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Minken, Zachary; Macalalag, Augusto Z. Jr.; and Richardson, Greer, "Developing Teachers' Intentions of Incorporating Socioscientific Issues in Lesson Design" (2020). *Faculty Curated Graduate Works*. 1.
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Developing Teachers' Intentions of Incorporating Socioscientific Issues in Lesson Design

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Abstract: In an effort to increase students' informed decisions and evidence-based argumentation and perspective taking in the STEM classroom, this case study explored the ways in which teachers' thinking and intention of incorporating Socioscientific Issues (SSI) into their lesson plans change after participating in an experiential workshop. Recognizing the difficulties inherent in SSI implementation, the day-long teacher development implemented a multi-layered approach which included declarative and procedural knowledge construction, namely understanding SSI components, SSI lesson planning, and learning STEM topics through the SSI framework. Pre-post conference questionnaires and lesson analysis showed that teachers were adept in developing SSI-focused lessons. In addition, the majority of teachers who had not previously taught an SSI lesson, did intend to develop SSI lessons in the future which included scientific phenomena or system dynamics. Implications for STEM teacher development are discussed.

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http://doi.org/10.46951/202085

Introduction

Current reforms on science, technology, engineering, and mathematics (STEM) education require educators to not only utilize science and engineering practices and cross-cutting concepts in teaching disciplinary core ideas (National Research Council, 2013), but also to focus on enhancing the ability of students to make informed decisions and evidence-based argumentation by engaging around socioscientific issues (SSI) in the classrooms (Zeidler et al., 2005). For instance, the SSI context on the global warming debate helped 12th grade students to discuss the advantages and disadvantages of energy production and consumption as well as positively influence students' ability to consider scientific data, co-production and interpretation of knowledge between science and society, and the social and political dimensions of global warming (Albe & Gombert, 2012). However, the study conducted by Saunders and Rennie (2013) suggests that teachers struggle to effectively implement SSI instruction, despite the positive impact it has on student learning. Thus, the focus of this study was to provide opportunities for teachers to learn how to use SSI in their instruction and to brainstorm ideas for lessons that incorporate evaluation and argumentation of multiple perspectives. Our research question is: In what ways do teachers' thinking and intentions of incorporating SSI in their lesson plans change after participating in the SSI workshop?

Several professional development programs showed mixed success in educating teachers of SSI instruction. For example, Çalik et al. (2014) studied teacher education programs with 1,600 prospective teachers in Turkey to help them develop their scientific thinking and habits of mind in order to effectively engage in SSI contexts presented to them. The study showed that it was challenging for prospective teachers to evaluate evidence and to support their arguments. Specifically, they tend to trust arguments from authority figures rather than demand for the evidence (Çalik et al., 2014). In another study conducted in South Korea showed that while most teachers perceived the importance of SSI, only a small number of teachers implemented SSI in the classrooms. In particular, the study found low teacher beliefs related to teaching SSI, perceived lack of time and resources, and emphasis on preparing students for admission to universities as obstacles that hindered their ability to teach SSI (Lee et al., 2006). The findings from a study conducted in France suggested teachers held competing views on citizenship education. While the majority of teachers focused on the importance of learning subject matter content, fewer teachers showed the will to develop their students' skills associated with engaging in debates and political decisions. Moreover, these teachers focused on their subject matter content without incorporating the controversial case-based issues of SSI (Barrue & Albe, 2013).

Literature Review

The SSI Framework in Classrooms

The SSI context can provide students opportunities to learn methods of inquiry while solving problems, evaluating claims from data, considering ethical and moral implications of their decisions, weighing multiple perspectives, and engaging in argumentation, all of which are essential characteristics for developing scientific literacy, ethical thinking, and personal character (Saunders & Rennie, 2013; Zeidler, 2014). Teachers who implement the SSI framework in their classrooms should

learn to include the following components: (a) identify the issue, (b) explore and explain the underlying scientific phenomena, (c) engage in scientific modeling, (d) consider system dynamics, (e) employ reflective skepticism, (f) compare and contrast multiple perspectives, and (g) elucidate their own position or solution (Sadler et al., 2019). Several examples of teachers' implementation of the SSI framework in their classrooms included the controversy and challenges associated with global warming and the greenhouse effect (Klosterman & Sadler, 2010), stem cell research, euthanasia, marijuana use, fast food health (Eastwood et al., 2012), and green energy technologies (Rose & Barton, 2012). These SSI contexts provided ways for teachers to enhance students' science content knowledge, ability to study the empirical and culturally embedded Nature of Science (scientific knowledge of the natural world is tentative and relies on iterative science inquiry processes of evidence-based explanation and argumentation from people of all cultures), and aptitude to evaluate the different assumptions and claims made during a discussion on SSI.

The Challenges of Teachers in Planning and Conducting an SSI Instruction

The implementation of SSI instruction has its challenges for teachers. A study conducted by Forbes and Davis (2007) that explored preservice teachers' critique and adaptation of curriculum materials on SSI suggested a tension between the science concepts and potentially contentious SSI contexts. The preservice teachers in their study showed difficulty in providing SSI contexts that were accessible to students while teaching the science concepts. Moreover, their lack of experience in learning through SSI and insufficient knowledge of the science concepts in their lessons contributed to the challenge of adapting SSI lessons. In another study with preservice science teachers in Turkey, Topcu et al. (2010) found that participants in their study were not adept at informal reasoning in the context of SSI. In particular, most of their preservice teachers were unable to provide counterarguments and rebuttal. In a study that analyzed preservice teachers' argumentation in SSI in Canada, the findings of Kim et al. (2014) suggest that preservice teachers were not familiar with challenging information and evidence during argumentation, which pointed to them not being aware of the importance of evidence or not feeling comfortable being critical of their peers during argumentation.

Several Successes in SSI Instruction

Although SSI is challenging to enact, in a study conducted by Saunders and Rennie (2013) with inservice teachers in New Zealand, the researchers found that their pedagogical model for ethical inquiry on SSI supported their teachers in: (a) providing a clear pathway for them to address controversial issues, (b) helping to develop pedagogical knowledge to engage and motivate their own students in SSI, and (c) increasing both teachers' and their students' knowledge about ethical decision making. In Thailand, the study of Nuangchalerm (2009) showed preservice science teachers' beliefs in socioscientific issues-based education's ability to promote higher order thinking, discussion skills, scientific argumentation and inquiry-based learning. Additionally, Macalalag et al. (2019) saw preservice and inservice U.S. teachers' positive views of teaching controversial and complex case-based issues shifted after attending a graduate course with local and international field study travel. The researchers found shifts in

teachers' perceived cultural practices of reducing carbon dioxide in everyday activities and in teachers' teaching of SSI in their classrooms. For instance, teachers initially thought of using carbon footprint (calculating contributions to carbon dioxide emission) in a lesson without considering the cultural context. However, after the course and field study, they realized that culture such as ways of selecting and using vehicles to do errands, usual practices of buying food from grocery stores or wet markets, and approaches of washing laundry in the United States compared to another country influence how individuals and groups of people contribute to carbon dioxide emissions.

Methodology

In an effort to address the complex nature of SSI instruction and learning, this case study examined the impact the SSI workshop, in the form of a STEM conference series, had on teachers' intentions regarding SSI lesson planning. The case study design (Merriam & Tisdell, 2016) was chosen to provide "an in-depth description and analysis of a bounded system" (p. 39): the Integrating STEM in Everyday Life conference series kickoff event.

Research Setting, Context, and Participants

This study was conducted as part of an Integrating STEM in Everyday Life conference series. The kickoff event for this conference series was held at a large public university located on the eastern coast of the United States. As part of this kickoff event, participants attended a one-hour long workshop on incorporating into lesson planning the Socioscientific Issues (SSI) Framework described by Zeidler and Kahn (2014) and Sadler et al. (2019). During this workshop, facilitated by the second author, participants were introduced to Zeidler and Kahn's SSI framework, and the ways in which it coincided with, and differed from, general STEM education. The workshop culminated with participants designing an SSI lesson in small groups based on a menu of topics presented.

Near the end of this workshop, participants were given one hour to work in groups to develop an SSI lesson plan based on sample SSI topics provided to them. The participants worked collaboratively in groups of 5 - 8 and developed their own format for the lesson plan. Participants wrote their lesson plans on writable surfaces using dry erase markers. The workshop facilitators circulated to observe and answer participants' questions while they worked. Finally, participants were given time to go around to each table to share their lesson plan ideas and ask questions.

After the SSI workshop, participants attended three additional workshops of their choosing. Each of these workshops was also one hour long and was geared toward incorporating SSI and STEM ideas and lessons into existing Math and Science courses. For example, one workshop, *Waste Not, Want Not: Reducing Food Waste Through STEM and Civic Engagement*, addressed ways in which students could use math to calculate the amount of money wasted due to school lunch items that go uneaten, winding up in the trash. The facilitator presented a case study of her own class of high school students, who had undergone this process. Participants were tasked with calculating how much food waste was costing their school district and developing a proposal for how to repurpose that money in sustainable ways.

A second workshop, *Analysis of Effects on Life-Cycle Development using Traditional Herbal Remedies*, focused on

how living organisms react to different foods, with a particular emphasis on both traditional/cultural natural remedies offered by participants, and on how *healthy* can mean different things for different individuals. The facilitators showed participants how to model the effects of these traditional remedies on the *Drosophila* species of fly, and the participants analyzed different vials containing various Drosophila specimens to show the physical effects of said remedies on the flies.

Of the 53 participants who attended the event, 49 consented to being part of the research study. As shown in Table 1, Thirty-one participants indicated the grade level they currently taught: approximately 77% (n = 24) identified as being teachers of grades 9-12, 10% (n = 3) as teaching grades 7-8, 6% (n = 2) as teaching grades 7-12, 3% (n = 1) as teaching grades 4-6, and 3% (n = 1) as teaching grades K-8. Thirty participants indicated their teaching status: approximately 63% (n = 19) identified as pre-service teachers, 27% (n = 8) reported having five or more years of teaching experience, 7% (n = 2) reported between two and five years of experience, and 3% (n = 1) reported having one year of teaching experience.

Table 1

Participant Demographics

Grade Levels (n = 31)			Experience (n = 30)		
Grade Level	n	%	Years	n	%
K-3	0	0	Pre-Service	19	63
4-6	1	3	1	1	3
7-8	3	10	2-5	2	7
9-12	24	77	5+	8	27
K-8	1	3			
7-12	2	6			

Note. One participant indicated grade level but not experience.

Data

Data for this study come from three sources: a pre-conference questionnaire, a lesson plan analysis, and a post-conference questionnaire. The pre-conference questionnaire was administered at the beginning of the SSI workshop and consisted of two open-ended questions. This pre-assessment was designed to determine a) if participants had ever before conducted an SSI-like lesson in the classroom and b) to elucidate their pre-conceptions of SSI-like lessons by asking them to describe an SSI-like lesson they had previously conducted or to describe such a lesson that they might like to conduct with their current or future students. Forty-nine participants completed this pre-assessment.

The lesson plan analysis was conducted using photographs of participant lesson designs and plans that were taken at the conclusion of the one-hour SSI introductory workshop. Participants worked in 11 groups to develop a lesson using a chosen topic in an attempt to demonstrate components of the presented SSI framework in their designs.

The post-conference questionnaire was administered after the final workshop of

the day and consisted of 15 items, 13 of which were closed-ended questions while 2 were open-ended. Six of the 13 closed-ended questions contained open-ended probing questions as follow up to the initial closed-ended question. There was also a space at the top of the post-assessment for the participants to include their name, school/organization, email, teaching status (i.e., grade level and years of experience). This post-assessment was designed to solicit participant feedback on multiple aspects of the conference. For the purposes of this study, the relevant question posed was designed to capture participants' attitudes and intentions surrounding SSI and sustainability, and their willingness to incorporate the concepts into future lessons. Thirty-eight participants responded to this post-assessment question.

Data Analysis

In order to analyze this data, we reviewed the pre-conference questionnaire, lesson plan photographs from the SSI workshop, and the post-conference questionnaire described above. The responses from the pre- and post-assessments were entered into a spreadsheet and de-identified through the use of ID numbers in place of names. The yes/no responses were totaled and expressed as percentages in order to provide a specific, yet overarching sense of the participants' histories and intentions with regard to SSI. The open-ended section of the pre-assessment asked participants to describe a lesson that they either had taught or would like to teach in the future involving an SSI framework. This section was analyzed through open coding in order to describe the central idea of each lesson. These codes were then grouped into three themes through axial coding (Marshall & Rossman, 2016). Marshall and Rossman (2016) define axial coding as "relat[ing] codes to one another, relying on complex thinking that is a mix of induction and deduction" (p. 223).

The three themes that emerged were (1) social, cultural, and political, (2) environmental education, and (3) technology and engineering. While all SSI topics intersect with multiple themes, we coded lessons based on what we felt was their strongest identifier. For example, lessons described primarily by their focus on underrepresented groups, voter apathy, or performance-enhancing drugs were characterized under the umbrella of the social, cultural, and political theme. Lessons described primarily by their focus on carbon footprints, sustainable farming, or alternative energy were characterized under the umbrella of the environmental education theme. Lessons described primarily by their focus on self-driving cars, tech safety, or GMOs were characterized under the umbrella of the technology and engineering theme.

After the themes were developed based on data from the pre-assessment, photographs of participants' lesson ideas taken during the SSI workshop were coded using those same themes, and then again using the SSI framework as described in Table 2 (see Appendix). Based on this analysis, we were able to describe two points of baseline data, as well as three additional findings. We discuss this in the following section.

Findings

Our data suggest ways in which teachers' thinking and intention of incorporating SSI in their lesson plans changed after engaging in the STEM in Everyday Life workshop. In particular, our data illuminate teachers' familiarity with SSI prior to the workshop, as well as their evolving understanding of SSI after the

workshop. Additionally, our data suggest a change in teachers' intention to incorporate SSI into their teaching practices at the conclusion of the workshop.

Baseline 1: Prior SSI Teaching

Our analysis of the pre-assessment data informed our first baseline measurement. On the pre-assessment, participants were asked whether or not they had previously taught a lesson or activity on a debatable or controversial and socially relevant scientific issue. As shown in Table 3, of the 49 participants who consented to participating in our study, 39% (n = 19) indicated that they had previously taught such an SSI-like lesson, while 47% (n = 23) indicated that they had not previously taught an SSI-like lesson.

Baseline 2: Descriptions of Prior SSI Lessons

Our analysis of the pre-assessment data informed our second baseline measurement. On the pre-assessment, participants were asked to describe a lesson or activity on a debatable or controversial and socially relevant scientific issue that they had taught previously. If they had not previously taught such a lesson, they were asked to describe a lesson or activity that might be interesting to their students that dealt with a debatable or controversial and socially relevant scientific issue. Altogether, 42 participants described a total of 54 lessons or activities meeting such criteria.

Table 3 shows that the majority of participants (55%, n = 23) had not taught an SSI lesson prior to attending the conference. Additionally, these lessons were primarily relating to environmental education (48%, n = 26), or were social, cultural, and political (46%, n = 25) in nature. Lessons that were taught were primarily social, cultural, and political (63%, n = 15) in nature, whereas lessons that were planned but not taught were primarily relating to environmental education (60%, n = 18).

Table 3
Baseline data: Prior SSI Teaching and Descriptions of Prior Lessons

Previously taught SSI?			Lesson Themes					
			Social, cultural, political		Environmental Education		Technology and Engineering	
	n	%	*n*	%	*n*	%	*n*	%
Yes	19	45	15	63	8	33	1	4
No	23	55	10	33	18	60	2	7
		Total	25	46	26	48	3	6

Note. Certain participants described multiple lessons.

Finding 1: Lesson Ideas from Group Work

Our analysis of the lesson plan photographs (see Table 4, see Appendix; n = 11) taken during the introductory SSI workshop revealed evidence that supports our first finding. Table 5 (see Appendix) shows that, of the 11 groups who created an SSI lesson plan, 46% (n = 5) were social,

cultural, and political, 46% (n = 4) were related to environmental education, and 18% (n = 2) were technology and engineering.

Finding 2: SSI Components in Lesson Ideas

Our analysis of the lesson plan photographs (Table 4; n = 11) taken during the introductory SSI workshop revealed evidence that supports our second finding. Table 5 shows that more than half of the groups (64%, n = 7) used four or more SSI elements in their lesson plans. Table 5 shows that of the 11 groups who created an SSI lesson plan, 18% (n = 2) included all seven SSI elements, 9% (n = 1) included six SSI elements, 18% (n = 2) included five SSI elements, 18% (n = 2) included four SSI elements, 9% (n = 1) included three SSI elements, 9% (n = 1) included two SSI elements, and 18% (n = 2) included only one SSI element. In their lesson designs, 100% (n = 11) of groups included an SSI Issue, 64% (n = 7) included scientific phenomena, 45% (n = 5) included STEM modeling, 64% (n = 7) included issue system dynamics, 45% (n = 5) included reflective scientific skepticism, 36% (n = 4) included multiple perspectives, and 55% (n = 6) included elucidate own position/solution. While 64% (n = 7) of the groups used four or more SSI elements in their lesson plans, only 36% (n = 4) incorporated multiple perspectives, an essential component of argumentation.

Finding 3: Intention to Incorporate SSI

Our analysis of the pre- and post-assessment data provided evidence to support our third finding. Specifically, 41 participants answered both the pre- and the post-assessment questions. Table 6 (see Appendix) shows that, of these, 34% (n = 14) indicated that they had never engaged students in an SSI-like lesson. At the conclusion of the conference, our post-assessment data indicate that 88% (n = 36) participants now intend to incorporate some form of SSI into future lessons. Of the 14 participants who disclosed that they had not previously taught an SSI-like lesson, 78% (n = 11) declared an intention to incorporate some form of SSI into their future lessons.

Discussion and Implications

Research documents both pros and cons of SSI. The benefits include increased student interest, agency for learning, and problem solving, while the challenges include insufficient time to implement and difficulty with argumentation development (Fadzil, 2017; Saunders & Rennie, 2013). The use of both explicit teaching of SSI structures as well as experiential learning with SSI processes is a promising model for teacher workshops of SSI. Across the day-long workshop, teachers were engaged in both declarative and procedural knowledge construction regarding SSI.

Recognizing that difficulties abound with SSI implementation, it was encouraging to note changes in thinking, intentions and actions around SSI teaching. Namely, prior to the experience a third of teachers surveyed had never conducted an SSI lesson. At the conclusion of the sessions, nearly 80% of those teachers indicated an intention to develop SSI lessons with their students. This shift suggests that the workshop had a positive impact on teachers, particularly those that had never taught using SSI previously.

All the groups included at least one SSI element, with 64% using scientific phenomena or system dynamics, respectively. More than half of the groups used four or more (64%) of the SSI elements. However, only 35% used multiple perspectives, an essential component of argumentation. Teachers' focus on scientific

phenomena and system dynamics also indicates an inclination toward teaching the content. In addition, lesson ideas did not vary greatly as topics were evenly split at 46% for social, cultural, and political or environmental education. Only a small number of groups chose technology and engineering.

A bright spot in this work is teachers' ability to choose the reform effort in which they engage. All participants were self-selected, many of whom had already used an SSI instructional approach. Rundgren and Chang Rundgren (2018) suggest this as a necessary component of teacher workshops in SSI.

The SSI framework holds promise for practicing teachers as well as preservice teachers. As K-20 education emphasizes cross-curricular learning, the SSI framework offers teacher candidates a model of instruction that improves student engagement, perspective taking and argumentation. Furthermore, SSI allows future teachers to foster culturally relevant integrated approaches to STEM teaching in their classrooms, a mandated competency across teacher education programs. As culturally-relevant teaching engages students in learning that is connected to their lived experiences (Ladson-Billings, 1995), SSI allows teachers to address the cultural diversity inherent in today's classrooms (Lew & Nelson, 2016; Mensah, 2011).

Our study had several limitations. First, lesson plans are one of many ways to study teachers' knowledge and pedagogy of SSI. As such, it may not be a full reflection of their understanding of how to implement SSI in their classrooms. Second, teaching intention is a powerful indicator of teaching practice, however this study did not include observations to describe teacher enactment in the classrooms. Third, this is a case study that has particular components of our setting without a comparison group, therefore additional research is warranted to inform the impact of our work in a different setting. Further research is needed to understand how workshop sessions influence teachers' ability to teach SSI in their classrooms.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1852807. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

We also would like to thank the teachers who attended our conference and voluntarily participated in our study. Special thanks to our colleagues, Dr. Victor Donnay, Ms. Bonnie Hallam, Dr. Tanya Berezovski, Dr. Herb Green, Dr. Carol Rulli, Dr. Marlene Hilkowitz, Dr. Susan Varnum, Dr. Paul Morgan, and other members of the Philadelphia Regional Noyce Program, for their contributions while planning and conducting workshops.

https://doi.org/10.1007/s11422-012-9407-1

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