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The lived experiences of pre-service science teachers designing and teaching socioscientific issues-based units

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Abstract

The purpose of this study was to explore the experiences of secondary science preservice teachers while designing and implementing SSI-based instructional processes, as well as their interpretations from these experiences. Phenomenological research that relies upon how individuals live out meanings in our everyday life was employed in this study. The participants of this study involved seven senior pre-service science teachers. Based on Seidman's (Interviewing as qualitative research: A guide for researchers in education and the social sciences, 2006) phenomenological interview model, three in-depth interviews were conducted with each participant. The data analysis procedure of this study was done inductively via thematic analysis. The analysis of the interviews revealed the following themes: (1) Transformation, (2) Dilemmas, (3) Critiques, (4) Struggles, and (5) Change. This study demonstrated that pre-service science teachers' views, ideas, and practices were transformed and changed during the 8 months of involvement in this phenomenological study. It was, therefore, fair to claim that the nature of phenomenological methodology provided opportunities for not only improvements on the participants but also observing and illustrating these changes.

Keywords: Socioscientific issues, Pre-service science teachers, Lesson design, Phenomenology

Introduction

Citizen's role in today's world is to be active in resolving disputes in social issues caused by science, technology, and society interactions (Patronis et al., 1999). Hence, education needs to be transformed in order to reflect "most students' school-based experiences to an active, critical, and politicized life-long endeavor that transcends the boundaries of classrooms and schools" (Kyle Jr, 1996, p. 1). This argument is especially accurate for science education. Science education is obsolete in its conventional form and it has been criticized for not helping students participate in the dynamic and open-ended real-world problems in an ever-changing, technologically oriented world (Bencze & Hodson, 1999; National Research Council, 2012). Hence, science teachers should be able to help students cope with the challenges of science that are involved in real societal issues (Sadler, 2011). Several researchers argue that most of the concepts in science education are interpreted and abstracted from their conceptual origins, which makes it impossible for the learners to grasp these concepts (Sadler, 2009).

Over the past few decades, a greater focus in science education has been put on fostering scientific literacy, which connects science learning with the lives of people (Aikenhead, 2006). Reform documents have repeatedly emphasized the aim of achieving scientific literacy for all citizens (Bybee, 1997). The National Science Teacher Association (NSTA) established the notion of scientific literacy as the primary goal of science education in the 1970s, and it has been associated with the motto, "science in its social context" (DeBoer, 2000). The latest curriculum reform documents, such as Next Generation Science Standards (National Research Council, 2012), centers on enhancing the scientific literacy capabilities of students

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to resolve not only the shortage of professionals in the fields of science and technology, but also people's lack of critical thinking, problem-solving and decision-making skills (Roberts & Bybee, 2014). Next Generation Science Standards (NGSS) emphasize interdisciplinary connections and calls for applying scientific knowledge and skills to personal and social situations (National Research Council, 2012).

To provide students with the requisite skills to live, work, and succeed in tomorrow's world, educators need to follow innovative teaching strategies that foster emerging skill sets. An important step is a recognition of contemporary and controversial issues in the science curriculum (Driver et al., 2000; Hodson, 2003). SSI is widely advocated for achieving the goal of scientific literacy. Hence, several researchers argue that socioscientific issues (SSI) is an important path to achieving the abovementioned targets (Bingle & Gaskell, 1994; Zeidler, 2014). A scientifically literate person must have the capacity to make educated decisions about SSI (Lederman & Lederman, 2014).

Several science educators have strongly argued that the use of socioscientific issues in science teaching, but these claims raise concerns that the use of socially applicable curricula can compromise the credibility of the conventional science curriculum and the comprehension of fundamental science concepts by students (DeBoer, 1991). In comparison, SSI proponents argued that many concepts are translated, condensed, and abstracted from their contextual roots in science classrooms, leading students to have trouble learning these concepts in the classroom (Sadler, 2009).

SSI is conceived as controversial issues of societal importance and strong ties with scientific concepts that have no clear solutions (Sadler, 2011). These problems are open-ended and ill-structured involving multiple solutions. In addition to scientific knowledge and practices, they require citizens to take into account the economic, social, ethical, and moral facets (Eastwood et al., 2012; Sadler, 2004; Zeidler, 2003; Zohar & Nemet, 2002). SSI can range from environmental problems to energy resources. Due to the fact that SSI is embedded in disciplines that go way beyond science, it is a pedagogical and curricular approach that is consistent with the current reform movements in K-12 science education (Zeidler, 2014). SSI's very existence forces students to reassess their prior discernment and theoretically improve their intellectual interpretation of the issue through personal interactions and social debate (Zeidler & Nichols, 2009).

Zeidler (2014) has argued that SSI education should: "(a) Utilize personally relevant, controversial, and ill-structured problems that require scientific, evidence-based reasoning to inform decisions about such topics; (b) employ the use of scientific topics with social ramifications that require students to engage in dialogue, discussion, debate, and argumentation; (c) integrate implicit and/or explicit ethical components that require some degree of moral reasoning; and (d) emphasize the formation of virtue and character as long-range pedagogical goals" (p. 699).

Even though its central role in reform documents and research in science education, teachers commonly note that they have several challenges in implementing SSI in their science classes (Lee et al., 2012). The potential reasons for teachers' exclusion from their classrooms of SSI are their unfamiliarity, lack of expertise and frustration with an SSI-focused teaching approach; restricted access to SSI-focused curriculum resources; and differences between the teachers' interpretations of SSI and the conceptual basis of pedagogy (Lee et al., 2012; Sadler et al., 2006). Also, SSI teaching allows science teachers to develop and implement new pedagogies as a conceptual paradigm that differs from conventional science teaching (Christensen & Fensham, 2012).

Several scholars have claimed that teachers' views, beliefs, and knowledge have a significant impact on how SSI are taught in their classes (e.g. Lee & Witz, 2009; Schalk, 2009; Tal & Abramovitch, 2012). Hence, the literature called for more emphasis on such views, beliefs, and knowledge as they help to reveal how science teachers regard many SSI in the science classroom (Asghar, 2013; Crawford et al., 2005; Hestness et al., 2011; Khalid, 2003; Wise, 2010). Similar arguments about preservice science teachers exist in the literature. Preservice teachers' views and beliefs about content have a significant impact on their subject-related instructional decisions (Kagan, 1992). Furthermore, when they do not feel confident with the content, they are more inclined to avoid teaching it (Appleton & Kindt, 1999). Thus, the literature calls for actions to describe the relationship between preservice science teachers' views and instructional decisions. Studies reported that many science teachers considered SSI challenging to teach, which influenced their decision to incorporate SSI in their science curriculum (Reis & Galvao, 2009; Sadler et al., 2006). Also, in order to understand how pre-service and in-service teachers from various contexts and cultures approach and teach SSI, there is also a need for further discussion of SSI in varied situations (Mansour, 2008; Sadler, 2011).

As a result of the lack of specific references to SSI in different countries' science curricula, the science teachers are hesitant to bring it up in their science classrooms (Reis & Galvao, 2009). Barrett and Pedretti (2006) criticized teachers for solely implementing the existing curriculum, focusing instead on their role as designers and facilitators of the SSI curriculum. A teacher must have

certain foundational competencies related to SSI instruction in order to be prepared to develop SSI curricula (Simmons & Zeidler, 2003). The instructional decisions in-service teachers make are heavily influenced by what they learn while enrolled in their preservice teacher programs (Appleton & Kindt, 1999; Olson et al., 2015). Hence, it is important to provide pre-service science teachers' experiences of designing and implementing SSI-focused instructional practices, as well as revealing those experiences in detail.

Teachers who are in the position of implementing the curriculum are expected to be well-prepared about SSI and have advanced decision-making and problem-solving skills (Sadler, 2004) because teachers' understanding and awareness of SSI is also reflected in their students (Clarkeburn et al., 2002). This situation shows the need to educate pre-service science teachers as individuals with SSI expertise (Cebesoy & Sahin, 2013). It is necessary to remember that pre-service science teachers ought to be trained by teacher education programs as professionals who are aware of socioscientific issues (Cebesoy & Sahin, 2013). Moreover, pre-service teachers' experiences of designing and implementing SSI-based processes need to be explored to identify their lack of knowledge and competencies, as well as the actions that need to be taken by teacher educators for successful implementation of SSI. Besides, the experiences of pre-service teachers in developing and applying SSI-based instruction must be discussed to recognize their lack of awareness and abilities, as well as the steps that teacher educators need to take for SSI to be effectively implemented. Therefore, this study centered primarily on analyzing the perspectives of pre-service teachers to plan and incorporate SSI-based units in-depth. The following research question drove the study: "How do pre-service science teachers design and implement SSI-based units?"

Methods

Research design

The purpose of this study was to explore the experiences of secondary science pre-service teachers while designing and implementing SSI-based instructional processes, as well as their interpretations from these experiences. A qualitative research approach is used for "exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2013, p. 35). Under this approach, phenomenological research that relies upon how individuals live out meanings in our everyday life (Van Manen, 1997) was employed in this study. Phenomenology is an approach based on the lived experiences that participants have experience in the specific area under inquiry (Van Manen, 1997). It draws on the participants' lived experiences, trying to recognize the elements of life that are taken for granted within a given social setting. It is a key to learning how people perceive reality (Gallagher, 2012) and captures a particular moment in time, free from generalization (Van Manen, 1997). Therefore, this study adopted a phenomenological method to examine pre-service science teachers' experiences of designing and teaching SSI over the span of 8 months. Since designing SSI-based units and implementing those units were two interconnected educational phenomena, they were treated as a single phenomenon.

Using phenomenological methodology in this study had distinct advantages over other qualitative research designs (Armstrong, 2010; Denscombe, 2010). The phenomenological design provided the opportunity to acquire real, in-depth accounts of complex events as experienced by individuals and groups of people while paying attention to people's everyday experiences. Also, it is suited to small-scale research because it is reliant on in-depth interviews which can be seen as natural rather than artificial. Hence, the phenomenological design was selected for the study.

Study sample

Purposeful sampling was used in this study to select the participants who were most suitable for the design and to make the study more relevant to the understanding of the phenomenon in the entire population. This study focused on a small group of pre-service science teachers in a teacher education undergraduate program. Therefore, a phenomenological inquiry made it possible for the participants to express their experiences from their own perspectives. Participants were chosen based on purposeful sampling or as described in phenomenology as "explor[ing] experiential descriptions from individuals who are capable of putting their own experiences in oral or written words" (Van Manen, 2016, p. 353).

Despite the fact that varied sample sizes have been suggested for phenomenological research, Ellis (2016) believes that a sample of 6 to 20 individuals is sufficient. For a phenomenological investigation, Creswell (2013) suggested long interviews with up to 10 people. The participants of this study involved seven pre-service science teachers who were in their final year in their undergraduate education. They had completed most of their coursework before they participated in the study. This study took place within the context of Practice Teaching in Science I and Practice Teaching in Science II courses in the seventh and eighth semesters of the program. All students enrolled this particular section of the course volunteered to take part in the study. There were five female and two male pre-service teachers in the study.

Study context

In qualitative research, it is crucial to expose personal ties to the subjects, as well as the potential assumptions and biases (Creswell, 2013). The researcher in this study was the instructor of the Practice Teaching courses of I and II during the two semesters of the academic year.

The first semester of the course, Practice Teaching I, was mainly dedicated to classroom observations and reflections of the experiences. In addition to these responsibilities, the participants attended extra sessions in which the researcher introduced them SSI. First, the researchers informed the participants about the study. All students enrolled the course participated in the study voluntarily. Then, the participants were presented SSI, including the theoretical framework, most common SSI scenarios, and the associated in-class activities. In addition, the researcher modeled two different SSI-based activities in order to provide a more detailed picture of how SSI occurs in a real classroom environment. Following this process, the participants designed their instructional plans in addition to their other responsibilities. The researcher supervised the participants during the design sessions. The main focuses of the SSI-based lesson plans were decided by the whole group, whereas each participant designed lesson plans individually. The SSI instructional modules designed by the participants include, but were not limited to, river pollution, locally produced foods, farmlands, air pollution, mining, nuclear energy, stem cell, genetically modified organisms (GMO), and concrete structures.

In the second semester of the course, Practice Teaching II, the participants had the opportunity to implement their lesson plans in real classroom environments. After each implementation, the participants and the researcher had meetings to discuss the instructional experiences of the participants. The participants observed the SSI-based instruction of each other's, then provided feedback based on their observations.

The theoretical framework driven the design and implementation of the SSI-based instructions was proposed by (Zeidler et al., 2005). They described the four tenets of their framework as follows:

> *The framework should be viewed as a tentative conceptual model that identifies four areas of pedagogical importance central to the teaching of SSI: (1) nature of science issues, (2) classroom discourse issues, (3) cultural issues, and (4) case-based issues. These issues can be thought of as entry points in the science curriculum that can contribute to a student's personal intellectual development and in turn, help to inform pedagogy in science education to promote functional scientific literacy. (p. 361)*

The authors also argued that their framework provide a working model that illustrates theoretical and conceptual links among key psychological, sociological, and developmental factors important to SSI and science education.

The participants used this framework in order to fully address the SSI scenarios they chose to teach. The framework was decided collectively, as the participants read the literature in SSI. Then, whole group discussions were held to investigate how each aspect of the framework could be included in the lesson plans. Despite the fact that participants were given the option of addressing the framework entirely or partially, they all chose to structure their plans around the four aspects of the framework. Hence, the SSI-based units designed by the participants incorporated all four areas of the framework.

Data collection

According to Moustakas (1994), the most common data collection method for phenomenological research is semi-structured interview because it "evokes a comprehensive account of the person's experience of the phenomenon" (p. 114). There are two main aspects that need to be focused on for data collection in phenomenological studies: the experiences of the participants in terms of the phenomenon, and the contexts and situations influencing these experiences (Creswell, 2013). The researcher performed a sequence of three separate interviews with each participant based on Seidman's (2006) model of in-depth, phenomenological interview. The objective of each interview in the model was described by Seidman (2006) as follows: "(a) to put the participants' the participant's experience in a context in light of the topic up to the present time, (b) to concentrate on the concrete details of the participants' present lived experience in the topic area of the study, and (c) to ask participants to reflect on the meaning of their experience" (p. 17–18). Therefore, in-depth interviews were conducted with the participants three times.

The first interviews were conducted prior to the implementation process, whereas the second interviews were held at the end of the first semester in which the participants designed their SSI-based lesson plans. The last interviews were conducted after they implemented the lesson plans designed. The first interview protocol focused primarily on the participants' perceptions of the SSI-based teaching and learning process, as well as their background and context. The second interview protocol aimed to elicit more information about the participants' current lived experiences during the study. In the final interview protocol, the participants were asked to reflect the meaning and significance of their experiences. Each

interview took between 45 to 85 minutes. In order to support the primary data source, the semi-structured interviews, the observation data was also collected. The lesson plan design sessions and the implementation of these lesson plans in the classroom environment were observed by the researcher. This data was used to support and validate the interview data.

All of the procedures performed in studies involving human participants were in accordance with the ethical standards. The study was carried out with the permission of the social and human sciences scientific research and publication ethics committee of the university where the study was conducted. The consent to publish is obtained from the department, as well as the participants of the study. Also, informed consent was obtained from all of the individual participants included in the study. The data sets and interview recordings are deposited in repositories located in the public university. The data generated and analyzed during the current study are available anonymized from the corresponding author by request.

Data analysis

The data analysis procedure of this study was done via thematic analysis. The inductive coding approach was utilized. The main purpose of the data analysis for this study was to identify and establish the common themes that emerged from the interviews. The phenomenological research approach requires evidence on the lived-experiences via interviews. In this study, it was aimed to grasp the meanings embedded in the experiences of the participants and describe these meanings within the context (Sundler et al., 2019) because "the reality in phenomenology is comprehended through embodied experience" (Starks & Brown Trinidad, 2007, p. 1374). After transcribing the interviews, the data in written form was analyzed via NVivo qualitative analysis software. The data analysis process was occurred based on the following steps (Yüksel & Yıldırım, 2015): First, the researcher compiled a list of relevant phrases, then grouped them into similar groups, and last, clustered the phrases to determine essential themes. After the themes were established, rich and thick texts were used to develop distinct descriptions. Finally, the researcher "synthesized the texture and structure into an expression" (Yüksel & Yıldırım, 2015, p. 11).

Findings

This research sought to examine the experiences of secondary science pre-service teachers when planning and integrating SSI-based learning methods, as well as their interpretations of those experiences. The phenomenological approach was employed to guide the analysis as illustrated by Van Manen (1990). The analysis of the interviews revealed the following themes: Transformation, dilemmas, critiques, struggles, and change. In this part, the findings were presented under these themes.

Transformation

The participants clearly emphasized the transformation of their ideas when explaining their experiences during the study process. Owing to their participation in developing and implementing their SSI-based instructional processes, their firm views, understandings, and concepts have shifted dramatically. The transformation did not happen suddenly, rather it extended over time. The types of ideas transformed varied greatly, including the areas of science, data, and environment, as well as truth and ethics.

Science and data

One of the greatest transformations occurred in the participants' perception of what science and scientific evidence meant. The participants firmly agreed that their prior understanding of science and data was not adequate to better address SSI. Their research on SSI has, however, led them to extend their understanding of how science works. As they investigated the issues that they focused in their instructional modules, they first realized the social and cultural impacts on science. They stated that how scientists go about their business was quite different from how they thought it was. This was the result of their prior learning experiences about science and scientific method, according to the participants.

The participants found this transformation of ideas about science quite surprising though. As pre-service science teachers, they did not expect themselves to have misconceptions about science. One reason behind the transformation was that they did not have experiences of learning SSI.

> *"I don't believe I've ever known much about SSI before. Of course, we heard about climate change or the contamination of water and air. But, you know what I mean, they didn't teach us these subjects, like SSI. Just the facts, a bunch of information."*

According to another participant, because her experiences of learning science were mainly based on science content and sometimes doing lab experiments, she learned science that was decontextualized from the society and environment in which it occurs.

In addition to science, the participants of the study reported that their views on data were dramatically altered. The findings showed that the participants' initial views about data were mostly numbers, while verbal comments were included in their interpretation of data after being exposed to SSI. As they researched SSI, they

realized that the insights of the people from diverse perspectives and backgrounds were essential.

> *"Data does not mean just numbers and tables. It is unfortunate that most individuals just believe in numbers. After doing research on SSI, I found that the words and statements of persons who face these challenges personally are worth more than anything."*

Moreover, they noted that scientists were not the only group who collects data, yet they can use secondary data that was from the people who witness and/or experience these issues. Hence, it is fair to say that their definition of what constitutes data has shifted significantly during the process. Just one participant maintained that empirical evidence should be based on a quantitative methodology, while three of the participants openly suggested that qualitative data, such as observations and interviews, was required for a holistic interpretation of the SSI.

> *"If we wanna understand the scientific aspects of SSI, yes, the data is necessary. But how to understand facets of economics, sociology, society, and so on. We need other kinds of evidence, such as observations and interviews, and qualitative data."*

Environment

The analysis of the data revealed that another transformation occurred in the participants' understanding of the environment. Initially, the participants approached the environment independently of human society. They claimed that while they acknowledged the human impact on the environment, they were not aware of the clear boundary between the environment and society. Their statements, however, suggested that the essence of SSI helped them appreciate the intertwined relationship between humans and the environment, as well as how these two affect each other. Hence, they accepted the truth that human beings are an essential part of the environment.

> *"The environment should not be treated as isolated from human society. We also sound that the world is on one side, while on the other side is culture. This isn't real. That's not true. As we have been researching SSI subjects. I found that we are living in the environment, really. As well as animals and trees, we are part of this system. In most SSI, that's where the social component comes from."*

One of the participants argued that they felt isolated from the world by living in a very developed area, so they did not consider themselves part of the ecosystem. Since SSI are mostly environmental issues that have strong ties with scientific and social situations, their environmental pre-conceptions blossomed into a comprehensive and inclusive way. His perception of the environment, as one of the participants said, originally consisted of plants, flowers, and animals, while SSI's comprehensive and multidimensional framework made her realize that there was more to the environment than these components. She added that in the sense of the environment, social elements of SSI, such as economics and culture, should also be taken into account.

Truth and ethics

The statements of the participants demonstrated how their sense of truth and ethics was transformed as they explored the SSI topics while planning and teaching SSI-focused units. Most of the participants said that before the SSI study process, they were more likely to accept the basic principles of ethics. However, as they researched the SSI issues more closely, they found that due to the existence of SSI, it was hard to speak about generally agreed ethical codes. The participants, therefore, felt that addressing SSI with preconceptions of fundamental reality and ethics could make it difficult to consider every aspect of the issue. To explain, one participant claimed that the SSI topics affecting groups of individuals with diverse worldviews allowed them to be mindful of these individuals' realities. In the sense of SSI, she added that the generally recognized ethical principles, like social and environmental ethics, could not be admissible because they have driven persons to view SSI from a particular viewpoint, which is not relevant to SSI.

> *"Well, universal truth, as we all know, is an easily embraced idea. Still, is it really ok to judge different groups based on those universally accepted ethical principles? With global rules that were invented without directly understanding that dilemma, how do we address a local issue?"*

One of the participants, on the other hand, claimed that he found this proposal troublesome. He concluded that to address any SSI, regardless of the views and positions of various actors, there must be a widely agreed reality.

> *"We are all human Different roles and viewpoints exist, but there are laws decided upon by all humans. Truth is truth. Reality is reality regardless of what different people think. Truth, regardless of what various individuals believe, is reality. In SSI situations, all persons must follow them. That's what our students should get."*

Dilemmas

During the development of SSI-based instructional modules, another theme found in the data was called

the 'dilemma'. The data showed that because of the substantial variations between their prior and final understandings and beliefs, the participants faced dilemmas.

Perspective taking or being right

In SSI situations, understanding the viewpoints of the multiple actors is considered to be a crucial skill in coping with these problems. The participants were also well-aware of the value of this unique capacity. The interview results revealed, on the other hand, that the participants grappled deeply with the notion of being on the right or wrong side. Some respondents claimed that knowing the views of various SSI groups might lead them to the wrong conclusions. Even though they acknowledged that sympathy was essential to address SSI comprehensively, it was claimed that sympathize with incorrect claims by the classes would be misleading. Giving the example of a local environmental problem, one participant claimed that one of the leading actors with clear statements regarding the topic undoubtedly had anti-environmental views. She explained her dilemma as follows:

> *"I recognize that in order to live, they should consider their economy, but sympathy is a strong word. I don't believe corporate owners across the city necessarily care about the environmental harm they are creating. They advocate their actions strongly and do not listen to others. But, we need to understand their point. They need money for their family, kids. The reality of life itself."*

Besides, another participant felt that it was necessary to take a firm stance against the groups on the wrong side. Even though it was found to be necessary to take the viewpoints of various SSI stakeholders, he was quite cautious about the possibility of sympathizing with the guilty party.

> *"You will find yourself on the wrong side of the tracks if you express support for those with false claims. There is no middle, right side or wrong side."*

Conversely, two of the participants strongly appreciated the perspective-taking approach by claiming that being able to consider one's point does not mean whether you agree or disagree.

> *"Being able to take views of other entities does not mean endorsing them. It just helps you see the issue from a broader perspective. For instance, when teaching climate change, we need to teach our students the claims of manufacturing factory owners. That does not hurt anyone, even little children."*

Social and cultural embeddedness of science

Even though the sociocultural influence on science is generally neglected, it is important to recognize the intertwined relationship between science and the sociocultural context in which it occurs, particularly in SSI contexts. However, little emphasis is given to the social and cultural embeddedness of science in the curriculum. In the situations in which they interacted with SSI, the participants often failed to grasp the social and cultural embeddedness of science. Due to their pre-existing conceptions of science, some participants were not able to adequately understand the social and cultural influences affecting scientific knowledge. To illustrate, one of these participants stated that it would be much easier to deal with SSI if science was fully isolated from the social, cultural, and even economic impacts.

> *"Perhaps, we can first attempt to consider SSI from a scientific viewpoint. If there is pollution, scientific data tells you. It doesn't matter where the scientist who collected the data came from. Science is removed from any social effect, also in SSI cases."*

On the other hand, two of the participants' dilemma about the sociocultural influences on science did not lead them to advocate "pure science". They argued that contextualized learning processes were more effective than the old-fashioned way of learning science, decontextualized from its real-world context. They added that comprehending science within its sociocultural context was necessary for SSI learning. Despite their view, these participants added that to grasp such sociocultural influences, students require high-order thinking ability. Hence, teaching SSI via contextualized learning processes was a dilemma for teachers, according to these participants.

> *"Our SSI teaching experience has told us that science can be taught in the sense of real life. This way it is learned easier and better. Otherwise, it is often meaningless for our students. In this way, we show them how to use scientific expertise in their lives. But, you know, not every student gets that, they need high order thinking."*

Pro-environmental decisions or personal and societal benefits

Another big dilemma observed in the participants' statements was either taking a pro-environmental stance or considering personal or societal benefits. Even though the participants were more inclined to advocate

environmental positions in SSI scenarios, they sometimes showed empathy towards individuals who take action for people's benefit. Their statements indicated the challenge they face when determining their position. For instance, one participant argued that despite the negative consequences on the river that runs through the area, the use of the riverbank by the local people was reasonable. She added that it was really hard to choose one side or another to make the ultimate decision.

In the local food production scenario, another participant stated that it was unfair to recommend people consume locally produced food due to the overpricing. Despite the fact that her research indicated the positive outcomes of locally grown food for both environment and the local economy, she sympathized with the people who can only afford the food from groceries. She also criticized that the groceries can offer more affordable food than locals despite their extra costs, such as shipping and wholesale intermediaries.

> *"I mean, everybody wants to support the community by purchasing local food. But, if the stores are cheaper, why not? Why would you expect to spend extra to help the local community? That local goods are more costly doesn't make sense. I cannot persuade my students to purchase more expensive items just for the sake of their community."*

Critiques

The data analysis revealed that the participants made clear critiques of the different facets and actors participating in education. The participants realized numerous challenges to their work during their experience of planning and teaching SSI. Hence, they illustrated those concerns and attacked them.

Education

Based on their previous experiences, the participants questioned the content-centered education, arguing that SSI allowed students to explore the subjects while moving beyond the boundaries of conventional education methods. All participants exhibited positive attitudes on the way SSI transformed teaching and learning. To illustrate, one of the participants argued that SSI-based experiences helped students learn more comprehensively and inclusively, which was not possible with traditional instructional approaches. She added that centralized multiple-choice tests spoiled the education. While the SSI-based learning processes were not entirely successful in succeeding in those tests, according to the participant, the knowledge and skills that students obtained via SSI were more in line with the ultimate objectives of education. She claimed that education should aim to raise individuals who are responsible citizens with a certain degree of fulfillment and happiness. Based on her experiences, she concluded that the students in SSI classes were more motivated to take responsibility for making meaningful improvements in society in SSI circumstances. Hence, she strongly advocated SSI to achieve these goals.

> *"I assume that SSI is necessary to accomplish the objectives of education in general, but our national examination-based educational system does not encourage teachers to fully address SSI in their classrooms. If you don't reform the system, how are you going to meet the aspirations of scientifically literate citizens?"*

Moreover, in order to promote the concept of SSI-based learning environments for students, another participant identified several elements, such as critical thinking, ethics, and multidimensional thinking. He concluded that he would rather be a pupil in an educational environment that brings students in such competencies, instead of offering only content.

Science instruction

The data collected from the participants also indicated that the current structure of science education was firmly called into question. After analyzing thoroughly SSI-based instructional processes, the participants criticized the science curriculum and teaching which is highly dependent on content, rather than skills and competences. They claimed that too much content was involved with the current science curriculum. Thus, the content-driven science curriculum had to be reformed, according to the participants. The nature of SSI that aims to foster essential skills, such as critical thinking, interdisciplinary viewpoints, and problem-solving, was deemed suitable for this change.

> *"The science curriculum itself was one of the strongest barriers we encountered when teaching SSI. We have so much content to cover; hence it does not encourage you to address anything extra. Whenever I wanted to give SSI-based interactions to my classmates, I was very nervous about the topics we had to address."*

In addition to the content-driven structure of science education, the participants also discussed the divergence of the content of science education from its real-world meaning, so that the participants called it "decontextualized". Designing and implementing SSI-based instructional units, the participants often intended to present the SSI-based content in its social and cultural context. Based on their experiences around SSI, the participants believed that science instruction should be supported

with contextual aspects in order to make the content more relevant to the students. Hence, learning science becomes more meaningful and effective for students.

> *"You will not take advantage of the context if you plan to use the national curriculum that is synchronously used all over the country. I would prefer to address contextualized content, but the curriculum was not designed for that. The content that has been fully decontextualized is not acceptable for use in SSI."*

School

As they created their SSI-based instructional plans, the participants frequently linked the community and school. They encouraged the students to visit their neighborhood to gather data. On the other hand, the participants commented on the physical layout of the schools that isolates them from the culture in which they are situated. They argued that a strong drawback to the SSI was generated by the school body. To illustrate, one of the participants complained about the fact that the school building and the walls around it did not encourage the students to be conscious of their community's problems. The barriers between the school and the community should be annihilated in order to meet the goals of the SSI strategy. Furthermore, the physical structure of the schools was an important part of this solution.

> *"Our school is completely segregated from the city. They feel super awkward whenever I invite my students to go visit their neighborhood to observe the issue. The school building carries the message that outside is very unsafe. Really, is it? That's where students spend most of their time."*

In addition, the school infrastructure was not sufficient enough for students to explore SSI topics. Two of the participants noted that the schools did not have large classrooms, computer labs, and so on; hence, the students could not study SSI topics effectively. To illustrate their point, these participants shared an anecdote where the students were not able to work in groups cooperatively to do their projects due to the limited number of computers in the school, as well as limited physical spaces to work independently.

Struggle

As they described their experiences during the process, the participants shared certain aspects that caused them to struggle. These aspects were listed as changing students' habits, collaborating with the classroom teacher, and working with the community.

Student habits

After designing and implementing SSI, the participants believed, more than ever, that the students should not be passive learners. They constantly stated that the role of students in society should be more evident. As instructors in SSI-based classes, the participants frequently struggled to have students actively participate in the process because of students' second nature of passively receiving information. Hence, the participants wished the students had previous SSI encounters. In order to encourage students to change their habits, two of the participants used community-involvement activities. To illustrate, one participant claimed that she needed to take her students outside of the school twice to teach them that working outside of the school borders was still part of formal learning. Another participant shared that she asked her students to conduct brief interviews with the community members about an ongoing SSI. According to the participants, despite their attempts, the students were still reluctant to do work outside the classroom.

> *"I have worked so hard to encourage them [students] to go outside and explore the problem actively. But they are not, you know, capable of doing so. They want to sit in the classroom and listen to their teachers. Sometimes, I almost begged them. It is not in them because they have been taught to be passive receivers for years."*

Besides being unwilling to leave their comfort zone, the students were not conscious of their position in their local community, according to the participants. That is why, the participants strongly struggled to make their students feel responsible for the issues in their own community, as well as taking actions to address those issues.

> *"Students don't think the problem is theirs. You live there, I say, but they believe they have no responsibility whatsoever for anything. So, they just don't want to be part of the solution."*

Thus, the participants sought for the change of the attitudes and perceptions of students about their position in the community. Most participants claimed that if the students were as they were, it was almost impossible to teach SSI effectively. They believed that it was quite difficult to achieve the objectives of SSI-based instruction because students insist on becoming passive recipients of the information and not leaving their comfort zone.

Mentor teacher

Another struggle encountered by the participants in the context of SSI was about their mentor teachers' attitudes and actions. Some participants addressed that the

teachers were not bold enough to present the controversial aspects of SSI, especially those that were directly connected to their local communities. Thus, the teachers presented SSI in a less controversial manner in their classrooms, according to them. One of these participants shared that as she was implementing her SSI-based instruction, she was constantly warned by the classroom teacher.

> *"It was an interesting experience. I have been warned by her anytime I address the controversial aspects of the issue. She constantly told me to be careful about what I teach."*

They believed that the way they were counseled to teach SSI could not bring students in the objectives of SSI. Another participant, on the other hand, agreed with the instructor who recommended that the contentious aspect of SSI be discussed less frequently. He said the teachers deeply feel the burden of their society, particularly the parents. Therefore, if the teachers address the views against their community, they could face even legal actions.

> *"I understand her. They are the ones who interact with the parents, as well as other community members. Our mentor is held accountable for that if we make any mistake. It is for this purpose that she wants to control everything. She is not in a position to take any risk."*

Community

Besides the hesitancy of students, the pre-service teachers were also in struggle due to the community's approach when students investigate community-based issues. The participants often stated that their students were not welcomed by the community. Thus, the students were hesitant to fully approach these issues. The participants mentioned that whenever they urged their students to go outside their school to do first-person research, they were not able to get adequate support from the community members. One of the participants emphasized that the community should be informed and educated about how student learning should be facilitated, especially on community-related issues.

> *"People in this area are not ready to support kids. Our students went outside to do research, but only few people helped them. Most of them did not have enough information, but the ones who have knowledge did not have time for the kids. The students then gave up and decided to talk to their teachers and parents instead."*

The participants noted that the community should provide students with a safe and friendly atmosphere while discussing the struggle they experienced. Otherwise, the teachers do not feel comfortable leading their students to transcend the boundary of the classroom.

Changes

The last theme that emerged from the data was called changes. As the participants experienced SSI-based processes, they observed changes in their behaviors and habits.

Teaching

The participants believed that the SSI-based experiences induced them to modify certain aspects of their teaching. Some participants stated that they began to use SSI-based approaches in different scenarios. To illustrate, one participant shared that after being exposed to SSI, she began to use approaches such as argumentation. Her teaching habits were used to be what she considered conventional methods, she said.

> *"I used to lecture, I think, like the way we were taught in classrooms. I found out new forms of teaching, more neutral ways of teaching when attempting to learn how to teach SSI. That doesn't say I wasn't aware of these ways of teaching, I know them entirely in theory. But, you know, how can I use them, how do they look in practice. I agree that SSI has provided me a rich context, like an opportunity, like a chance to see them whether they are effective or not in reality."*

Similarly, another participant said that while teaching SSI, she was able to use a variety of different teaching strategies. The explanation behind this, she explained, was the flexible nature of SSI. Last, one of the participants highlighted changes in her way of teaching science in terms of the content she chose to use. He added that he felt compelled to enrich the content through different resources like news, documentaries, and other tools due to the existence of the SSI.

> *"I realized that textbook is not enough to teach SSI. I feel like I was unsatisfied with the details I had when I began working on developing my SSI strategy. I then looked for additional resources that I could use in my plans. Therefore, I searched for additional resources that I could use in my plans. Same in teaching. I often used extra resources related to nuclear energy."*

Based on the statements of the participants, it was fair to claim that SSI-based context required them to transform their teaching practices. They felt that they were

challenged to improve their instructional strategies, as well as the resources that they had access to.

Daily practices

The participants of the study also discussed the impact on their everyday lives of developing and integrating SSI-based units. Two of the participants specifically stressed the shift in their everyday routines after the process. To illustrate, one of the participants stated that he acted in a more pro-environmental manner in his life after he realized the short-term and long-term effects of his daily routines on the environment. He also added that before expecting anyone who had vested interests in the SSI situations to do something, he had to adjust his actions.

> *"Yeah, we want farmers to use environment-friendly farming practices, for sure, but what about us? I realized that my awareness of the environment, which redounded my behaviors, increased. About these topics, I feel more sensitive."*

Another participant stated that while she was a student, which means having less income, she tried to buy locally produced food items to support the community. She stated that because she was able to get to know local farmers during the SSI-based teaching process, she felt responsible for being part of the solution. Hence, her everyday life patterns were changed dramatically based on what she learned while teaching SSI.

Different from other participants, one participant addressed how SSI-based processes altered the way she looked at the issues. She specifically pointed out that she was able to approach issues through sympathy and multiple viewpoints. She also claimed that she was not an easy-going person in certain scenarios, but she was able to sympathize with others due to her experiences of listening and understanding individuals who were usually blamed in SSI scenarios.

Resources

The last changing aspect under this theme was the resources to get information. The participants shared that when they needed information about SSI, they were more likely to obtain it from the first person, if possible. Criticizing the fact that much of the resources present the issues from a single viewpoint, they believed that one should be able to reach out to different actors in the issue in order to be able to make decisions. Based on that, the participants asserted that they sought to find the information from multiple sources after their experiences in SSI. According to the participants, they began to express this action in their everyday lives. In addition, although the initial thoughts of the participants had mostly been to receive information from the academic resources, after their experiences of SSI, they were mostly to acquire information from non-academic sources of information, such as newspapers, magazines, internet pages, and even social media.

> *"Hmm, scientific resources are important, and first to listen, but you know, you cannot hear people's reactions and voices in those resources. We need a variety of different resources, like social media, to understand SSI."*

Discussion

This study aimed to explore the experiences of secondary science pre-service teachers while designing and teaching SSI, as well as their interpretations from these experiences. The findings of this phenomenological study revealed the experiences and interpretations of the participants under the themes of transformation, dilemmas, critiques, struggles, and change. Based on the participants' experiences during their involvement in the study over 8 months, the findings demonstrated the lived experiences of the participants in detail.

Teachers must have competencies in order to develop SSI-based lessons (Simmons & Zeidler, 2003), and these competencies are heavily influenced by their experiences in preservice teacher programs (Appleton & Kindt, 1999; Olson et al., 2015). This study provided a detailed account of pre-service teachers' specific experiences while designing and implementing SSI. It was demonstrated that, rather than providing pre-service teachers with only theoretical knowledge about SSI, real-world in-class experiences help them face the realities of teaching the contentious nature of SSI. The study's findings demonstrated how their lived experiences changed over the course of two semesters of designing and implementing SSI.

The study's participants developed their SSI-based training using a theoretical framework (Zeidler et al., 2005) that includes four tenets: nature of science issues, classroom discourse issues, cultural issues, and case-based issues. The data revealed that the participants' experiences revolved on these four tenets. To example, while planning and implementing their SSI-based lessons, participants specifically addressed case-based and cultural issues. On the other hand, their problems and criticisms revolved around these qualities as well. More importantly, their statements demonstrated that these specific features had a significant impact on the transformation of their attitudes, beliefs, and actions. As a result, it is critical to recognize that the employment of a framework for developing and teaching SSI has a significant impact on the lived-experiences of the instructors, as well as the learners in their classrooms.

The results showed that the participants strongly emphasized the role of the community in SSI teaching, as well as the pitfalls of conventional approaches to improving relations between school and community. Public encouragement and attention have been found to be critical in improving the efficacy of teaching and learning processes focused on SSI. House and Williams (2003) argued that "the effect is clearly enhanced if interventions or changes are attentive to the broader social forces that produce the disparities" (p. 122). Hence, the participants sought community support in order to fully address SSI in their classrooms. They also shared their struggle in absorbing locals into the SSI learning process of their students.

The study of the results revealed that the participants aimed at actively engaging students in the problems. However, one of their greatest challenges stemmed from the fact that they were trying to persuade students to take responsibility for these problems. They assumed that this was key to the effective implementation of SSI-based learning processes in their classrooms. Hodson (2003) argued that not only do people who take action on SSI develop a greater understanding of the problem, but they also believe they have inherent motivation to tackle or solve the problem. Similarly, this study showed that the participants strongly endorsed the claims of Hodson (2003) by agreeing that learners should not obtain knowledge passively, but instead should be given the opportunity to actively engage in addressing SSI. They also noted, however, that students were not prepared to leave their comfort zone and take action because of the existing nature of education.

The social and cultural embeddedness of science was not agreed upon by all participants in this research but it was assumed that science should be independent of the social, cultural, and even economic influences. Whether they accept social and cultural influences on science or not strongly impacted their approach to SSI, as well as their way of teaching SSI. The literature demonstrates that the nature of science seeks students to examine the issues by recognizing scientific phenomena' social and cultural embeddedness, and tentative nature (Sadler, 2004). When they understand this nature of science, the students are more likely to actively engage in and act on SSI (Carter & Wiles, 2014; Khishfe & Lederman, 2006; Kolstø, 2001; Sadler et al., 2007). Given that the perception of SSI by teachers is also expressed in their students (Clarkeburn et al., 2002), the identification of social and cultural embeddedness of science by pre-service science teachers, as well as the types of scientific data, is an important predictor of how their potential students view science and more specifically, SSI topics.

One of the strongest critiques about the current form of science education is that ideas and concepts are translated, diluted, and abstracted from their contextual roots in science classrooms, causing students to have difficulty understanding these concepts (Sadler, 2009). The results of this study showed similar conclusions as well. While discussing the science teaching practices that they had encountered, the participants stressed the isolation of the science content from its real-world context. Hence, in order to make it more meaningful to learners, they intended to view the SSI-based content in its social and cultural sense. Research on SSI suggests that science content should be grounded in real-world contexts to provide a broader meaning for learners. (Lambert & Bleicher, 2013; Sadler, 2009; Sadler et al., 2007). Relevant to the research on SSI that highlight the significance of the context for meaningful learning, the findings that criticized the attempts to teach SSI through decontextualized and irrelevant learning experiences were not unusual.

The aspects of the nature of science were one of the key findings in this study. The results of the study indicated that the views of the participants were strongly transformed in terms of such as science, scientific evidence, and culturally and socially embeddedness of science. The participants' prior perspectives about those aspects of science were more conventional, whereas their views had shifted sharply to "science in its context" which was different from the "pure science" approach. The literature (e.g. Khishfe & Lederman, 2006; Lambert & Bleicher, 2013; Shea et al., 2016; Walker & Zeidler, 2007; Wu & Tsai, 2007) highlights a strong relationship between teaching SSI and the nature of science. In support of these claims, this study showed that the experiences of designing and implementing SSI contributed to preservice science teachers' understanding of the nature of science. One of the biggest transformations occurred in the participants' views on scientific evidence. Even though the research demonstrates that the empirical evidence is not enough to make a decision and resolve the controversies in SSI situations (Bell & Lederman, 2003; Levinson, 2006; Sadler, 2004; Wu & Tsai, 2007), it is not uncommon for individuals do not accept statements or observations as a form of data. The participants' prior views on data were mainly based on quantitative forms, whereas their understanding of scientific data was expanded as they dealt with SSI. To sum up, considering that the teachers struggle to teach SSI topics due to their lack of knowledge in the nature of science (Bunten & Dawson, 2014; Carter & Wiles, 2014), this study provided significant insight into the way pre-service science teachers' development of NOS knowledge via their experiences of teaching SSI.

One reason for teachers to provide learners with invariably academically abstract and decontextualized science

content was the controversial nature of many issues in the curriculum (Sadler, 2011). That is why teachers often deal with socioscientific issues with limited contexts (Kara, 2012). This study also supported that the participants struggled with the content preferences of the science teachers. It was found that the pre-service science teachers who participated in the study were more motivated and courageous to cover controversial aspects of SSI than in-service teachers. They also transformed their way of teaching science as they experienced SSI during the study. Instead of decontextualizing the SSI content to be on the safe side, they took advantage of the contextual factors (e.g. cultural, social, economic, and political aspects of SSI) in order to enrich the SSI content they addressed in their teaching. Besides, the participants claimed that possible negative reactions from the families and community were one of the key reasons why teachers were hesitant to cover controversial topics in their classrooms. Even though they somewhat sympathized with the teachers, the participants shared their critiques and struggles in dealing with the way SSI was taught in conventional science classes.

Conclusion

Learners gain major skills as more time is spent on a topic of study (Gewertz, 2008; Viadero, 2008). Hence, providing enough time for learners to process information is found to be necessary (Arends & Kilcher, 2010). This study demonstrated that pre-service science teachers' views, ideas, and practices were transformed and changed during the 8 months of involvement in this phenomenological study. It was, therefore, fair to claim that the nature of phenomenological methodology provided opportunities for not only improvements on the participants but also observing and illustrating these changes. The literature emphasizes the need to educate pre-service science teachers as socio-scientific practitioners (Cebesoy & Sahin, 2013), and this study offered a methodology to educate SSI pre-service teachers as well as to observe lasting improvements for those people.

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