Implementing Socioscientific Issues

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Abstract**:** This study explores two teachers participating in professional development workshops implementing SocioScientific Issues (SSI) into STEM classrooms. Two research questions were investigated: (a) To what extent did teachers implement SSI into their lesson plans and (b) In what ways did lessons change from the beginning of the workshop?

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We strive: Initial explorations of STEM teachers' successes and challenges in implementing socioscientific issues

Current education reform movements in science and mathematics advocate for teaching science, technology, engineering, and mathematics (STEM) disciplines by solving real-world problems (National Research Council [NRC], 2013; Sadler et al., 2007). Incorporation of socioscientific issues (SSI) into STEM classrooms can provide meaningful contexts for students to learn concepts and practices in these disciplines (Zeidler et al., 2005). Yet common STEM teaching practices rarely allow students, especially low-income students of color (Marco-Bujosa et al., 2020), to connect STEM lessons with their own lives (Zeidler, 2016). While this may not be a result of purposeful resistance to teaching for diversity, teachers may lack the awareness, support, confidence, knowledge, or skills to implement socially relevant curriculum and culturally responsive strategies (Rodriguez, 2005). Moreover, teachers may be hesitant or struggling with some fundamental components of the framework such as inquiry, problem-based learning, argumentation, and authenticity (Authors, 2020). Fortunately, directed coursework and professional development can provide prospective teachers with the knowledge, resources, and experience to develop the necessary skills for effective SSI implementation (Authors, 2020).

The SSI framework consists of debatable issues that can enhance learning of STEM concepts as students engage in real-world and authentic problems (Zeidler, 2014). SSIs are ill-defined problems that have their basis in science, but necessarily include moral and ethical decisions that cannot be resolved through science alone (Ratcliffe & Grace, 2003). As such, SSI can provide meaningful and relevant contexts for students to learn science concepts and practices across STEM fields (Zeidler et al., 2005). Through reflection on their personal experiences, prior knowledge, and cultural background, students' STEM learning will be promoted and their skills developed to inquire about and engage with ill-structured problems and controversial scientific issues (Ziedler, 2014), especially those that have a disproportionate, negative impact on their lives. SSI implementation can provide avenues for teachers to enhance their students' scientific knowledge and literacy skills, such as evidence-based reasoning, consideration of multiple perspectives, and reflective scientific skepticism (Authors, 2021). However, most teachers are unfamiliar with SSI and require coursework or professional development in order to learn how to effectively plan instructional activities by engaging their students on its components (Authors, 2017).

The *USTRIVE project,* funded through a large National Science Foundation Discovery Research in K-12 federal grant, was developed to foster STEM learning for close to 3,000 students in grades 7 – 12 over four years through integrated professional development workshops and the development of professional learning communities focused on supporting teachers in the use of SSI and incorporation of aspects of social justice in their STEM classrooms.

In implementing SSI in the classroom and addressing controversial issues, teachers must be knowledgeable in several key areas within the SSI framework, including logical reasoning, recognizing fallacious reasoning, comparing and contrasting multiple perspectives, engaging in scientific modeling, and more (Zeidler et al., 2002). Successful implementation of SSIs strongly depends on the scientific content knowledge of the teacher, and also the pedagogical knowledge that they bring to bear. By developing understandings of SSIs, particularly those involving local problems, and linking them to effective pedagogical practices, students are given opportunities to analyze and resolve situations that relate directly to them and their lives (Hernández-Ramos, 2021). Shulman (1987) defined the intersection of pedagogical knowledge and content knowledge, situated within teachers' knowledge of the learning context, as Pedagogical Content

Knowledge (PCK), a powerful framework for understanding teacher growth and development. As such, PCK was chosen as the conceptual framework for the current study. Goals of the USTRIVE project included (1) development of teacher PCK to support the capacity to develop, implement and reflect on instructional units that uses SSI to promote students' scientific literacy, cultural competence, and sociopolitical consciousness; (2) development of teacher dispositions toward social justice and SSI; (3) fostering of teacher PCK to develop, write and implement units of study with lesson plans, assessments, and classroom resources.

For the current study, the PCK framework was applied with a qualitative case study methodology to analyze initial findings regarding teacher development after the first semester of implementation of the USTRIVE project. The following research questions guided this study: (a) To what extent did teachers implement SSI and its components in lesson plans designed through USTRIVE workshops and (b) In what ways did their lessons and planning change from the beginning of the workshop?

Conceptual Framework

According to Shulman (1987), PCK is the knowledge teachers require that is essential for them to effectively plan and implement teaching methods to help learners of various levels and backgrounds learn concepts and skills during instruction. PCK exists at the intersection of areas of teacher knowledge that facilitate effective pedagogical decision making. It is a special amalgamation of knowledge and teaching practices that directs teachers' actions while planning and implementing their lessons (Shulman, 1987). PCK in general, and PCK for teaching SSI, includes several subdomains. It includes knowledge about the content and curriculum, such as teachers' awareness of the curriculum goals, objectives, and the vertical alignment and progressions of students' learning (Magnusson *et al.*, 1999; Bayram-Jacobs *et al.*, 2019). It also requires instructional strategies to craft and engage students in debatable issues or questions, support students in their inquiry experiences, and develop their reflective scientific skepticism as they compare and contrast multiple perspectives (Authors, 2020). A teacher's knowledge of instructional strategies includes the teacher's ability to make appropriate choices about pedagogical strategies available in incorporating SSI (Magnusson *et al.*, 1999). This is closely intertwined with the teacher's knowledge of student understanding and assessment. A teacher of SSI must have the versatility to incorporate a variety of teaching strategies that allow students to explore the underlying scientific phenomena, employ reflective skepticism, engage in scientific modeling, compare multiple perspectives, and elucidate their own position, all of which are key components of SSI (Sadler *et al.*, 2019). All of this knowledge is situated within a knowledge of the teaching and learning context. Teaching SSI effectively requires understanding the learning contexts in terms of background knowledge of the experiences, culture, and interests of students, while considering issues that are grounded in their community (Authors, 2020).

Methods

This study employed the PCK framework to guide a qualitative case study methodology to address the stated research questions. Case study research involves the exploration of a bounded "case" or "cases" within clearly defined, real life contexts (Cresswell & Poth, 2016). This methodology allows researchers to delve deeply into complex aspects within the bounded system defined by the selected case (Johnson & Christensen, 2019). According to Cresswell and Poth (2016) cases may be concrete, as in small groups, individuals, or an organization. They may also be more abstract entities like a relationship, a community, or a project. The case for the current study includes two teachers participating in a large-scale U.S. government funded grant that involved weekly workshops and workshops focused on integration of SSI into STEM subject areas. At the time of the study, Ms. Rodriguez held a B.S. in Mathematics and a M.A. Secondary Education and Teaching. She had 19 years of teaching experience and currently teaches in a large urban kindergarten to grade 12 school in Philadelphia. Ms. Rodriguez teaches grades 11 and 12 precalculus. Our second participant, Ms. Anderson, holds a Master's of Education and has been teaching for 22 years. Ms. Anderson teaches in a large urban middle school in Philadelphia. She teaches 6th grade science. These two participants were selected for the case because they demonstrated sophistication in creating SSI Unit Plans based on the rubric requirements defined by the research team of the grant. As such, this allowed us to analyze the differences in improvement from the participants' baseline lesson plans to their most recent.

Case study research is further defined as "a qualitative approach in which the investigator explores a real life, contemporary bounded system (a case) or multiple bounded systems (cases) overtime, through detailed, in-depth data collection involving multiple sources of information and reports a case description and case themes" (Cresswell & Poth, 2016, p. 96). Data analyzed for the current study included information from a baseline questionnaire administered at the beginning of the grant experience and lesson plans developed by the participants. Lesson plan data was analyzed using a rubric developed by the research team and provided to participating teachers. Themes were developed from the initial lesson plan analysis, triangulated across participants and observational data, and compared with baseline data to illuminate areas of growth as well as challenges faced by participants.

Baseline Questionnaire Data

During the first Professional Development (PD) workshop, the teachers were asked to describe a lesson they taught that exemplifies an ideal STEM instruction (See Appendix 1). Next, the teachers recounted the ways, if any, they engaged and motivated their students to learn

STEM with a focus on debatable issues and/or real-world problems. Finally, the teachers expressed any challenges they have encountered in the past when trying to implement a STEM lesson anchored on a debatable issue and/or real-world problem. The baseline questions were chosen to gauge the teachers' perceptions of ideal STEM instruction and to understand what they believed made a STEM lesson exemplary. Second, their answers provided an avenue to get a sense of the teachers' knowledge related to SSI/sTc before engaging in the project. Finally, we strived to understand why the teachers may have not attempted or have been unsuccessful in implementing lessons with a focus on debatable issues and/or real-world problems.

For the baseline data, we used an inductive approach to data analysis to allow the data to speak for itself rather than assigning themes derived from the literature. We created a coding guide based on the initial questions asked at the beginning of the workshop, specifically on implementation of STEM lessons and lessons with a debatable and/or real world issue.

Lesson Plan Data

As part of our professional development workshops from September to December 2021 (3 hours per week, 45 hours total), time was allotted for teachers to develop and write lesson plans by integrating the SSI components in the 5Es framework (e*ngage, explore, explain, elaborate,* and *evaluate*) (REF). Specifically, as part of *engage*, teachers planned and wrote how they would help their students establish relevance by identifying an SSI issue and by exploring the underlying scientific phenomena that are relevant to their students' lived experiences. In *explore*, they indicated their plan on how to engage students in scientific modeling through development, use, evaluation, and revision of scientific models. In *explain*, teachers wrote how to help their students express new learning by considering issue system dynamics that social, political, economic, ethical, and religious considerations associated with their SSI debate. As part of *elaborate*, teachers wrote a plan to help students apply their prior learning and acquire new learning experiences by asking them to employ reflective skepticism and compare and contrast multiple perspectives as part of SSI. Finally, in *evaluat*e, they wrote how to help their students measure their learning by elucidating their own position or solution at the end of the SSI debate or statement.

For the two lesson plans that were submitted by Ms. Rodriguez and Ms. Anderson in December 2021, we used deductive coding guided by the SSI framework of (Boyatzis, 1998). We used these codes to find themes and analyze the extent to which the teachers incorporate SSI components in their lesson plans and describe ways their lessons change from the beginning to the midterm point of the first year of our professional development workshops.

Findings

Ms. Rodriguez described two lessons which she felt exemplified ideal STEM instruction. In a derivatives unit, her students determined the maximum area of a protesting space while considering a six-foot distance between each protestor. In the second lesson she described, Ms. Rodriguez also challenged students to collect data related to the extinction of a subspecies of a rhino. Students identified a regression model to best fit the data, used the model to make predictions, decided if the chosen model was the best fit by providing supportive evidence, and created an alternative model if needed. Ms. Anderson shared an ideal STEM lesson from the Waterworks curriculum called Rain to Drain. Students need to construct a situation out of the materials and explain what is happening to the amount of water used in the experiment and how they can save more water.

Neither teacher had previously taught a STEM lesson with a debatable issue focus; however, Ms. Rodriguez has had discussions in the past regarding pollution in which she had students take sides. Both teachers described past challenges with incorporating a debatable issue and/or real-world problem into STEM lessons. Ms. Rodriguez stated that it was a challenge to find real and relevant data to use in her lessons, while Ms. Anderson conveyed challenges she has encountered are time, behavior, and the reading levels.

Analysis revealed evident growth in participants' ability to implement specific aspects of SSI into their lessons. The lesson plans developed by Ms. Rodriguez and Ms. Anderson promote real-world and STEM-based issues that are relevant to students' lives and their community. In particular, the SSI debatable questions in Ms. Rodriguez's lessons are, "Should the government regulate housing prices?" and "Should there be a limit on housing prices?" She hoped to engage her students in the following real-world problem: "Property prices are inclining and forcing people to abandon the idea of becoming homeowners, [which] impact homeowners and renters." She continued by explaining that this problem of unfair cost of housing promotes inequality to those who can and can't afford to buy and rent houses. At the end of her lessons, Ms. Rodriguez hopes her students will be able to: (a) "Explain the fundamental concepts of time value of money," (b) "Calculate present and future value of a single and a series of cash flows," and (c) "Apply the concepts and calculations of time value of money in personal financial management." Similar to Ms. Rodriguez, Ms. Anderson's lesson engages students in an SSI and a real-world problem of "whose job is to provide clean water to our community?" According to the description of her lesson, "We assume that we can turn on our faucet in Philadelphia and water that is acceptable for living will exist." She continued by saying that "families rely on bottled water to accomplish daily living," which implicitly suggests possible impact to the environment (use and recycling of plastics) and the added cost of buying them. At the end of her lessons, Ms.

Anderson hopes her students will be able to “explain the need, usage, and importance of water as a person, community, and global community.”

In addition to identifying an SSI issue, our two teachers present two different approaches on how to engage their students in exploring the underlying scientific or mathematical phenomenon. Ms. Rodriguez plans to show a short video from MTV Cribs and ask the following questions to elicit her students' initial ideas and interests with regards to buying or renting a house. Then, she will ask her students to go to Zillow.com to choose two homes in the region and to analyze the cost of these homes with annual salary per profession and cost of education. On the other hand, Ms. Anderson will use an activity to discuss why water is important and how humans use water. The difference between the two pedagogical approaches is that Ms. Rodriguez plans to elicit her students’ initial ideas and dispositions on SSI, while Ms. Anderson plans to use an activity without eliciting her students’ prior knowledge or beliefs.

In terms of engaging students in scientific modeling through development, use, evaluation, and revision of scientific models as part of SSI, we found that both lessons describe ways students can participate in discussions and investigations. For instance, Ms. Rodriguez has several questions to guide her students’ inquiry: “(a) What is the standard of living in certain areas? (b) What is the median wage in certain areas? (c) Compare crime rates and poverty in those areas? (d) What is the population in Philadelphia and surrounding areas? (e) Is there a correlation between population and standard of living? and (f) How do population/standard living relate to crime rates/poverty?” On the other hand, Ms. Anderson describes a series of investigations: “Task card 1- Water Usage Chart- How do we use water? Task card 2- Water Descriptive Words- How is water essential (define in your own words what this word means) to life and culture? Task Card 3- Global Awareness Fact Sheet- How do you relate to the facts provided on the Global Awareness Fact Sheet? Task Card 4- Power of Water - an article regarding Tsunamis and Hurricanes - Explain how water behaves?"

Unfortunately, we found that both lessons provided little or no evidence in considering issue system dynamics of social, political, economic, ethical, and religious considerations associated with their SSI debate. For example, in Ms. Rodriguez's lesson, she plans to show a video on the housing crisis in the U.S. and the growing movement to end single family housing zones. She also plans to provide reading material about the housing market over the last 20 years and invite a guest speaker on financing homes. However, it is implicit how her planned activities could promote discussions with regards to social, political and economic aspects of the cost of buying homes. Similarly, Ms. Anderson's plan does not include explicit consideration of system dynamics: "Students will present their findings from the Task card with the class."

In addition to system dynamics, we also found little or no evidence of employing reflective skepticism and comparing multiple perspectives in their lesson plans. Although Ms. Rodriguez's activities will promote problem solving, it is unclear if and how students will question and critique the different information they find or were presented to them. Instead, students were tasked to analyze different variables before answering if they can afford their dream home: "Given three mortgage rates from different banks, they have to calculate the mortgage payments using the future/present value formulas and the total amount paid over 15- and 30- years. They have to consider any student loans, bills, and other debts." On the other hand, she plans to ask her students to do a role play: "Who are the stakeholders in housing prices?" that could potentially promote the examination of multiple perspectives from realtors, buyers, tenants, investors, banks, government, and others. Ms. Anderson plans to ask her students to reflect on "What happens as a result (as an individual, community, globe) of actions we take towards water?" Note that this question will examine results from multiple sources, which is different from comparing and contrasting multiple perspectives.

Finally, we found that both lessons allowed students to reflect and state their own position or solution at the end of the SSI debate or statement. Specifically, Ms. Rodriguez will ask her students to "make a decision based on evidence; create presentation slides and script for student presentation." While Ms. Anderson will provide an exit ticket question: "how do I show I value water?"

Conclusion

The following research questions guided this study: (a) To what extent did teachers implement SSI and its components in lesson plans designed through USTRIVE workshops and (b) In what ways did their lessons and planning change from the beginning of the workshop? Our findings suggest that although Ms. Rodriguez and Ms. Anderson had science and math contexts in mind in the beginning, neither teacher had attempted to implement an SSI component prior to the PD. Both teachers recounted challenges with incorporating a debatable issue and/or real-world problem into STEM lessons in the past. For example, Ms. Rodriguez stated that it was a challenge to find real and relevant data to use in her lessons, while Ms. Anderson conveyed challenges with time, student behavior, and the reading levels of the students.

After engaging in 15 weeks of PD focused on SSI, we found that the teachers provided better real-world and SSI contexts in their lessons than in the beginning of our workshops. The lesson plans developed by Ms. Rodriguez and Ms. Anderson both promote real-world and STEM-based issues relevant to their students' lives and their community. Ms. Rodriguez aimed to introduce her students to the inequality that those who can and can't afford to buy or rent houses because of the unfair cost of housing. Similarly, Ms. Anderson focused on the importance of freshwater for people, communities, and the world.

Interestingly, our teachers presented two different approaches on how to engage their students in exploring the underlying scientific or mathematical phenomenon. However, we found that both lessons provided little or no evidence in considering issue system dynamics of social, political, economic, ethical, and religious considerations associated with their SSI debate. They also showed little or no evidence of employing reflective skepticism and comparing multiple perspectives in their lesson plans. These challenges of our teachers are common to those who are unfamiliar with SSI and who are starting to develop their PCK toward SSI (Zeidler, 2014; Lee, 2016). Finally, we found that both lessons allowed students to reflect and state their own position or solution at the end of the SSI debate.

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Appendix 1: Baseline Data Questions

1. Please describe a lesson that you taught that exemplifies your ideal STEM instruction.
2. In what ways, if any, have you engaged and motivated your students to learn STEM with focus on debatable issues and/or real-world problems?
    1. If yes, please describe your lesson.
    2. If not, why not? What challenges have you encountered?