The Eurasia Proceedings of
Educational & Social Sciences (EPESS)
ISSN: 2587-1730

**The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2023**

**Volume 31, Pages 119-126**

**ICRESS 2023: International Conference on Research in Education and Social Sciences**

# SSI: Teachers Make STEM Concepts Relevant to Their Students

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**Abstract:** Socioscientific issues (SSI) are ill-defined problems that teachers could use to make STEM concepts meaningful and interesting for their students. However, it is challenging for most teachers to plan and implement SSI in their classrooms because they lack the knowledge and teaching repertoire. We conducted a qualitative case study of five teachers to answer our research question: How did teachers' pedagogical content knowledge (PCK) of SSI develop by the end of the professional development program? Our analysis of interviews, video reflection, and lesson plans pointed to teachers' PCK of understanding of students and instructional strategies as they engage their students in identifying the issue, considering issue system dynamics, and comparing multiple perspectives (social aspects of SSI). Our findings supported the teachers' PCK model that Lee (2022) proposed particularly the knowledge of students' SSI learning and teachers' choices of teaching and learning strategies for a particular group of students. Specifically, the teachers in our case study were able to use SSI contexts such as GMO foods and effects of fast fashion (chemicals on manufacturing and discarding clothes) on water quality on students' motivation to learn about the scientific and ethical debates on GMOs and water resources. Moreover, a teacher was able to ask students to consider issue system dynamics such as habits, culture, lifestyle, costs, and income when examining different food choices. They were also able to engage students in developing, testing and analyzing scientific phenomena such as the effect of chemical dyes in clothing on water and genetically modified foods. They were able to incorporate elucidating one's position on SSI and employing reflective scientific skepticism in their lesson ideas. Finally, teachers in our study used videos, guided questions, town hall meeting presentations, investigations, and other active learning strategies with their students.

**Keywords:** Socioscientific issues, Teacher education, STEM, Pedagogical content knowledge, Lesson study

## Introduction

The Socioscientific issues (SSI) based science education calls for the ethical and moral considerations of the issue at hand with an acute awareness of the impact on society (Zeidler, Sadler, Simmons, & Howes., 2005). SSIs draw from students' daily lives and call upon them to explore the connections between scientific phenomena and their historical, political, and social aspects. Albe's (2008) study of 11th graders found working with SSI was "very motivating for the students" (p. 85). Klosterman and Sadler's (2010) study of 83 high school students found their study "provides support for the use of SSI as a context for learning science content" (p. 1017). Tal and Kedmi (2006) found SSIs promote "higher order thinking skills of argumentation and value judgment, which are central constituents of decision-making processes" (p. 615). Zeidler et al. (2005) note SSIs are controversial issues where scientific inquiry calls for "evidence-based reasoning" (p. 698) and leads to "character formation/conscience building" (p.698). Scientific knowledge in SSI classrooms is built through engaging students in scientific modeling (Peel et al., 2019) and scientific discourse (Zeidler & Nichols, 2009).

However, pre-service and in-service teachers face several challenges while planning and teaching SSI lessons in their classrooms. Walker and Zeidler (2007) note teachers need professional development to gain the "pedagogical techniques necessary to create content-specific and NOS-embedded learning activities that emphasize discourse and debate" (p. 1405). Zeidler (2016) notes most of the current STEM programs are "conceived and entrenched in science, technology, engineering and mathematics siloes and then one moves to the "crosscutting connections among the areas" (p. 17). Undermining the development of scientific literacy. Macalalag, Johnson, and Lai's (2020) study of 24 pre and in-service STEM teachers noted the planned "instructional activity may not engage students in broader socioscientific and cultural contexts or perspective taking" (p. 390). thus impacting student scientific literacy development. Teachers in Johnson, Macalalag, and Dunphy's study struggled with "incorporating scientific argumentation through SSI cases" (p. 1) and the teachers in Macalalag and Parker's (2016) study struggled with certain science concepts (motion and energy), inquiry (planning the investigation), and engineering design (identifying constraints).

Minken et al. (2021) found teachers in their study struggled to ask guiding questions that would have helped students determine the credibility of the sources of information ("reflective scientific skepticism", p. 137). The researchers concluded teachers needed help to support student claims of SSI understanding with evidence. Previously Minken et al. (2020) described how elementary teachers implemented SSI in their classroom instruction and the effects it had on student learning. They found that over two-thirds of pre-service and in-service teachers who had not previously taught lessons involving SSIs expressed an intention to do so at the end of a workshop on the SSI framework. Macalalag et al. (2019) found that teachers became more focused on real-world examples of SSI, motivating students to learn STEM concepts and practices, and teaching by observing nature after participating in the STEM teaching methods course.

Barendsen and Henze (2017) noted that various elements of a teacher's pedagogical content knowledge (PCK) components (knowledge of goals and objectives, knowledge of student understanding, knowledge of instructional strategies, and knowledge of assessment, p. 1149) are interconnected but "can be investigated separately" (p. 1143). Their study of an experienced chemistry teacher found the teacher focused mostly on personal life as opposed to society (knowledge of content, under the goals and objectives category). The teacher's practice often differed from the plan, for example, while the teacher in this study noted they "monitor students' understanding by check questions" (p. 1162). In reality, the classroom practice was disjointed at the observer very few opportunities to check understanding and at the same time, the teacher often gave the answers before allowing students any time to think. In another example, the teacher noted they intend "to stimulate students to come up with questions" (p. 1162). But in the researcher's observation, they lectured predominantly. If and when students wanted to contribute to the issue at hand, their contributions "tended to be ignored of cut off" (p. 1162). Thus demonstrating the deep need for professional development.

Bayram Jacobs et al. (2019) noted teachers need to pay equal attention to "science content and SSI skills" p. 1207), which means they need to have a good understanding of student difficulties and repertoire of "appropriate instructional strategies" to teach SSIs. Bayram et al. (2019) argued for PD and curricular materials to help teachers develop the needed pedagogical content knowledge PCK) to teach SSIs. Some strategies noted in this study include "argumentation, discussion (including ethical and religious aspects), and group work" (p. 1220). Teachers also used various "pedagogical tools" (p. 1220) such as decision-making tools and tools to support development of explanations. To answer some of these challenges, we conducted a qualitative case study to answer the following research question: How did teachers' pedagogical content knowledge of the social, scientific, and discursive components of SSI develop by the end of the professional program?

## Teachers' Pedagogical Content Knowledge (PCK) of SSI

According to the NRC the teachers' "special understandings and abilities" (1996, p. 62) that coalesce as their knowledge of the students and student learning, the teaching and learning of the science content and curriculum is the teacher's PCK. This very PCK enables teachers to adapt teaching to the target student populations. Bayram-Jacobs et al. (2019) write, "Teacher knowledge is an indicator of the quality of instruction and teacher behavior in the classroom" (p. 1209). PCK helps teachers' better use the content knowledge to explain concepts for example, Kulgemeyer & Riese's (2018) study of 198 German pre-service teachers found "PCK mediated the path of CK to the teaching quality in explaining situations" (p. 1413).

The pre-service teachers in Beyer and Davis's (2012) study were tasked to critique and adapt inquiry-oriented science lesson plans and curricular materials. The researcher noted, "With support, novice teachers are able to develop and apply their PCK" (Beyer & Davis, 2012, p. 152). But, these teachers also struggled with assessment (focusing on assessment of science concepts, p. 151), strategies to include all students, and knowledge of the science curriculum (p. 143). For example, teachers had "alternative ideas about what and how to assess" (p. 143), but most also failed to provide opportunities to apply learning to "new task or situation" (p. 143). Teachers held "naïve ideas" (p. 145) and assumed the curricular materials were "aligned with standards" (p. 145), thus failing to check standards and alignment for themselves. Most of the teachers also failed to help students connect science to the student's "personal, cultural, and/or social experiences" (p. 145). They almost always provided the definitions of various terms at the start of the lesson, in contradiction to how NGSS (2013) expects science lessons will be facilitated. The teachers struggled with inquiry for example, they did not understand what "making predictions during investigations" (p. 146) meant, interpreting it as eliciting the student's prior knowledge instead. They also did not have a good understanding what creating evidence-based explanations or how to go about it (p. 146). Beyer and Davis (2012) found "teachers' PCK improved significantly" (p. 130) with multiple practice opportunities.

Lee (2022, p. 305) describes a model of PCK for teaching SSI where the content knowledge (CK) to teach SSI informs the teacher's orientation for teaching SSI (OTS). This OTS is further connected to the teacher's knowledge of instructional strategies for teaching SSI (KIS); knowledge of curriculum (KC); knowledge of student SSI learning (KSL); knowledge of learning contexts (KLC) and knowledge of assessment of SSI learning (KAS) (Lee, 2022, pp. 305-306). The CK is informed by the teacher's knowledge of the nature of science and knowledge of cutting-edge science and technology. Astutely, teachers are aware of the perceptions of parents, peer teachers, and school administrators on the chosen SSI, they are also aware of the availability of time, quality, and availability of resources to implement the SSI, this represents the teacher's knowledge of learning contexts (KLC) (Lee, 2022, pp. 307-308). Learning about SSI can result in teachers' desire to implement the framework.

The 15 pre-service Korean teacher participants in Lee's (2022) study struggled with creating "SSI scenarios" (p. 311). For example, although they understood the scientific content, they could not link the science to the "social and moral connotations" (p. 313) of the issue at hand. They also struggled with seeking multiple perspectives, for example, they would divide students into pros and cons to debate SSI issues (p. 314). They also struggled with classroom discussions. For example, if the students brought up unexpected items, the teacher got "lost in the question of how to support students in moving forward" (p. 317). The students came up with "limited information" (p. 317) so debates were of a lower quality and the teachers learned they needed to better facilitate student searches and reasoning. At the conclusion of the study, the pre-service teachers reported they were better prepared to teach SSI lessons (p. 324) by participating in the SSI-grounded teacher education program (p. 301).

## Research Methods

We conducted this qualitative case study (Marshall & Rossman, 2011) in order to answer our research question: *How did teachers' pedagogical content knowledge of the social, scientific, and discursive components of SSI develop by the end of the professional program?* This study built off of prior research conducted over the course of the Integrating STEM in Everyday Life conference series. For a more detailed explanation of the conference series, please refer to our previous work (Macalalag et al., 2019, 2020). To answer our research question, we analyzed interview, video reflection, and lesson plan data gathered from five teachers who participated in the Integrating STEM in Everyday Life conference series. This study took place over the course of a 15 month-long professional development conference series comprising one kickoff conference event, a series of four intensive workshop sessions, followed by a culminating conference event. At the initial kickoff conference, we introduced the SSI framework and recruited 29 predominantly secondary STEM teachers to participate in our intensive workshop series, during which participants deepened their PCK of SSI by developing and implementing SSI lesson plans. At the culminating event, participants in our intensive workshop series developed their own workshops that they presented to other educators from outside that program.

Participants in this study included five in-service grades Kindergarten to 12 teachers from urban schools in the northeast of the United States of America. These teachers were selected in part because they represent a variety of experience, content area, grade level, and sophistication in their SSI lesson plans and because they volunteered to create video reflections. Teacher experience ranged from teachers with less than a decade of experience to those with over three decades of experience. The selected participants represented content areas including Mathematics, Science, English, and Special Education.

Data for this study came from three sources: interviews, lesson plans, and video reflections. While all (n=5) study participants submitted a final lesson plan and a video reflection, only three volunteered to participate in interviews. The final lesson plans were developed by teachers in collaboration with peers and an assigned university faculty mentor to incorporate the socioscientific issues framework (Sadler et al., 2019) into their teaching practice, and were collected from teachers' shared google folders after the end of the professional development program. Near the end of the program, we asked teachers to complete video reflections, which were screencast presentations from teachers that elaborated on the successes and challenges of their SSI lesson development and implementation. Finally, teachers were recruited for qualitative, semi-structured interviews at the conclusion of the professional development program. During these interviews, teachers provided insight into their knowledge, experience, and thinking around the three components of SSI (social, scientific, discursive). The social components of SSI consisted of identifying the issue, considering issue system dynamics, and comparing and contrasting multiple perspectives. These were considered social codes because they revealed the degree to which the lessons considered political, moral, cultural, and ethical components of the problem (Zeidler, 2016), citizenship education (Barrue & Albe, 2013) and values (Lee et al., 2013) class. The scientific components of SSI, knowledge of scientific phenomenon and STEM modeling, were designated as such due to their scientific nature. Finally, the discursive components of SSI included employing reflective scientific skepticism and elucidating their own position/solution. In analyzing the lesson plans, teachers were given a score of 1-3 for each code in the social, scientific, and discursive components based on their level of sophistication according to our previously developed SSI rubric (Minken et al., 2021). This score was then scaled for ease of comparison by converting the score to a percentage of total possible points in a given component: since there are three codes each for social and scientific, these both had a maximum score of 9, while the discursive components of SSI consisted of only two codes, giving a maximum score of 6.

## Findings

As shown in Figure 1, teachers in this study evidenced varying levels of sophistication in their lesson planning across the different domains of SSI (i.e., social, scientific, discursive). All teachers showed more sophistication in their planning of the social components of SSI than in their planning around the scientific and discursive components. However, while levels of sophistication in planning scientific components of SSI were only slightly less (within 22%) than the social components, all teachers showed relatively minimal evidence of sophistication (< 50%) regarding the discursive components of SSI. This suggests that the primary focus for teachers in their lesson planning was on the social and scientific components, as opposed to the discursive components of SSI, such as reflective scientific skepticism and elucidating one's own position or solution with respect to the SSI. In the remainder of this section, we describe some examples of teachers PCK with respect to the social, scientific, and discursive components of SSI.

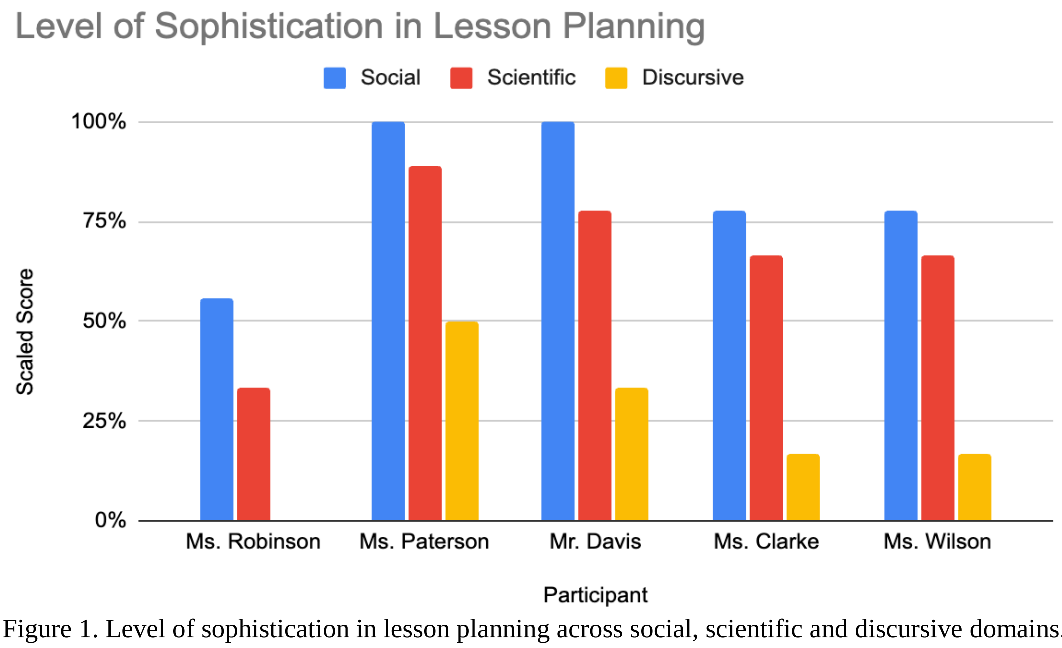


Figure 1. Level of sophistication in lesson planning across social, scientific and discursive domains.

**Social Components of SSI**

Our analysis of lesson plans showed social components of SSI such as identifying the issue, considering issue system dynamics, and comparing and contrasting multiple perspectives. For instance, in the lesson written by Ms. Paterson (pseudonym), she asked her students to create a campaign to argue for or against genetically modified organisms (GMO) foods in schools. "You have been hired as a Marketing Representative for a local politician from our city who is running for office. S/he wants you to help her/him to create a campaign arguing for or against GMO foods in our schools. Provide research based arguments to back up her/his claims. Support your ideas with mathematics, i.e. probability, graphs, etc." Ms. Paterson used the issue of GMO foods to elicit what her students know about it and to use mathematics to communicate their ideas. Her lesson plan also included asking students to consider system dynamics: "Policy makers will need to decide if the claimed benefits are worth the costs to public and private funding sources, and to families purchasing meals. We are all, for obvious reasons, very aware of and concerned about the food we eat, though differences in habits, culture, race/ethnicity, and lifestyle, in addition to income and cost considerations, lead to very different food choices across the United States." In this example, Ms. Paterson asked her students to think about different systems such as income, costs of food, culture, lifestyle, and others when arguing for and against GMO foods.

Our analysis of data on the social components of SSI also pointed to teachers' PCK of understanding students. For example, Mr. Davis mentioned in his interview about the possible struggles of students to understand individual actions and to explain why people accept or ignore evidence: "I think they're struggling to differentiate between what actions people take, for whatever reasons, and what actual data-driven evidence-based decisions would be like. Or what they are. That just because a leader doesn't do something, doesn't mean that it's the right thing to do. They are following the appeal to authority and that won't necessarily lead you to the correct decision." Mr. Davis pointed out that students struggled whether to accept or not explanations or decisions made by people in power. In addition to PCK of understanding students, our data analysis showed teachers' PCK of instructional strategies toward teaching SSI. For instance, Mr. Davis mentioned in his interview the different instructional strategies he used to teach about the GMO foods debate. "I started off by allowing the students to just voice their own opinions and views on GMO foods, about would they eat them or not, do they not pick foods for that reason, etc. and then, to include multiple perspectives, I assigned them different societal roles in different situations and they also had to decide whether they were going to grow GMO foods in their hypothetical country or area…" In addition to asking his students to voice their own positions and research on multiple perspectives, they had to defend them using evidence: "…in each step where we had a discussion, there would be critical stakeholders represented by the students, and they would have to think about and research what roles those stakeholders might have and what positions they would have, and then defend them, even if they were not aligned with the students own perspective on the topic…What is the argument, what is the evidence, and why is that evidence not compelling for you?" Students also worked in groups while doing these activities in class.

**Scientific Components of SSI**

We saw scientific components of SSI and teachers' PCK of understanding students in our analysis of data. In the lesson plan written by Ms. Clarke, she mentioned possible conceptions and alternative conceptions of students with regards to water use and chemical pollution from clothes we wear. For example, students may or may not know how their household and daily use of water could impact others and how chemicals on clothes they wear could affect water quality. "Students may have a hard time conceptualizing how water usage in Philadelphia could impact someone else in the neighboring towns and/or cities. Students may need to be scaffolded through different parts of the lesson depending on whether or not they have had some real-world experience with the issues discussed. I.e., they may have limited experiences buying their own clothes so they are not aware of how much things cost, etc." In this lesson on fast fashion, Ms. Clarke hopes to have students examine the chemical dyes used to make clothes and how manufacturing and washing of clothes could impact water quality. In terms of teachers' PCK of instructional strategies, Mr. Davis used a video and guided questions on Super Salmon to engage students on SSI on classical vs.transgenic breeding. Some of the guided questions included: "What allows transgenic salmon to grow in winter? What are some possible consequences if transgenic salmon escape from their pens into the ocean population? How might transgenic salmon affect the evolution of other salmon populations?" These questions will allow students to analyze what they saw on videos and elicit their knowledge and position with regards to transgenic breeding. In addition to using video and guided questions, Mr. Davis shared during his interview using hands-on investigation, analysis, discussion, and reading articles as instructional strategies to examine an SSI. "They would have this activity where they're going around the room and if they're within six feet of each other, they have to exchange the water in the cup or spray each other with the spray bottle a little bit and then after like 10, 15, 20 minutes, we would put the blacklights on and they could see where the blacklight stuff had spread, and you could see that with one student, how far the stuff had spread." Mr. Davis is using this investigation to show "how easy it is for things that are contagious to spread.. from one person to another." These examples exemplified teachers' PCK of instructional strategies as they teach scientific components of SSI.

### Discursive Components of SSI

Our data analysis also showed discursive components of SSI such as employing reflective scientific skepticism and elucidating their own position/solution. In terms of teachers' PCK of understanding students, Mr. Davis mentioned during his interview that it is beneficial for teachers to hear students' point of view on SSI that they are learning. "I think the framework is beneficial for so many scientific concepts and allows students to say what they think, to voice that and defend it, and then to challenge them with other points of view." He continued by saying that this process will allow students to explain their ideas and listen to others. In addition to elucidating one's position, Ms. Robinson mentioned the importance of questioning the credibility and sources of information. "You just have to talk to them about reliability and whether or not the articles are valid and how to determine that, and where the sources are coming from… Because a lot of times the magazines and articles that they're gonna get are not gonna be scientific articles or science based articles from some kind of a journal, so you need to start making them aware of the types of sources and figuring out which ones are valid and not valid." The ability of students to evaluate claims or explanations and to look for potential biases are part of scientific skepticism. In terms of teachers' PCK of instructional strategies within the discursive components of SSI, Ms. Paterson described how she would help students to review their sources by using a checklist while conducting library research. "So I would provide students with practice on how to find and use resources for answering questions or solving problems, using perhaps a checklist, which shows the credibility of the source. So asking them questions such as, as they're reading, I could ask them: 'Is the information relevant? Is it current? Is it accurate?' Ask them questions about the author: "Is the author an expert, a scholar on the topic? Are there any biases given?" According to Paterson, using this checklist will help her students to examine and discuss sources of information. Another instructional strategy proposed by Ms. Clarke was to engage students in a scenario of presenting their position and information to a city council. "As a member of the City Council, you will be asked to pick a side of this issue and create a presentation on it to influence the rest of the Council. Back it up using research from the internet. We will then vote as a class on the presentations and write a letter to the City Council sharing our insights." This scenario is a good example of discursive components of SSI such as employing reflective scientific skepticism and elucidating their own position/solution.

## Conclusion and Discussion

SSI are real-world, ill-defined problems that teachers could potentially use to engage and motivate their students to learn STEM concepts (Zeidler, 2016). However, it is challenging for most teachers to plan and implement SSI in their classrooms because they lack the knowledge and teaching repertoire (Macalalag, 2020). We conducted a qualitative case study with five teachers in order to answer our research question: *How did teachers' pedagogical content knowledge of the social, scientific, and discursive components of SSI develop by the end of the professional program?* Our findings supported the teachers' PCK model that Lee (2022) proposed particularly the knowledge of students' SSI learning and teachers' choices of teaching and learning strategies for a particular group of students. Specifically, the teachers in our case study were able to use SSI contexts such as GMO foods and effects of fast fashion (chemicals on manufacturing and discarding clothes) on water quality on students' motivation to learn about the scientific and ethical debates on GMOs and water resources. Moreover, a teacher was able to ask students to consider issue system dynamics such as habits, culture, lifestyle, costs, and income when examining different food choices. Similar to the work of Westbrook and Breiner (2019) who engaged their teachers in discussing the water quality crisis in Flint, Michigan, our teachers were able to use real-world examples to motivate students to learn concepts in science and mathematics. We saw that our teachers were able to help students not only to voice and defend their opinions, but also evaluate claims and evidence presented to them as part of scientific skepticism. In terms of teachers' PCK of instructional strategies, teachers in our study used videos, guided questions, town hall meeting presentations, investigations, and other active learning strategies with their students. Such PCK points to the knowledge of teachers to enact suitable teaching pedagogies for their students (Shulman, 1986; van Driel et al., 1998).

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

## Acknowledgementsor Notes

* This article was presented as an oral presentation at the International Conference on Research in Education and Social Sciences ( www.icress.net ) held in Budapest/Hungary on July 06-09, 2023

*This material is based upon work supported by the National Science Foundation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We would like to thank our teachers for volunteering to participate in this study.

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**To cite this article:**

Macalalag, A.Z., Minken, Z., & Varma, C. (2023). SSI: Teachers make STEM concepts relevant to their students. *The Eurasia Proceedings of Educational & Social Sciences (EPESS), 31,* 119-126.