CASE-BASED LEARNING FOR ENHANCING PROSPECTIVE ELEMENTARY TEACHERS' CONCEPTUALIZATION OF SOCIOSCIENTIFIC ISSUES AND SOCIOSCIENTIFIC ISSUE-BASED TEACHING

by

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(Under the Direction of Janette R. Hill)

ABSTRACT

Efforts to integrate socially-relevant issues in science education is not a new idea. However, socio-scientific issue (SSI)-based teaching has created challenges in emphasizing the interrelationships among subject matter with the goal of creating scientifically literate citizens. Another challenge relates to how to introduce the ideas to prospective teachers as well as the pedagogical strategies for teaching SSIs; addressing this challenge was the focus for this study. The inquiry in this mixed methods study focused on one overarching question: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching?

An instructional design framework was developed for a case-based learning environment and implemented in a science methods course for early childhood education prospective teachers. The participants (four primary and twenty-two secondary) engaged in several activities for four cases such as participating in online and classroom discussions and writing reflection papers. The participants also engaged in an example SSI activity for an elementary classroom, and worked as a group to develop their own instructional resource designs about a SSI of their choice. Finally, the prospective teachers presented their instructional resources to the class and wrote individual reflections for their designs.

Data from the study documented the participants' evolution of socio-scientific reasoning (SSR) skills, conceptualization of SSIs and SSI-based teaching, as well as their planning after engaging in the designed CBLe. The analysis of the participants' pre- and post-Socioscientific Issue Questionnaire (SSIQ) scores revealed that participants' post-SSIQ scores were statistically significantly higher than pre-SSIQ scores for three of the four constructs of SSR (i.e., complexity, inquiry, perspectives). Four primary participants' online discussion posts and reflections for cases supported that engaging in case-based learning experiences enhanced prospective teachers' conceptualization of SSIs, SSR skills, confidence to teach SSIs, and appreciation of the purposes of SSI-based teaching. Finally, the findings suggested that the primary participants advanced their conceptualization of SSI-based teaching after the planning activity. Implications for research and practice, suggestions for curriculum designers and science educators, and future research directions are explored.

INDEX WORDS: Socio-Scientific Issues, Socioscientific Issue-Based Teaching, Case-Based Learning, Elementary Teacher Education, Mixed Methods Study

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BS, Bogazici University, 2010

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2017

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August 2017

DEDICATION

This dissertation is dedicated to my parents, whose incredible love and caring made me the person that I am today; to my brother, who has been holding my hand since my first day at school; and to the ones who bring out the best in me… I love you all dearly…

ACKNOWLEDGEMENTS

Firstly, I would like to express the deepest appreciation to my advisor Dr. Janette R. Hill, who continually and influentially conveyed a spirit of adventure in regard to research and scholarship. Without her guidance, persistent help, and positive energy this dissertation would not have been possible. I could not have imagined having a better advisor and mentor for my Ph.D. study. Besides my advisor, I would like to thank the rest of my dissertation committee: Dr. Deborah J. Tippins, for her detailed feedbacks and also for the hard questions which incented me to widen my research from various perspectives; and to Dr. Ikseon Choi, for his insightful comments and encouragement.

My sincere appreciation goes to Sophia Jeong, my research sister, this dissertation would not have been possible without her assistance and encouragement. I believe our collaboration will extend the borders and continue for the following years. I also would like to extend my gratitude to my participants, Sophia’s students, for their time and engagement. I hope they will be able to apply what they learned about socio-scientific issues in their teaching careers.

I would like to acknowledge the exceptional learning experiences I had in the Learning, Design, and Technology (LDT) program at the University of Georgia. Without the support and friendship of the members of LDT, I would not have been able to develop as a scholar during these four years. Special thanks to Dr. Kopcha, for helping me start my journey at UGA; Ms. Gretchen Thomas, for giving me the opportunity to teach EDIT 2000; and my beloved cohort, Rita, Jasmine, Supriya, Nazil, Neo, Jen, Lucas, and Diego.

I would also like to extend my gratitude to my former professors in Computer Education and Educational Technology department at Bogazici University for encouraging me in the pursuit of my doctoral degree in the United States, I really appreciate their intellectual support. I would also like to acknowledge all the friends and colleagues in Turkey who have always encouraged me to build a career in academia. Worthy of particular mention are Ali and Şebnem, my grad life cannot be told without mentioning their emotional support and friendship.

I would like to express my deepest gratitude to all the friends who made this process a bearable one. To Yasemin and Burcu, who are more than friends to me, thanks for your endless encouragement – beyond words, beyond distance, beyond time. And thanks for understanding that I had to do this one last thing before I could be there all the time. We spent half of our lives together, now I am excited to see what the other half will hold. To Zennure, for being there during all of my grad-life challenges and helping me hanging in there! I will miss our long walks and conversations on our pink chairs. Although I cannot mention all their names in this limited space, I had many loving friends in Athens. I thank Ayça, Bahadır, Ceren, Erkan, Kübra, Lori, and Serap for making Athens my second home.

Words cannot express how much I appreciate my family. I am grateful for all the support they have provided me over the years and raising me as an independent individual. Also, I need to thank my brother, who taught me the value of hard-work and education. Without him, I may never have gotten to where I am today. Lastly, I would like to express my heartfelt gratitude to Ramazan, whose love, encouragement, and belief helped me every day through this process. Thank you for being a person who doesn't require any kind of praise or gratitude for being a caring and trustworthy best friend to me. We have built some amazing memories to reminisce on here in Athens, now, I am coming home...

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CHAPTER 1

INTRODUCTION

Background of the Problem

One of the most enduring goals of science education is to prepare scientifically literate students. According to Anderson (2007), scientific literacy refers to the science-related knowledge, practices, and values that students acquire as they learn science. It is important to develop scientifically literate students because in our current society, citizens increasingly need to make data-based decisions on things such as their diet choices, types of energy sources, or following or rejecting their doctors' suggestions. Science education aims to prepare a scientifically literate national work force equipped to compete in an increasingly scientifically and technologically oriented global economy (Lumpe, Haney, & Czerniak, 2000), using evidence to inform decision-making in multiple contexts.

Science education also seeks to help students make informed decisions on a daily basis, including larger socio-scientific issues. Socio-scientific issues (SSIs) are defined as social issues with conceptual and technological relations to science that are controversial in nature requiring moral reasoning in order to make decisions regarding the resolution of these issues (Sadler, 2004; Zeidler & Nichols, 2009). Sadler (2004) stated that science is inseparable from the society from which it arises. Many researchers in science education advocate the inclusion of SSIs in the science education curriculum and in classroom debates since SSIs have societal interests and effects besides having a scientific knowledge base. In addition, integration of SSIs that incorporate ill-structured problems in science curricula provides opportunities for developing scientifically-literate citizens (Driver, Newton, & Osborne, 2000; Evagorou, Jimenez-Aleixandre, & Osborne, 2012). Abd-El-Khalick (2003) argued that bringing socio-scientific issues into the science classroom would give science educators the opportunity to engage learners in problem-solving in which scientific knowledge and ways of thinking are evident in the discussion of issues that are immediately relevant to students' lives.

In line with advocacy efforts for integrating SSIs in science curriculum, research studies related to SSIs and what students gain by engaging in socio-scientific inquiry have increased in number (e.g., Nicolaou, Korfiatis, Evagorou, & Constantinou, 2009; Simon & Amos, 2011; Zeidler, AppleBaum, & Sadler, 2011). In recent years, many research projects have focused on an extensive range of learner audience in terms of age showing that SSIs can be used productively with learners covering broad age ranges (Sadler, 2011). Despite this progress in exploring the impact on students, there have been fewer studies focused on understanding how SSIs can be integrated productively into science learning environments (Sadler, Foulk, & Friedrichsen, 2017). To better understand the larger challenges associated with SSIs, I will further explore the background of SSIs as well as present a potential strategy that may help address some of the challenges.

Efforts to integrate socially-relevant issues in science education is not a new idea. The science, technology, and society (STS) movement aimed to educate students about interdependence of these three domains (Yager, 1996). However, socio-scientific issue-based instruction transcends the notion of science-technology-society (STS), emphasizing the interrelationships among subject matter with the goal of creating scientifically literate citizens. The moral and ethical threads that SSI encompasses separate it from STS and creates scientific learning that is personally relevant to the students and has an effect on their lives by promoting growth and development of character (Sadler, 2004; Zeidler & Nichols, 2009).

In the science education literature, there has been an emphasis on SSI regarding students' decision making as well as conceptual understanding and interest on science. To date, there is very little research regarding teacher education for SSIs or about the difficulties of teaching SSIs in the classroom, especially at the elementary school level (Espeja & Lagarón, 2015; Sadler, Foulk, & Friedrichsen, 2017). The reason for this might be that we still do not know enough about the lower age boundary for productive use of SSI-based teaching. While some researchers have suggested sixth grade as a lower limit (Aikenhead, 2011), other research indicates that it may be possible to extend SSI audiences with age-appropriate activities (Dolan, Nichols, & Zeidler, 2009; Evagorou & Osborne, 2013).

According to developmental psychologist Kohlberg's theory of the Stages of Moral Understanding (1976), most young children can understand the difference between "good" and "bad" behavior, and this understanding provides the basis for more complicated moral thinking in the future. Seven-to-ten-year-olds have a strong sense of fairness, understand the necessity of rules and want to participate in making the rules. They begin to believe that children have opinions too, and they begin to sort out which values profit them most - a sort of "what's in it for me" stage. Based on SSI research as well as learning theories, I believe we should start engaging our children in these real issues that are immediately relevant to their lives as early as upper-elementary years. This study sought to extend the research in earlier grades by preparing prospective elementary teachers to integrate SSIs in their future classrooms. Thus, I next explore a specific challenge with integration of SSIs into the classroom: teacher readiness.

Teacher Readiness for SSIs

The first step to successfully implementing SSI activities in classrooms is to help teachers overcome challenges of teaching science through SSIs. Integrating socio-scientific issues into science classrooms is not an easy task. Despite the recognized benefits, SSIs are not generally integrated in today's classrooms because of several challenges for teachers (Espeja & Lagarón, 2015). Developing a position on a socio-scientific issue and defending it using a well-reasoned justification involves complex cognitive skills that are challenging to both teach and assess (Chowning, Griswold, Kovarik, & Collins, 2012). Zeidler, Sadler, Simmons, and Howes (2005) reported that teachers may have difficulty in making connections between science and daily life because it is difficult to coordinate scientific data and social aspects of the problem.

According to Presley et al. (2013), there are several teacher attributes that are essential in order to integrate SSIs in science classrooms. First, in order to successfully implement SSI-based instruction, teachers should be familiar with the science content as well as have an awareness of the potential political, economic, and ethical challenges associated with the issue (Presley et al. 2013; Sadler, 2011). Second, SSI-based instruction requires teachers to become learners alongside their students because SSI often involves cutting-edge science. In other words, the teacher should have sufficient amount of knowledge and awareness about the issue in order to effectively guide the students to resources that will lead to new information and considerations. Third, the teacher's development of "a degree of comfort with uncertainty" is critical in successful SSI-based teaching and learning. Effective SSI-based instruction "takes advantage of the uncertainties and transforms them into powerful and engaging learning experiences for students" (Presley et al., 2013, p. 29).

To help prospective and in-service teachers gain these attributes and prepare for challenges of SSI-based teaching, teacher educators should provide them with “access to examples and models of what it means to engage with SSIs in informed ways” (Sadler, 2011, p. 360). While the challenges are not insignificant, a few studies indicated that even short-time trainings supported prospective teachers’ understanding of SSIs and their self-confidence to teach controversial issues (Hestness, McGinnis, Riedinger, & Marbach-Ad, 2011; Lee, Chang, Choi, Kim, & Zeidler, 2012; Yahaya, Zain, & Karpudewan, 2015).

The ability to teach SSIs to prospective teachers is promising; however, there has been ongoing criticism of teacher education programs, some of which are dominated by methods designed to deliver a body of facts and principles (e.g., lecture only). Such criticism is not new to the field of science education. Research indicates that prospective elementary teachers report engaging in negative experiences in their science classrooms when scientific knowledge is presented as something to memorize and unconnected to their lives (Dolan, Nichols, & Zeidler, 2009).

In addition, many elementary teachers feel there is not enough time for science in their classrooms because of the full curriculum. Pianta, Belsky, Houts, and Morrison (2007) described results from a longitudinal study tracking the nature and quality of elementary-school classroom experiences for more than 1,000 children who enrolled in more than 2,500 classrooms distributed across more than 1,000 elementary schools and 400 school districts. The study reported that in fifth grade more than 30% of instruction was in literacy and 25% was in math. Science and social studies activities occurred less than 10% of the time. Another study reported that some elementary teachers indicated that they had to cut time from science instruction after No Child

Left Behind (NCLB) became a law (Griffith & Scharmann, 2008) and supported that there is not enough time for science in elementary classrooms.

For both challenges given above, SSIs can be useful to convince prospective and in-service teachers that science can be interesting and worthwhile to teach (Dolan, Nichols, & Zeidler, 2009). Engaging in a socio-scientific issue topic supports complex cognitive skills for students and provides opportunities for an integrated curriculum. Zeidler and Nichols (2009) stated that "a carefully designed SSI topic can involve a mix of reading skills, science content, social studies, mathematics, and art, as well as providing students (and teachers) with real experience involving moral reasoning, epistemological development, and peer debate" (p. 53). By engaging SSIs in teacher education, prospective teachers will learn about this approach for their own classes and appreciate the value of making science more relevant for students' lives and more connected to other disciplines.

Case-Based Learning in Teacher Education

Integrating SSIs into teacher preparation is an important first step to making learning of science more engaging. Another step to ensuring that today's prospective teachers become tomorrow's well-prepared beginning teachers (Avraamidou & Zembal-Saul, 2010) can come if teacher education programs focus on engaging prospective teachers in authentic activities and the analysis of practice (Ball & Forzani, 2009). Teacher educators, like educators of other professionals, have sought ways to pass on the profession's increasingly complex knowledge and skills in ways that would prepare new teachers to apply their knowledge within equally complex educational contexts (Hammerness, Darling-Hammond, & Bransford, 2005). Central to these efforts is a tension between ensuring a manageable level of complexity for novices, and simulating authentic complexity, content knowledge, and skill expectations (Williams, 1992).

Creating effective learning environments is critical to make the tensions not only manageable for the teachers but also engaging for the learners.

There are numerous ways to create more authentic learning environments for teacher education programs (Goodman, 1987). The recent trend internationally is for teacher training to take place within undergraduate and graduate-level degree programs (Howe, 2006). There are basically three categories for teacher education: (1) normal schools solely for teacher training of two to four years in duration; (2) bachelor's degree programs with an emphasis on subject matter and less pedagogical preparation, typically offered only in the last one or two years of a program; and (3) master's degree and/or fifth year programs focused on teaching practice and pedagogy, open to candidates with a bachelor's degree (Cobb, Darling-Hammond, Murangi, 1995). Each of these programs, while differing in its specific methods of training, promotes the investigation of both theoretical issues and practical implications as a guide for the preparation of teachers (Darling-Hammond, 2012). Therefore, to help prospective teachers understand the value of SSI-based teaching and prepare for potential challenges of this approach, teacher educators should integrate and model SSI-based teaching and learning activities in their courses.

The use of cases in teacher education has been advocated by many as a promising instructional method for creating authentic learning environments (Koury et al., 2009; Levin, 2001; Lundeberg, Levin, Harrington, 1999). Socio-scientific issue-based instruction is similar in its teaching approach to case-based teaching in that they both frame science content within a story (Latourelle, Poplawsky, Shmaefsky, & Musante, 2012). Thus, I believe case-based pedagogy is an appropriate instructional method to support prospective teachers' conceptualization of socio-scientific issues and issue-based teaching when we incorporate case materials related to SSI-based teaching and learning in a constructivist case-based learning environment.

Case-based pedagogy emulates real classroom environments, and thus enables students to think like teachers (Shulman, 1992). Shulman (1992) states that "…proponents of case methods believed that existing pedagogies were breeding inert ideas and case methods were seen as a solvent for such problems" (p. 1). However, attempts to systematize case-based methods through additional instructional support have been rare since most published studies "describe the potential of the approach, provide descriptions of case systems, and use satisfaction data as outcome measures" (Fitzgerald et al., 2009, p. 32). To the best of my current knowledge, no research studies exist reporting on the effects of case-based teaching on prospective teachers' conceptualization of SSI-based teaching and learning. This study seeks to explore this area to inform both the practice and research communities.

Purpose Statement and Research Questions

The purpose of this study is to (a) develop a feasible design framework for a case-based learning environment that incorporates cases related to socio-scientific issue-based teaching and learning and (b) apply the model to enhance prospective teachers' conceptualization of socio-scientific issues and SSI-based teaching in a science methods course for elementary education. The inquiry in this study focused on one overarching question: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching? This study attempted to answer the following research questions:

1. To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSIs?

1.1. How does the CBLe support prospective elementary teachers' evolution of socio-scientific reasoning?

1.2. How do prospective elementary teachers' conceptualization of SSIs evolve during the SSI case activities?

1.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of socio-scientific issues?

2. To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSI-based teaching?

2.1. How do prospective elementary teachers' conceptualization of SSI-based teaching evolve during the pedagogy case activities?

2.2. How do prospective elementary teachers translate their understanding of SSI-based teaching into planning after experiencing the CBLe?

2.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of SSI-based teaching?

Definitions of Terms

I will briefly define the key terms in this section to make the terms used in the dissertation clearer to the reader.

- *Case reflection paper*. Relatively brief responses to a case that provide additional perspectives on what happened and why. The pedagogy case analysis may comprise answers to following questions: How do you make sense of what happened, based on what you know about socio-scientific issue based teaching? How would you turn this lesson into a socio-scientific issue activity? What lessons do you take from this case for the future, for teaching socio-scientific issues?

- *Pedagogy cases.* In this study, a pedagogy case refers to narratives of teaching that are used to (a) guide reflection and (b) teach others. Although they are story-like, cases are not simply stories that a teacher might tell. They are crafted into compelling narratives, with a beginning, middle, and end, and situated in an event or series of events that unfold over time. In this study, these narratives present a rich and realistic insight into the complex and challenging world of socio-scientific issue-based teaching and provide an opportunity for analysis of practice.
- *Prospective teachers.* Early childhood teacher education students who are enrolled in the science methods course.
- *Socio-scientific issues (SSIs).* In this study, socio-scientific issues refer to the open-ended, ill-structured problems, which are typically subject to multiple perspectives and solutions (Sadler, 2004); that require moral, ethical evidence-based reasoning in their solutions (Zeidler & Nichols, 2009). Socioscientific issues are controversial, socially relevant, real-world problems that are informed by science and often include an ethical component (Sadler, Barab, & Scott, 2007). Examples include fish farming, genetic testing, global warming, and captive breeding in zoos.
- *SSI cases*. Narratives about real socio-scientific issues that present complex arguments from multiple perspectives in a story format.
- *Socio-scientific reasoning*. According to Sadler, Barab, and Scott (2007), socio-scientific reasoning is a theoretical construct designed to "uniquely capture the array of practices fundamental to the negotiation of SSIs" (pp. 377-378). Socio-scientific reasoning includes four practices that are essential for responsible decision-making in the context of any SSI (Sadler, 2014). The four practices are presented as follows:

"(1) Recognizing the inherent complexity of SSIs, (2) Examining issues from multiple perspectives, (3) Appreciating that SSIs are subject to ongoing inquiry, (4) Exhibiting skepticism when presented with potentially biased information." (Sadler et al. 2007, p. 374)

- *SSI-based teaching.* SSIs-based teaching combines the use of controversial socially-relevant real world issues with science content. Issues-based teaching is a variant of problem-based teaching in which authentic, real-life issues or topics are the central focus with an emphasis on the socioscientific aspect. The issue does not have closed boundaries that lead to a specific answer, but is open to exploration, inquiry, and integration of multiple disciplines. Students can investigate a wide range of subjects and the ramifications of them in science, society, politics, economics and any other realm that affects the everyday life of the learner (Latourelle et al., 2012).

Subjectivity Statement

When I started to work on this section, I realized that when I start to think and write about myself, I always start with my educational background, courses I have taken, how I am passionate about learning, how I believe I can help someone to learn something a little bit better through instructional design and technology. Researchers develop subjectivity statements in different ways. One approach is the story of the research relationship from introduction to withdrawal from interaction. Another is more autobiographical, focusing on who researchers believe themselves to be as individuals, their backgrounds, and how these are related to those they study. I am choosing the second way.

Ever since I was a primary school student, I had a strong desire for a teaching career and I have known that facilitating someone's learning is one of my biggest interests. Owing to my undergraduate and graduate studies, I had a broad vision of how people learn and ways to facilitate human growth through the design, development, implementation, and evaluation of learning environments. During my doctoral studies, I have received various support that has allowed me not only to learn the rigor of research but also to explore my own views on a variety of topics regarding how people learn through instructional design and technology. I strongly believe instructional design can make a difference—especially for teacher education.

When I remember my own learning experiences as a prospective teacher, one of the most valuable experiences I had during my undergraduate education was my field experience. I still remember how much effort I put on my lesson plan, because it was real! Having a meaningful task to do, having authentic audience and context affected my motivation drastically at the time. When the day arrived, I met with my guide-teacher at the school, and she asked me how I was feeling. When I told her that I was motivated but also nervous because of thinking about all of the things that could go wrong, she shared her story of first day of teaching with me. It was a disaster! She mentioned how she ignored a "disruptive" student because she had not known what to do in that time, and this ignorance turned out badly. He fell onto another student while he was running around the room! Then, she asked me what I would do, if I had a similar situation in that day. I analyzed the problem, proposed some solutions and we discussed it. That was a very powerful, meaningful, authentic learning experience for me! Since that time, I believe in the power of *stories* in education, but only I had not known that it is actually an instructional method called *case-based learning* until I took a course during my doctoral studies.

I am a *constructivist*. I believe in power of the process of "meaning making" from everything we see, hear, do, and tell. Case-based learning is a method that works for myself as a student since it easily starts the meaning making process for me. This study was a great opportunity for me to explore how I could improve this method and implement it in my future class as the instructor and explore whether it really works for different people or not. I realized that during the interviews, I really got happy when a participant talked about something I had expected – positive or negative. I guess this might have influenced my participants' further explanations. However, my interview guide had diverse questions, which I thought it would allow me to prompt participants' responses. For example, I asked both which activities facilitated or hindered their learning. Thus, they had the opportunity to talk about their opinions. With a semi-structured approach, I asked open-ended questions and structured questions, which enabled me to hear about *their* experiences, not my assumptions.

Overall, all activities were implemented smoothly and recruitment of participants was very opportune. All prospective teachers were motivated to participate in designed activities and we had engaging classroom discussions. We even had difficulty in closing up the discussions and moving to the next activity of the class meeting. Many times, I found myself thinking about the insider-outsider dichotomy during the classroom meetings. Suzuki, Ahluwalia, Arora, and Mattis (2007) discussed that: "One need not be either an insider or an outsider; one may be both an insider and an outsider. Indeed, we must be mindful that people hold a multiplicity of identities that shape subjectivity and influence interpersonal dynamics" (p. 300).

Even if it was difficult to not to share my point of view during intense classroom discussions, I pushed myself to stay as an outsider and not to get too involved in the discussions or give the "correct answer" to prospective teachers' comments. The instructor was also very successful in terms of not leading them to a specific conclusion. She summarized key issues and asked questions that helped prospective teachers identify issues and stay on track. She also asked my general comments at the end of the each case discussion and occasionally for other issues during the classroom meetings. Thus, I was also able to – and needed to- get an insider perspective. I was a member of the class, helping them with other classroom activities and sharing my passion for case-based learning.

While I was conducting the interviews, having an insider perspective was very helpful for getting detailed and *honest* answers for negative experiences questions. I was already an insider because I had been in all class meetings and already observed what worked and what did not work to a degree. My relationship with the prospective teachers has been very close and friendly and I tried to show them that I was genuinely interested in how these activities worked for them and for this course. I explicitly asked them to put their best effort into the case assignments and I believe they did so. I felt comfortable interviewing them and, as far as I tell, they were open and honest in their answers to interview questions and in sharing their opinions for all their course work.

Overview of Chapters

This dissertation is organized in six chapters. In Chapter 1, I introduced the background of the problem, purpose and research questions, and the definitions of relevant terms. In Chapter 2, I present the literature review and theoretical framework of the study. The literature review is organized in two sub-sections: Socio-scientific issues and case-based learning, and their connections to teacher education. The theoretical framework includes instructional principles deriving from constructivism and explanation of the instructional design framework of the study. In Chapter 3, I introduce the case-based learning environment developed and implemented for the purposes of this study. I also provide thick descriptions of the learning materials and activities that were used in the study. Next, I describe the mixed methods design of the study including the data collection procedures and analysis, and limitations of the study. In Chapter 4, I report the findings and interpretation with respect to research question one. In Chapter 5, I present findings for the second research question. In Chapter 6, I provide a brief summary of the study by discussing the findings, report implications for research and practice, and suggest further research directions.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

In this chapter, I present the literature review in two subsections: socio-scientific issues (SSIs), and case-based learning (CBL) with connections to elementary teacher education. The chapter will conclude with the theoretical and instructional design frameworks for the study.

Socio-Scientific Issues

Socio-scientific issues are defined as social issues with conceptual and technological relations to science, and are controversial in nature, requiring moral reasoning in order to make decisions regarding the resolution of these issues (Sadler, 2004; Zeidler & Nichols, 2009). Sadler (2004) stated that science is inseparable from the society from which it arises. Besides having a scientific knowledge base, socio-scientific issues (SSIs) have societal interests and effects. Bearing in mind that one of the most important goals of science education is to help students to understand how society and science are mutually dependent, the integration of SSIs in science curriculum has been supported broadly among science educators, researchers and the science education community (Driver et al., 2000).

Integrating SSIs into curriculum is also known as socio-scientific issues-based instruction, which combines the use of controversial socially-relevant real world issues with course content to engage students in their learning. Issue-based teaching is a variant of problem-based teaching in which authentic, real-life issues, or topics are the central focus with an emphasis on the socio-scientific aspect (Latourelle et al., 2012). Researchers have argued that socio-scientific issues should be an important component in preparing scientifically literate students because SSIs more accurately represent science in the real world context with all of its connections to society, technology and culture (Kolstø, 2001; Sadler, 2014).

In line with the efforts to integrate SSIs in science curriculum, the research related to SSIs and what students gain by engaging in socio-scientific inquiry has increased in number during the last two decades. Socioscientific issues have been connected to important aspects of science education such as argumentation (Evagorou & Osborne, 2013; Jiménez-Aleixandre, Rodriguez, & Duschl, 2000; Zohar & Nemet, 2002), reasoning (Kolstø, 2006; Sadler, Klosterman, Topcu, 2011; Wu & Tsai, 2011), nature of science (Wong, Wan, & Cheng, 2011) and the acquisition of conceptual knowledge (Dawson & Schibeci, 2003; Klosterman & Sadler, 2010). According to Fowler, Zeidler, and Sadler (2009), student learning and development in these areas are standard expectations in the classrooms of today. I will briefly highlight important findings from some studies that were conducted in elementary classrooms.

One study conducted by Dolan, Nichols, and Zeidler (2009) investigated fifth grade students' understanding and engagement of science concepts through the use of a socioscientific issue-based curriculum. Prior to including any SSI-based issues and activities into the curriculum, the instructor made sure that students had solid comprehension of the science concepts that would be discussed. Three units were developed and implemented in a single fifth grade class. Students were asked to think critically and utilize their analysis, synthesis and evaluative skills throughout these activities, which included debate and continued dialogue about controversial issues ranging from beach erosion to harp seal harvesting. Students showed enthusiasm and deeper understanding about the richness of science concepts, how their influence on personal health, and local environments and communities.

In another research project, Evagorou (2011) worked with a group of teachers to collaboratively develop curriculum materials making use of technologies (the WISE platform and handhelds) in order to support elementary school students' argumentation through the context of an SSI. The teachers developed the learning environment within the WISE platform (Linn, Davis, & Bell, 2004) and posed the following guiding question to the students: What are the effects of the pig farm on your area and what course of action do you suggest? The teachers stated that the socio-scientific topic was chosen because it was relevant to the students' everyday lives and was an issue that could potentially engage these students in the investigation and challenge them to construct arguments considering all aspects of the topic (moral, financial, environmental, and social).

During the study (Evagorou, 2011), the curriculum materials were implemented in one fifth grade and one sixth grade class that the participant teacher was teaching science. The fifth-grade class had 17 students and served as a forum to pilot test the curriculum. The sixth-grade served as the class in which Evagorou collected the main data for the project. According to the teacher, the majority of the sixth graders were low achievers in science. Students engaged in eight interconnected lessons that ranged from an introduction to argumentation, to an introduction to the problem, a visit to the nearby pig farm and a whole-classroom discussion of the decisions the groups reached.

Evagorou (2011) indicated that study results showed that even though only two groups improved their levels of argumentation, all six groups improved in terms of the number of pieces of evidence they included in their arguments. The findings of this study suggested that the learning environment supported the students in collecting and including new pieces of evidence in their argument, even though the structure of the argument (e.g., inclusion of rebuttals) did not necessarily change. This study is promising in terms of highlighting the improvement of low achieving young students' levels of argumentation after engaging in a designed learning environment for a short period of time.

In a similar study, Evagorou and Osborne (2013) conducted a case study to explore how young students (two different pairs from a class of 12- to 13-year-old students) constructed arguments collaboratively when they participated in a specially designed instructional approach within a socioscientific issue. In order to engage students in socioscientific argumentation, they used an online learning environment, Argue-WISE that was designed within the WISE (Web-based Inquiry Science Environment) platform (Linn et al., 2004). For this study, the researchers purposefully worked with students who were drawn from a class that was characterized by their teacher as above average achievers, something that was also supported by the students' Cognitive Ability Test. The driving question used in the learning environment was whether the UK government should kill the gray squirrels in order to save the indigenous red. Students engaged in four, 50-minute lessons, in which they had to work in pairs in order to study the problem and find evidence within the learning environment to support their argument. Interestingly, findings indicated that even though initial arguments of both pairs were of the same quality and shared the same claim, the two pairs provided quite different arguments, both in terms of the quality and the claims, with one of the pairs providing better-written arguments (Level 4 out of 5) by the end of the instruction.

Although some argue that SSIs may be too advanced for elementary students, science educators should not deny the positive outcomes of these units on younger learners. The relevancy of these topics to students' lives boosts enthusiasm and engagement, resulting in deeper understanding of controversial issues and science concepts. With few studies focusing on the use of SSIs in elementary classrooms, improvement of young students' higher order thinking skills and learning of and about science is a wide-open field of study. Focusing on students at a younger age will help educators to plant the seeds early to increase interest in science and enhance their understanding of how science and society are connected.

However, integrating socio-scientific issues into science classrooms is not an easy task. Despite the recognized benefits, SSI are not generally integrated in today's classrooms because of several challenges for teachers (Espeja & Lagarón, 2015). The first step to successfully implementing SSI activities in classrooms is to prepare prospective and in-service teachers to overcome challenges of teaching science through SSIs. I will present research studies focusing on socio-scientific issues in teacher education with implications for my research in the following section.

Socio-scientific Issues and Teacher Education

As mentioned earlier, there is very little research regarding teacher education for SSIs or about the difficulties of teaching SSIs in the classroom, especially at the elementary school level (Espeja & Lagarón, 2015; Sadler, Foulk, & Friedrichsen, 2017). During the last decade, a few studies reported on prospective teachers' understanding of SSIs (Hestness, McGinnis, Riedinger, & Marbach-Ad, 2011), reasoning around SSIs (Lee, Chang, Choi, Kim, & Zeidler, 2012; Topcu, Sadler, Yilmaz-Tuzun, 2010), views about SSIs (Özden, 2015), self-efficacy for teaching controversial issues (Yahaya, Zain, & Karpudewan, 2015), experiences with SSIs (Ekborg, Ottander, Silfver, & Simon, 2013; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006), and appreciation of the value of teaching SSIs (Espeja & Lagarón, 2015). I highlight below some of these studies, including implications for the current study (see Table 2.1 for an overview of the implications based on the review of literature).

Table 2.1

Key Implications for SSIs and Teacher Education

Challenges regarding SSIs	Key Implications for SSIs in Teacher Education	Key Study
Prospective teachers would have difficulty in translating their understanding of SSIs to a developmentally-appropriate level for their elementary-school learners	- Model how learning activities (designed for adults) might be adapted for use across the elementary grade levels. - Integrate an age-appropriate SSI activity before the participants design their own activities.	Hestness et al. (2011)
Prospective teachers might not be able to develop necessary skills to understand and teach SSIs during their educational experiences.	- Design appropriate learning experiences for prospective teachers to develop their own informal reasoning practices and understanding of SSIs. - Explore prospective teachers' socio-scientific reasoning	Sadler, Topcu, and Yilmaz-Tuzun (2010)
Prospective teachers would have a weak sense of efficacy in teaching of controversial issues.	Integrate controversial topics into teacher education programs to prepare prospective teachers emotionally for teaching these topics in their future classrooms.	Yahaya, Zain, and Karpudewan (2015)
Prospective teachers have positive views on the use of SSIs in science education but they may also believe that it simplifies science education	Highlight purposes of teaching SSIs such as enhancing understanding of nature of science and critical thinking skills along with scientific knowledge.	Özden (2015) Ekborg et al. (2013)
Understanding the purposes for teaching SSIs may be challenging for prospective teachers	Place explicit emphasis on some complex reasons to teach SSIs (e.g. nature of science, scientific literacy)	Espeja and Lagarón, 2015
Teachers may have difficulty in emphasizing the ethical nature of SSIs, the conflict of interests (multiple perspectives), and creating awareness of the interdependence between society and science	- Place emphasis on characteristics of SSIs (e.g. complexity, need for inquiry, affecting different groups) - Integrate strategies for facilitating students' search for information and argumentations with SSIs	Ekborg et al. (2013)

Hestness et al. (2011) investigated the inclusion of a curricular module on global climate change in an elementary science methods course. For this study, the researchers designed the global climate change curricular module to meet the needs of the participants and to fit appropriately into their teacher education program. Prior to the class sessions devoted to the module, teacher candidates provided information about their own understandings of global climate change by responding to the prompt: Draw what happens during the process of global climate change. Participants engaged in two consecutive class sessions (110 minutes for each session) within the course, which were devoted to the implementation of the global climate change module. The authors explained related activities as follows:

- Engaging in an activity that modeled a pedagogical approach to involving students in data analysis related to climate change.
- Working in self-selected groups of four to six members to examine data related to a physical or life science aspect of climate change (e.g., data on penguin population changes in Antarctica, changes in greenhouse gas levels as detected in ice cores).
- Creating visual representations of their data, discussing interpretations, and posing new questions.
- Introducing relevant climate change literature for elementary-aged students, taking time to review children's books and other media addressing global climate change and considering the ways that these resources could be used in the classroom.
- Exploring web-based resources with the potential to support teachers in introducing climate change in the science classroom.

Hestness et al. (2011) analyzed findings from 63 teacher candidates' drawings, questionnaires, and journal entries collected throughout their participation in the module and highlighted three cases to illustrate the diversity of participants' experiences. Findings of the study suggested that a curricular module on global climate change improved teacher candidates' "understanding of science content related to climate change, some of its social implications, its local and global relevance, and understanding of pedagogy for including the topic in their own instruction" (p. 367). One of the most important implications from this study was that a number of teacher candidates stated that they would have difficulty in "translating the information to a developmentally-appropriate level for their elementary-school learners" (p. 368). Thus, the researchers suggested that science teacher educators should spend time demonstrating how learning activities might be adapted for use across the elementary grade levels. For my study, I tried to enhance prospective teachers' understanding of age-appropriate SSI-based instruction by integrating an example SSI-based teaching activity (see Appendix D) before the participants design their own activities.

As aforementioned earlier, there are a few studies reporting on prospective teachers' moral and/or informal reasoning practices. Topcu, Sadler, and Yilmaz-Tuzun (2010) conducted a study to explore the extent to which contexts of SSIs affect the prospective teachers' informal reasoning processes. The researchers chose 39 prospective teachers from an undergraduate program designed to prepare students for teaching middle school science (sixth through eighth grades). They engaged participants in interviews designed to prompt argumentation related to multiple socioscientific scenarios. The scenarios featured in the interviews were taken from previous studies of SSR and argumentation (e.g., Bell & Lederman, 2003; Sadler & Zeidler, 2005).

The data from Topcu, Sadler, and Yilmaz-Tuzun's (2010) study was analyzed using an interpretive qualitative research approach using a framework initially proposed by Toulmin

(1958). The study yielded conflicting results in terms of the extent to which informal reasoning was context-dependent. However, the findings clearly suggested that the prospective science teachers in this sample were not particularly skilled at informal reasoning in the context of SSI. They summarized this issue as follows:

> Sixty-one percent of responses across all seven scenarios were scored at a Level 1 or 2, indicating that in most of their responses, PSTs [Prospective science teachers] were not able to construct counter-arguments and rebuttals even when they were specifically prompted to do so. This pattern of informal reasoning indicates that the PSTs were not considering perspectives other than their own very frequently. The results indicate that the PSTs struggled with similar informal reasoning issues as seen in studies with students such as forming robust counter-arguments and rebuttals (Jimenez-Aleixandre et al., 2000; Kortland, 1996). (p. 2490)

The authors stated that all of the participants had completed courses in the major science disciplines including biology, chemistry, ecology and physics. However, their low level of informal reasoning skills suggested that they might not be able to develop necessary skills to understand and teach SSIs during their educational experiences. This study highlighted the need to design appropriate learning experiences for prospective teachers to develop their own informal reasoning practices and understanding of SSIs.

Reasoning around SSIs is also known socio-scientific reasoning which is an important construct for this study. According to Sadler, Barab, and Scott (2007), socio-scientific reasoning is a theoretical construct designed to “uniquely capture the array of practices fundamental to the negotiation of SSI” (pp. 377-378). In their initial work (Sadler et al., 2007), they framed socio-scientific reasoning in terms of four practices essential for responsible decision-making in the context of any SSI (Sadler, 2014). The four practices were presented as follows:

1. Recognizing the inherent complexity of SSIs.
2. Examining issues from multiple perspectives.
3. Appreciating that SSIs are subject to ongoing inquiry.
4. Exhibiting skepticism when presented with potentially biased information. (Sadler et al. 2007, p. 374)

Even though there is an increase in number of the research studies that explore middle or high school students' socio-scientific reasoning, to the best of my current knowledge, there are no research studies exploring prospective elementary teachers' SSR. This study aims to contribute to the science teacher education literature in this sense. Hence, I used a Socioscientific Issue Questionnaire (SSIQ) (see Sadler, Klosterman, & Topcu, 2011) as a data source to explore the participants' evolution of SSR after engaging in designed learning activities.

Yahaya, Zain, and Karpudewan (2015) conducted a quasi-experimental design with mixed method approach to investigate the effects of socioscientific instruction on prospective biology teachers' sense of efficacy in the teaching and learning of controversial family health issues. The researchers worked with a total of 251 students from two teacher training colleges. Out of this number, 93 students were assigned as experimental group and the rest as control group. The experimental group engaged in topics designed with socio-scientific issue-based instruction approach such as human reproductive anatomy and physiology, pregnancy, abortion, contraception, and sexually transmitted infections. In each of the topics, participants were given a brief lecture with some notes. The problem or issue under discussion was framed in a story from which the participants were asked to take a position. The activities went on for 7 weeks covering all the topics outlined in the module.

Yahaya, Zain, and Karpudewan (2015) collected quantitative data using a sense of efficacy scale questionnaire from both groups before and after the implementation. They also conducted interviews with ten participants randomly selected from the experimental group before and after the implementation of the activities to deepen and elaborate the quantitative data. The quantitative and qualitative findings indicated that the integration of the SSI-based instruction significantly affected the prospective teachers' sense of efficacy in favor of the experimental group, which showed a stronger sense of efficacy. It was concluded that the socioscientific instruction was significantly effective in promoting the prospective teachers' weaker sense of efficacy in the controversial family health issues.

Even though this study did not explore prospective teachers' own conceptualization of SSIs or socio-scientific issue-based instruction, it supported the argument that engaging in similar activities enhanced their self-efficacy to teach controversial issues. Hence, teacher educators should integrate controversial topics into their courses to prepare prospective teachers emotionally for teaching these topics in their future classrooms.

To be able to design proper activities for prospective elementary teachers, I also searched for studies to understand their views about SSIs. Özden (2015) examined prospective elementary teachers' views about socio-scientific issues in a mixed methods study. The researcher taught the science methods course for prospective elementary teachers at a state university in western Turkey. Students engaged in two lessons about SSIs and their use in education in which the instructor discussed the topics of global warming and nuclear energy. Further, the instructor informed the participants that the topics discussed were named SSIs and asked them to reflect on the characteristics of SSIs and how to handle SSIs at the elementary school level.

After these introductory activities, the instructor recruited participants for his research. Eight prospective teachers volunteered for the semi-structured interviews. Interviews included four open-ended questions: 1) How do you describe in your own words the concept of SSI? 2) Can you give examples of SSI that can be used in science and technology courses? 3) What can be the contribution of involving SSI into science and technology course? 4) What should be the roles of teachers in teaching SSI? The researcher conducted the interviews and analyzed the data using thematic analysis.

Özden (2015) also developed a questionnaire and collected data from 113 prospective elementary teachers. The questionnaire included thirteen Likert-type items to obtain participants' views on the use of SSI in elementary science education. Their responses were analyzed using frequency, percentage, and mean scores.

Findings of the study (Özden, 2015) suggested that prospective teachers have positive views on the use of SSIs in science education. The item on which participants agreed the most was "Prospective teachers should be trained about SSIs" ($M = 4.15$). The author also reported that prospective teachers thought that SSIs should be integrated in science lessons ($M = 4.04$) and this would increase students' interest in learning science ($M = 3.74$), facilitate learning of science ($M = 3.78$), and improve scientific literacy ($M = 3.88$). The author stated that participants believed science education involving SSIs can promote students' higher order thinking skills such as argumentation, opinion development, scientific skills and creativity.

Another interesting finding of the study was that one third of the participants agreed that "Integrating SSI into science education simplifies science education" and 24.8% of them were indecisive about this issue. This statement is aligned with the findings of Ekborg et al. (2013), in which they reported that 23% of the participants agreed with the statement "The students did not learn as much science as usual." Participants' view about *learning less science* may be stem from their limited understanding of the characteristics of socio-scientific issues. For example, analysis of the interviews in the Ekborg et al. (2013) study showed that only one participant mentioned the ethical characteristics of the SSI. Other studies, highlighted in the following paragraphs, also suggested that prospective teachers usually do not have comprehensive understanding of SSIs and thus most of them do not realize that "these activities can also help students develop their knowledge of science and about science, probably because it is more difficult to relate these ideas to the aims of SSI activities" (Espeja & Lagarón, 2015, p. 88). Accordingly, it can be asserted that prospective teachers are highly in need of being trained about SSIs.

Espeja and Lagarón (2015) reported preliminary results of a research project in which they designed and implemented a training for elementary teachers. From my review of the educational research literature, this was the only study I identified that explored the effects of a specifically designed training on prospective elementary teachers' understanding of SSIs and SSI-based teaching. The aim of the project was to engage prospective elementary teachers in critical discussions on current scientific topics through socio-scientific issues and prepare them to teach SSIs.

Espeja and Lagarón (2015) implemented the designed activities within a course that senior elementary prospective teachers take for their undergraduate degree. 15 students participated in the designed activities for the study. They devoted the last 3 sessions of the course to the SSI training program, in sessions of 1-2 hours. The first two sessions were designed to enhance participating teachers' understanding of the main characteristics of SSIs. The instructor presented the SSI topic (global warming) and a classroom discussion was held on students' initial reflections on the topic. Then, students collected information about the issue before the next class session. The third session was devoted to reflecting on the reasons to integrate SSIs in elementary classrooms and the specific pedagogy when designing and implementing SSI activities. The instructor presented an example of an SSI activity for elementary classrooms (edible insects) and the participants reflected on the reasons to teach SSIs and how to teach them.

Three extra volunteering sessions were held to design, implement and reflect on participants' (three students) own SSI lesson plans (Espeja and Lagarón, 2015). In the first session, participants read and reflected on the example lesson plan and started designing their own activities. Following the reflection, they worked on their designs with the support of researchers on their own time. During the second session, participating prospective teachers implemented their lessons in a real classroom and during the last session they reflected on the all activities they engaged in for the study.

Espeja and Lagarón (2015) collected data through participants' pre- and post-individual reflections before and after the modules. Two open-ended questions were asked: "1. What do you think are SSI? Give examples." and "2. Is it important to teach SSI in schools? Why?" They also collected participants' classroom productions, and recordings of the discussions in the classroom. To explore the development of participants' conceptualization of SSIs and their appreciation of teaching SSIs, they selected pre- and post-intervention extracts or quotes in which participants' model or concept of SSI was explicit and in which they expressed their appreciation of purpose of teaching SSI. They analyzed the data and categorized in a category system built from the literature. This category system also informed this study for data analysis.

For data analysis, both for the conceptualization of SSIs and for the purposes for teaching SSIs, the researchers evaluated "% of prospective teachers that were at each level before and after the training program, identifying in each case the most common pattern of evolution present in analysis and the % of student teachers following that pattern" (Espeja and Lagarón, 2015, p. 83). Findings suggested that the training facilitated the development of prospective teachers' understanding of SSIs in terms of richness and depth. Participants included new aspects of SSIs in their post-reflections, such as uncertainty and argumentation, and demonstrated higher levels of complexity in the all aspects analyzed.

Espeja and Lagarón (2015) stated that regarding the appreciation of purposes of teaching SSIs, most of the prospective teachers remained in the same level of appreciation and only a few of them showed improvement in this regard. They explained this finding as follows:

> At the end of the modules, most prospective teachers were able to appreciate the importance of critical thinking and other Higher Order Thinking Skills, such as argumentation or the ability to consider a wide range of points of view when teaching SSI, and realized that their students can benefit from participating in a SSI activity regarding these aspects. On the contrary, most of them didn't realize that these activities can also help students develop their knowledge of science and about science, probably because it is more difficult to relate these ideas to the aims of SSI activities. (p. 88)

Espeja and Lagarón (2015) inferred that these results may be related to the limited time that was devoted to explaining the reasons to teach SSIs. Regardless of this finding, this study has a few important implications for my study. First, understanding the purposes for teaching SSIs may be challenging for prospective teachers and therefore, explicit emphasis should be placed on some complex reasons to teach SSIs (e.g. nature of science). Second, this study found that it is possible to enhance prospective teachers' conceptualization of SSIs "in a short period of time and with students that have no previous knowledge on SSI, if using the right materials and strategies" (p. 88). Therefore, I adopted some of the materials used in this study to enhance participants' conceptualization of SSI-based teaching with the authors' permission. Third, the category system developed by the authors for data analysis resonated with my data analysis, thus I modified their category system for this study (see Data Analysis section in Chapter 3).

My review of the literature did not reveal any studies exploring case-based pedagogy for supporting prospective teachers' understanding of SSIs. However, Ekborg, Ideland, and Malmberg (2009) presented a conceptual framework consisting of six components to describe the characteristics of SSIs, and constructed six authentic and current cases in which these components vary. In a secondary study, Ekborg et al. (2013) conducted a mixed methods study to explore in-service teachers' experience of working with these cases in Swedish classrooms. The researchers worked with a large group of teachers (n=55); each teacher chose one of six cases with the characteristics of SSI and was free to organize the work as he/she found appropriate. Ekborg et al. (2013) collected data through an online questionnaire and conducted semi-structured interviews with a group of seven teachers. The majority of the respondents were experienced teachers who had worked more than 5 years as science teachers with grade 7^{th} to 9^{th} students. According to the questionnaires, the teachers spent between 5 and 10 hours with the case.

Findings of the study (Ekborg et al., 2013) suggested that teachers were quite content with the students' learning of scientific facts, how to apply scientific knowledge and to search for information. However, they found that the students did not easily formulate questions, critically examine arguments or use media to obtain information about the task. Moreover, 23% of the participants agreed with the statement “The students did not learn as much science as usual”. The authors also stated that the teachers understood SSI work as free work and only a few of the teachers developed explicit strategies for teaching SSI. Participating teachers of this study did not consider SSIs as specifically new or different from their ordinary teaching. They emphasized that they felt confident with teaching SSIs. However, they also described difficulties; three teachers expressed an explicit need for support in their answers to an open-ended question in the questionnaire. One participant in their study stated that “the students had a tendency to get more involved with energy saving instead of the core science, and she had no strategy for how to connect this interest with the scientific content.” The authors’ inference from this contradiction is presented as follows:

> […] Another reason for feeling comfortable might be that the teachers did not work with SSI as described by Ratcliffe and Grace (2003) and Zeidler et al. (2005). The teachers used the cases to create interest when introducing a topic, but generally they did not stress ethical issues, the conflicts of interest or content about science, and they did not create awareness of the interdependence between society and science even if this was stressed in the framework. (p. 614)

This study presented conflicting results in terms of teachers’ experiences working with SSIs, and students’ learning judged by only what their teachers believed that the students had learned. However, findings reported in this study suggest several important implications for my study. First, even experienced teachers need help developing teaching strategies for SSIs. Thus, explicit example SSI-based activities, and strategies for facilitating students’ search for information and argumentations with SSIs should be integrated in teacher education programs. Second, an emphasis should be placed on characteristics of SSIs. Teachers may have difficulty in emphasizing the ethical nature of SSIs, the conflict of interests (multiple perspectives), or creating awareness of the interdependence between society and science. Third, teachers' interpretations of scientific content might be limited to "knowledge as a set of facts to be taken in by the students" (p. 613). It is important to highlight purposes of teaching SSIs such as enhancing understanding of nature of science and critical thinking skills along with scientific knowledge.

It is evident from the studies highlighted here that SSI-based instruction is a promising method and prospective teachers have positive opinions about integrating socio-scientific issues into their classes when they are trained and encouraged to do so. Research explored here suggested that engaging in training related to SSI-based teaching and learning enhances prospective teachers' understanding of SSIs, reasoning skills, confidence to teach SSIs, and appreciation of the purposes of integrating SSIs in their future classrooms. It is also evident in the literature that prospective teachers usually do not develop necessary skills and understanding that enable them to teach SSIs in their future classrooms. Ekborg et al. (2013) reported that their participants appreciated the idea of using SSIs in classrooms as they interpreted these as a way to increase students' interest in school science; however, they also have difficulty in connecting students' interest with the *core scientific content.* Thus, it is important to integrate appropriate SSI-based activities in science methods courses to promote prospective teachers' conceptualization of SSI-based teaching and learning.

There are only a few studies reporting outcomes of designed trainings on prospective teachers' understanding of SSIs and how to teach them in their future classrooms, and even less for elementary teacher education. This study aims to contribute to science teacher education literature by designing a case-based learning environment and incorporating activities in a science methods course to explore prospective elementary teachers' evolution of conceptualization of SSI-based teaching and learning. I will present the case-based learning concept and its connections to teacher education in the following section.

Case-Based Learning

Defining case-based learning is a perpetual task. Cases are used for different purposes, fields, and forms. No consensus exists across fields on how cases can be used in learning, increasing the difficulty in defining case methods. Educators have used case-based methodologies across professional education disciplines (e.g., law, business, and medicine) for well over 100 years in the United States (McAnich, 1993). Students' and instructors' perceptions of case studies have been reported as fairly positive in the case-based learning literature (Harvard, 2009; Yadav et al., 2007). Furthermore, extensive research exists regarding the format of cases as well as effective case instruction (e.g. Kim, Phillips, Pinsky, Brock, Phillips, & Keary, 2006). However, significant questions remain to be explored regarding the influence of different methods on the effectiveness of case instruction, the best way to utilize cases in teacher preparation programs, and the role of case-based pedagogy in professional practice.

In their cross-discipline literature review of 100 research studies on the format of case studies, Kim et al. (2006) identified critical components of cases to ensure that students are presented with quality cases to study, and this study informed my design framework. The researchers catalogued emergent themes and identified several core attributes of effective cases as follows:

- Cases must be relevant to learners' interests.
- Cases must be life like and contain realistic materials without non-pertinent features.

- Cases must be engaging, meaning they offer rich presentations and allow for multiple voices and perspective.
- Cases must be instructional. The authors defined instructional as building upon students' prior knowledge and connecting it to new concepts.

These components highly resonate with the instructional design principles that I will discuss for the proposed case-based learning environment in the Theoretical Framework section.

Even though divergent views in case-based learning illustrate the difficulty of arriving at a universal definition, we can still capture two common elements of case-based learning across fields. These two elements are the cases themselves and the discussion (either online or in class) of them (Merseth, 1991). Simply providing well-written content for cases is not sufficient for successful case-based learning. According to Blackmon, Hong and Choi (2007), the key to the case method is discussion, and thus:

> Discussion has to be integrated into students' learning process. Engaging learners in discussion provides students opportunities to analyze, propose solutions, evaluate potential solutions, solve problems, or make decisions. These activities give students an active role in the learning process. The content of cases and the process of discussion are inseparable in case-based learning.

Since the 1920s, various case formats have been developed to illustrate the dilemmas and challenges of teaching and learning (Koballa & Tippins, 2003). There is a variety of approaches to developing and using classroom cases in science teacher education (Bryan & Tippins, 2006). Bryan and Tippins (2006) have categorized the more recent pedagogical approaches to developing cases as *case-as-layered-commentary*, *video cases*, and *integrated media cases*. They further explained the cases-as-layered-commentary as follows:

J. Shulman (1992) initially introduced the idea of case-as-layered-commentary, a format comprised of multiple voices. A case-as-layered-commentary features narrative accounts of classroom dilemmas written by prospective and practicing teachers. Peers and other educational scholars with unique knowledge of the particular situation develop commentaries and responses that provide context-specific insights into the case. When case narratives are developed with layered commentary, they create an opportunity for shared inquiry and a link to research, transcending the experience of the individual classroom teacher. The permeability of the layered case encourages inclusion of multiple perspectives and alternative ways of framing and comprehending the dilemmas of practice. (p. 303)

In addition, in a comprehensive review of the use of cases and case methods in teacher education, Merseth (1996) draws upon the work of Lee Shulman (1991, 1992) and categorizes cases into three groups: (a) cases as exemplars; (b) cases as opportunities to practice analysis and contemplate action; and (c) cases as stimulants to personal reflection. For the purposes of this study, I adopted the cases-as-layered commentary approach and chose cases to provide opportunities with analysis and reflection. I used two cases on real-life, socioscientific issues and two pedagogical cases that present the dilemmas of teaching and learning of socio-scientific issues in the classrooms. With these purposes, I integrated case-based activities including open-cases of practicing teachers that I adapted from Tippins, Koballa, and Payne's (2002) book, *Learning From Cases: Unravelling the Complexities of Elementary Science Teaching* (e.g. Ch. 9, Case 9.1: The Day the Lobster Died) and dilemma cases adapted from the National Center for Case Study Teaching in Science (NCCSTS).

Unsurprisingly, since the 1990s, advocates of case-based teaching have produced a large body of literature highlighting its advantages (e.g. Shulman, 1991; Lundeberg et al., 1999; Wasserman, 1994). Harrington (1995) listed some advantages of case-based pedagogy as follows:

- Students sort out factual data, apply analytic tools, articulate issues, reflect on their relevant experiences, and draw conclusions they can relate to new situations.
- They acquire substantive knowledge and develop analytic, collaborative, and communication skills.
- Cases provide students with the opportunity to see theory in practice.
- Students seem more engaged, interested, and involved in the class.
- Since many cases are based on contemporary or realistic problems, the use of cases in the classroom makes subject matter more relevant.

However, many challenges faced by both instructors and students in cased-based learning environments are less often noted (Mostert, 2007). According to Mostert (2007), there are some pedagogical and practical challenges in case-based teaching such as unfamiliarity with case teaching, lack of motivation for participation in case discussions, class size, and problems in written expression.

The influence of faculty expectations, biases, and classroom environments may also significantly impact how students view and respond to cases. In their national survey study, Yadav et al. (2007) surveyed 101 science faculty at universities and colleges in the United States and Canada to understand more about faculty perceptions of the instructional benefits of and barriers to using case studies. The results provided evidence that, overall, faculty think cases have a positive impact on student learning, critical thinking, and participation. They listed the top five obstacles faculty encountered: (a) lack of preparation time required for use of cases in teaching; (b) assessing student learning, student discussion, or small group work; (c) lack of relevant case studies; (d) student resistance to the case-based approach to teaching; and (e) pressure to cover more content.

CBL in Teacher Education

As noted earlier, the use of cases in teacher education has been advocated by many as an important pedagogical tool. In teacher education, cases can be used to reflect the inherent uncertainty and complexity of the world of teaching and learning (Tippins, Nichols, & Dana, 1999). With case-based learning, students develop higher-order thinking and reflection skills by reading and discussing complex, real-life scenarios (Butler, Lee, & Tippins, 2006). A number of studies have provided insight into the potential benefits of using case-based learning in elementary teacher education (Angeli, 2004; Butler, Lee, & Tippins; 2006; Choi & Lee, 2009; Kim & Hannafin; 2011; Yoon, Pedretti, Beneze, Hewitt, Perris & Oostveen, 2006). I explore these studies in the following sub-sections, concluding with implications for the current study (see Table 2.2).

Table 2.2

Key Implications for CBL in Teacher Education

Challenges regarding CBL	Key Implications for CBL in Teacher Education	Key Study
Well-written content for cases is not sufficient for successful CBL	There are several core attributes of successful cases such as being: (a) relevant, (b) authentic, (c) engaging, (d) instructional	- Kim et al. (2006)
There is a variety of approaches to developing and using classroom cases in teacher education	Choose appropriate cases for your targeted educational outcomes	- Bryan and Tippins (2006) - Merseth (1996)

Prospective teachers may not be familiar with CBL or the pedagogy that is presented in the case materials	- Integrate introductory activities about CBL and other necessary background information prior to discussing and analyzing real cases - Explore participants' initial conceptions and provide opportunities to re-evaluate initial conceptions	- Angeli (2004)
Prospective teachers may begin with tendencies to simplify the given situation and identify problems from a single perspective when they engage in a case reading	- Provide opportunities to experiment with case dilemmas from various perspectives and to clarify and re-structure prospective teachers' beliefs about teaching and learning - Facilitate prospective teachers' reflective thinking through discussions of the case	- Butler, Lee, and Tippins (2006) - Choi and Lee (2009)
Prospective teachers may have vague conceptual knowledge about different pedagogies before engaging in specifically designed trainings	- Provide guiding questions to facilitate reflection and opportunities with documentation of participants' reasoning and decision making.	- Kim and Hannafin (2011)
There is a rareness of empirical support for the effectiveness of case-based pedagogy	- Explore different types of cases, the instruction surrounding the use of cases, and the measureable impacts on prospective teachers' understandings, reasoning skills, beliefs, and classroom practice	- Grossman (2005)
The methods used to explore case-based pedagogy need to be expanded	Have an outside researcher design and collect data to help alleviate possible biases.	- Lundeberg et al., 1999
The lack of resources and instructional models to support teachers' and curriculum designers' work toward creating case-based learning experiences is a primary constraint limiting widespread use of the approach	- Explore how learning theories support case-based learning - Build models on supporting learning theories - Explore how cases and models are potentially affecting prospective teachers	- Lundeberg and Yadav (2006) - Kantar (2013)

Angeli (2004) examined the extent to which case-based learning could have an effect on prospective teachers' beliefs about the pedagogical uses of information and communication technology (ICT) in the classroom. Participants were recruited from a teacher education program aimed at preparing students to teach in pre-primary and lower primary education. One hundred second year early childhood prospective teachers enrolled in an ICT course participated in the study. Research data were collected with a questionnaire, reflection papers, course evaluations and focus-group interviews.

Angeli (2004) taught four sections of the course which included thirteen 60-minute lecture meetings and thirteen 75-minute laboratory meetings for each section of the course. During the first three weeks, Angeli introduced theoretical issues related to ICT integration (e.g., teaching methods, learning theories and lesson plan design) and several types of educational software. Angeli stated that "these introductory lectures were considered necessary prior to discussing and analyzing real cases of teachers who integrated ICT tools into their classrooms, because students had no previous knowledge of teaching methodology" (p. 142). With similar concerns, I integrated a 3-hour introductory meeting to introduce SSI-based teaching methodology to my participants.

To explore participants' initial beliefs regarding teaching with ICT, Angeli (2004) administered a questionnaire consisted of two statements: (a) I am interested in teaching with ICT and (b) I am skeptical about teaching with ICT before the case-based activities. Participants were also asked to explain their position and reasons for holding that point of view about integrating ICT into K-3 classroom environments. In the remaining lectures, students read 10 cases of teachers who had integrated ICT in teaching and learning. Four different types of cases included (a) cases of teachers who initially held negative beliefs and successfully integrated ICT into their classrooms, (b) cases of teachers who initially held negative beliefs and failed to successfully integrate ICT into their classrooms, (c) cases of teachers who initially held positive beliefs and successfully integrated ICT into their classrooms, and (d) cases of teachers who initially held positive beliefs and failed to successfully integrate ICT into their classrooms.

After the completion of case activities, the participants in Angeli's (2004) study were asked to write reflection papers explaining their beliefs before and after completing the course and evaluation essays stating their perceptions of the case-based approach. Lastly, there were twenty semi-structured focus interviews. During the interviews students were asked to comment on any aspect of the course they wanted and to compare and contrast the beliefs they had at the beginning of the course with their beliefs after completing the course. Thus, the purpose of the interviews was to investigate the validity of the information students wrote in their reflection papers and evaluation essays and to further explore how the course affected their beliefs about the pedagogical uses of ICT in K-3 education.

The findings from Angeli's (2004) study showed that initially the majority of prospective teachers had negative beliefs and certain misconceptions regarding the pedagogical uses of ICT and that case-based learning affected their beliefs and conceptions positively. Results suggested that the case-based approach helped participants re-evaluate their initial beliefs and "become adequately informed of the pedagogical uses of ICT" (p. 147). To be able to explore participants' initial conceptions regarding SSI-based teaching and how their conceptualization evolves through case activities, I integrated reflection questions regarding SSI-based teaching starting from the beginning of the semester.

Butler, Lee and Tippins (2006) investigated prospective teachers' perceptions of case-based pedagogy as an instructional strategy for understanding diversity. Participants were three female students were enrolled in a required undergraduate science methods course for prospective elementary teachers program at a large university in the Southeast. This study was particularly important for my study since it explored the effectiveness of case-based pedagogy in a very similar context (i.e., science methods course for elementary teachers). The prospective teachers experienced case-based pedagogy by reading five cases featuring dilemmas that address issues of diversity, writing reflective responses to the cases, and discussing the cases during the elementary science methods course. After the case-based experiences, the three prospective teachers had interviews with the researchers, focusing on their perceptions about case-based pedagogy experiences in relation to multicultural education.

The participants in the Butler, Lee and Tippins' (2006) study reported that they connected the case situations to their own experiences, thoughts, and beliefs about teaching and learning by making efforts to resolve the issues regarding diversity during their case analyses. The researchers interpreted that case-based pedagogy was considered an effective instructional method in this context "to facilitate preservice teachers' reflective thinking, providing them with opportunities to experiment with case dilemmas from various perspectives and to clarify and re-structure their beliefs about teaching and learning" (p. 24). The findings of Butler et al.'s (2006) study supported the idea that CBL is an effective strategy to enhance students' ability to assess an issue from multiple perspectives and provides opportunities for reflection.

Choi and Lee (2009) conducted a design-based research study to develop a "case-based instructional model that could enhance college students' ill-structured problem solving abilities" (p. 99). Choi and Lee implemented the model to improve prospective early childhood teachers' real-world problem solving abilities to deal with dilemmas regarding classroom management faced by practicing teachers in elementary classrooms. The researchers conducted two different studies and revised the model after the first study. Statistical analyses for both studies (multivariate analysis of variance) showed that the individual components of the model promoted ill-structured problem solving abilities respectively, and that the model as a whole learning environment was effective to a degree for the transfer of learning in ill-structured problem solving.

Choi and Lee (2009) indicated that although the results of the studies showed the effectiveness of the model to a certain degree, there were also critical limitations of the environment with a short-time (3-week) implementation. The scores indicated that students began with tendencies to simplify the given situation and identify problems from a single perspective, mainly the teacher's perspective from the case. Throughout the implementation, the students began to understand the complexity of given situations and to acknowledge the possibility of different interpretations of problems from multiple perspectives. Findings of this study also suggested the importance of the ability to consider different perspectives and understanding the complexity of given cases improved throughout the implementation. This is an important implication for the current study.

Kim and Hannafin (2011) examined how prospective teachers gain situated knowledge about teaching with technology by engaging in web-enhanced case-based learning environment, which was developed in a previous study (Kim & Hannafin, 2009). Prospective teachers engaged in authentic case activities including real teachers' teaching-with-technology experiences during a 16-week course. Participants of the study included five education-major students that were selected using maximum variation sampling procedures with respect to year in college, majors, prior experience, initial technical skills, and understanding of technology integration.

The case activities were embodied in three course projects such as “developing lesson plans and instructional materials using concept-mapping software, using presentation software, and developing Web-based instruction units” (p. 1379). They also included a 15-min microteaching session to explore prospective teachers’ technology integration knowledge and skill. The participants accessed the developed case library as a source including experienced teachers’ exemplary cases. During each task, they provided a form of guiding questions to facilitate reflection and documentation of participants’ reasoning and decision making.

Kim and Hannafin (2011) reported that the participants initially expressed naive understandings about teaching with technology, “focusing mostly on teaching skills, simple pedagogical approaches, and technical issues” (p. 1383). However, all participants improved their conceptual knowledge about teaching with technology. The participants also identified new opportunities for teaching with technology after engaged in designed case-based activities. Results from the Kim and Hannafin’s (2011) study indicated that the developed learning environment enhanced participants’ initial beliefs and knowledge about computer use by engaging them in and addressing authentic teaching problems. Thus, participants’ understanding about teaching with technology evolved from “positive but vague perceptions to concrete and clear understandings of technology’s educational role” (p. 1387). The current study has a similar educational purpose (improving conceptual knowledge about SSIs), thus, findings of Kim and Hannafin’s (2011) study and implemented design decisions informed the development of learning activities for this study to a great extent.

The studies highlighted in the last few paragraphs showcased promising results of the CBL pedagogy; however, advocates of CBL also acknowledge a rareness of empirical support for the pedagogy (Grossman, 2005). In her review of case-based methods for the American

Educational Research Association Panel on Research and Teacher Education, Grossman (2005) noted that more information is needed about the different types of cases, the instruction surrounding the use of cases, and the "measureable impacts on students' understandings, reasoning skills, beliefs, and classroom practice" (p. 442). This study aims to contribute to the case-based learning literature by developing an instructional design framework and implementing the activities in a teacher education course to explore the *measurable impacts* on prospective teachers' conceptualization of and reasoning around socio-scientific issues.

Additionally, the methods used to explore case-based pedagogy need to be expanded (Lundeberg et al., 1999). Much research on the use of cases is collected via action research where the researcher collects data from his or her own class for the course of the quarter or term. Ultimately, having an outside researcher design and collect data may help alleviate possible biases (Lundeberg et al., 1999). This study included an outside researcher, myself, with a close rapport with the participants and the instructor.

To determine if a method contributes substantively to learning, there needs to be an adequate definition of the pedagogical strategy and a clear sense of the anticipated outcomes the strategy is believed to promote. It is obvious in the literature that over the last two decades, teacher educators and educational researchers have struggled, with mixed results, "to fully explain how case-based pedagogy can align with and extend the goals of teacher preparation" (Hammerness, Darling-Hammond, & Bransford, 2005, p. 363). The lack of resources and instructional models to support teachers' and curriculum designers' work toward creating case-based learning experiences has been consistently highlighted as a primary constraint limiting widespread use of the approach. Lundeberg and Yadav (2006) stated that to assess the impact of case-based instruction, research designs should be built on educational theories of student learning and researchers should question how cases are potentially affecting students.

Foundational learning theories provide the basis for understanding learning and for designing effective learning environments, including CBLe. One way of organizing foundational learning theories is according to four broad historical and/or philosophical trends: 1) behaviorism, 2) cognitivism, 3) constructivism, and 4) social constructivism. These learning theories can be classified on a continuum in terms of whether they place the teacher and behaviors, or the learner and internal mental processes at the center of instruction. While one end of the continuum represents behaviorism, the other end of the continuum represents social constructivism. Whereas behaviorist theories characterize the underpinnings of teacher-centered instruction, cognitive and constructivist perspectives come into play in shaping learner-centered instruction (Larochelle, Bernarz, & Garrison, 1998).

Without understanding the case-based pedagogy from supporting learning theories, it is difficult to analyze the challenges of the pedagogy and perhaps impossible to identify effective ways to use it (Kantar, 2013). Case-based pedagogy has its roots in constructivism (Hartfield, 2010) and is supported by several other theories, including cognitive flexibility and situated cognition (Blackmon, Hong & Choi; 2007). The proposed framework is drawn from constructivism and its instructional principles. I explain the theory and its implications for my instructional design framework in the following sections.

Theoretical Framework

Constructivism is a philosophical view on how we come to know or understand. Schunk (2008) argued that strictly speaking, constructivism is not a theory but rather an epistemology about the nature of learning. This philosophical view is commonly referred to as constructivist theory because constructivism makes general predictions that can be operationalized and tested. He noted that:

> Constructivist theorists reject the notion that scientific truths exist and await discovery and verification. They argue that no statement can be assumed as true but rather should be viewed with reasonable doubt. The world can be mentally constructed in so many different ways so no theory has a lock on the truth (p. 236).

There are three key assumptions that characterize a constructivist philosophical view (Richey et al., 2011). Savery and Duffy (1996) describe these assumptions as follows:

1. Knowledge is constructed from our interactions with the environment: This is the core concept of constructivism. What we understand is a function of the content, the context, and the goals of the learner. Since understanding is an individual construction, we cannot share understandings; rather, we can test the degree to which our individual understandings are compatible.
2. Cognitive learning or puzzlement is the stimulus for learning and determines the organization and nature of what is learned. Cognition is an adaptive process that functions to make an individual's behavior more viable given a particular environment.
3. Learning is an active process in which meaning is developed on the basis of experience and through the evaluation of the viability of individual understandings. This is because people produce knowledge based on their beliefs and experiences in situations, which differ from person to person (Schunk, 2008) and knowledge evolves through social negotiation.

Thus, constructivism acknowledges the learner's active role in knowledge building, the importance of experience in this process, and the realization that the knowledge created will vary in its degree of validity as an accurate representation of reality (Duffy, Cunningham, & Jonassen, 1996). These three fundamental tenets provide the foundation for basic principles of the teaching, learning, and knowing processes as described by constructivism.

However, constructivism is not a unified theory (Schunk, 2008), and these tenets may be emphasized differently, resulting in various degrees or types of constructivism (e.g., radical, cognitive, contextual or social constructivism). For example, social constructivism emphasizes the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding (Derry, 1999). In science education literature, these tenets may be termed as "personal" or "contextual" constructivism. Cobern (1993) presented the evaluation of constructivism in educational research as following:

> The early emphasis in constructivism was clearly upon the individual, thus, the initial constructivist departure from neo-Piagetian research is best termed *personal constructivism* (p.53) … However, a perception of insufficient progress toward improved science instruction led some researchers doubt the theoretical adequacy of personal constructivism. Drawing on sources in the sociology of knowledge, Solomon (1987), Sutton (1989), and Millar (1989), among others, have moved the science education research field from personal constructivism towards contextual constructivism. (p. 55)

This study neither offers a conceptual analysis of these avenues of constructivism nor draws upon only one of them. In fact, I believe these categories are not mutually exclusive but complementary (Cobern, 1993). While creating my design principles, I tried to bring different perspectives of constructivism together to develop a better approach for the learning environment. This concept of “developing learning environments” and its connection to constructivism are presented in next section.

Developing a Constructivist Case-Based Learning Environment

Given the recent calls for the transformation of higher education to expand and transform the role of universities in promoting lifelong learning (Sursock, Smidt, & Davies, 2010), college educators are recommended to design constructivist learning environments to allow learners to become active builders of knowledge. Constructivist perspectives in instructional design have shown the connection between our underlying views of knowledge and how we think about instruction (Wilson, 1996). Table 2.3 summarizes how different philosophical conceptions can influence our views.

Table 2.3

How Our Views of Knowledge Influence Our View of Instruction

Theoretical Perspective	**Views of Knowledge**	**Views of Instruction**
Behaviorism	A quantity or packet content waiting to be transmitted	A product to be delivered by a vehicle.
Cognitivism	A cognitive state as reflected in a person’s schemas and procedural skills	A set of instructional strategies aimed at changing an individual’s schemas.
Cognitive Constructivism	A person’s meanings constructed by interaction with one’s environment	A learner drawing on tools and resources within a rich environment.
Social Constructivism	Enculturation or adoption of a group’s ways of seeing and acting	Participation in a community’s everyday activities.

Note. Adapted from Wilson (1996). What is a constructivist learning environment? In B. G. Wilson (Ed.), *Constructivist Learning Environments: Case Studies in Instructional Design*, (pp 3-10), New Jersey, NJ: Educational Technology.

Table 2.3 suggests that viewing instruction as a learning environment is related to a meaning-construction view of knowledge (Wilson, 1996). Thinking of instruction as an environment emphasizes the place and/or space where learning occurs, and Wilson (1996) describes a constructivist learning environment as "a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem solving activities" (p. 5). Therefore, I see this instructional design framework as a guide to develop a case-based learning environment consisting of selected information resources (e.g. case studies related to authentic socio-scientific issues) to pursuit targeted learning goals (e.g. conceptualization of SSI-based teaching and learning).

Instructional Principles Deriving from Constructivism

To be able to design effective constructivist learning environments, it is important to understand constructivist pedagogy, the link between theory and practice, and its theoretical underpinnings. Many theorists and practitioners have generated constructivist pedagogies with an array of results (Brooks & Brooks, 1993; Driscoll, 1994; Jonassen, 1991). While these pedagogies share a set of core design principles, principles tend to vary greatly. The general theoretical and practical constructivist consensus indicates that several factors are essential in constructivist pedagogy (Brooks & Brooks, 1993; Honebein, 1996; Savery & Duffy, 1996). I explain some of these principles and how they inform my model in the following sections.

Embed learning in authentic and relevant contexts. We learn in order to be able to function more efficiently in our world (Savery & Duffy, 1996). The purpose of any learning activity should be clear, and learners should perceive and accept its relevance to their lives. Knowledge construction is enhanced when the experience is authentic. For the social constructivists, authentic experiences are important, so that the individual may construct knowledge personally and mediate that knowledge socially (Doolittle & Camp, 1999).

To provide authentic activities, the case-based learning environment should encourage learners to explore a resource with all the complexity and uncertainty of the real-world. The learners would have a role in “selecting which information is relevant, and finding a solution which suits their needs” (Herrington & Oliver, 1995, p. 257). Thus, I used cases of socio-scientific issues relevant to participants’ lives (e.g. Zika virus) and real teachers’ classroom experiences, which include dilemmas of socio-scientific issue-based teaching to support prospective elementary teachers’ conceptualization of SSI-based teaching and learning (SSI-TL). More details about learning experiences that were featured in the learning environment are presented in Instructional Design Framework section.

Embed learning in social experience. Constructivism suggests that learning is a social process of making sense of experience in terms of what is already known (Tobin & Tippins, 1993). Social interaction facilitates the development of socially relevant skills and mediated knowledge. As an individual gains experience in a social situation, this experience may validate an individual's knowledge structures, or it may contradict those structures. The importance of a learning community where ideas are discussed and understanding deepened is critical to the design of an effective learning environment (Savery & Duffy, 1996). Thus, the learning environment should encourage collaboration between both teachers and students, and students and students. The proposed model incorporates this principle by facilitating collaboration between students who are required to prepare for analyzing and discussing a case, and then suggesting a solution. This includes online discussion of the case before the whole group discussion during class meetings following students’ final reflection of the case.

Provide experience in testing ideas against alternative views and encourage multiple perspectives. In social constructivism, there is no privileged "truth," only perceptual understandings that may prove to be more or less viable. In this context, knowledge is socially negotiated (Savery & Duffy, 1996). Problems in a real-world context rarely have one correct solution. Thus, students must engage in activities that enable them to evaluate alternative solutions to problems as a means of evolving their knowledge (Honebein, 1996). This being the case, a student's understanding and adaptability is increased when he or she is able to examine an experience from multiple perspectives.

These multiple perspectives provide the student with a greater opportunity to develop a more viable model of their experiences and social interactions. This principle has two implications for this study: (a) case materials should allow learners to elicit information from multiple sources and examine problems from a variety of perspectives (Morrow, Epling, Terán, Sutphen, & Novick, 2003), and (b) multiple correct responses, decision-making opportunities, and explanation should be included in case-based learning. This principle also has a strong connection to one of the practices of socio-scientific reasoning, which is assessing issues from multiple perspectives (Sadler, 2014).

Provide opportunity and support for reflection for both the content learned and the learning process. The underlying view of constructivism claims that learners are active in their construction of knowledge and meaning. The key outcome of this activity involves “students’ ability to explain why and how they solved a problem in a certain way; to analyze their construction of knowledge and processes” (Honebein, 1996, p. 12). Student thinking needs to be stimulated by providing time to think: students need time to engage in the process required to evaluate the adequacy of specific knowledge, make connections, clarify their thinking processes.

This principle was incorporated in the case-based learning environment by requiring students to reflect upon the whole process of their learning experience, and on their proposed solutions (Blackmon, Hong & Choi, 2007). Guiding questions for the final analysis of the cases after online and classroom discussion provided opportunities to reflect by asking students how their initial ideas evolved, and individual interviews included questions about students' reflections on their learning experience with cases.

Design the learning environment to support and challenge the learner's thinking. Since social constructivism avoids any direct knowledge of reality, the primary role for the teacher is to guide students to an awareness of their experiences and socially agreed-upon meanings. This teacher as a guide metaphor indicates that the teacher is to motivate, provide examples, discuss, facilitate, support, and challenge, but not to attempt to act as a knowledge conduit. This does not mean that any activity or any solution is adequate. Teachers should value as well as challenge learners' thinking (Savery & Duffy, 1996). The teacher plays multiple roles in a case-based learning environment. The instructor should summarize key issues and ask questions that help students identify issues and stay on track, but do not lead them to a specific conclusion.

These five principles (summarized in Table 2.4) tremendously informed my design decisions for the instructional design framework, which I present in the following section.

Table 2.4

Five Constructivist-based Design Principles and their Application in the Current Study

Key Principle	**Key Design Decisions for Current Study**
Embed learning in authentic and relevant contexts.	- Use cases of socio-scientific issues relevant to participants' lives (e.g. Zika virus) and real teachers' classroom experiences, which include dilemmas of socio-scientific issue-based teaching to support prospective elementary teachers' conceptualization of SSI-TL.
Embed learning in social experience.	- Facilitate collaboration between students who are required to prepare for analyzing and discussing a case, and then suggesting a solution.
Provide experience in testing ideas against alternative views and encourage multiple perspectives.	- Case materials allow learners to elicit information from multiple sources and examine problems from a variety of perspectives (Morrow et al., 2003). - Case materials allow for multiple correct responses, decision-making opportunities, and explanation should be included in case-based learning.
Provide opportunity for and support reflection for both the content learned and the learning process.	- Require students to reflect upon the whole process of their learning experience, and on their proposed solutions (Blackmon, Hong & Choi, 2007).
Design the learning environment to support and challenge the learner's thinking.	- Teachers should value as well as challenge learners' thinking (Savery & Duffy, 1996). - The teacher plays multiple roles in a case-based learning environment (challenge, support, and guide) but not lead to a specific conclusion.

Instructional Design Framework

While there are a variety of ways to organize learning activities around cases in case-based learning (Choi & Lee, 2009), I draw from Harrington and Garrison's (1992) concept of *cases as shared inquiry*, and aforementioned instructional principles of constructivism. The current model comprises two sections: 1) design principles informing the development of the learning environment and 2) a sequence describing the kinds of learning experiences that students can experience in a shared inquiry process (see Figure 2.1).

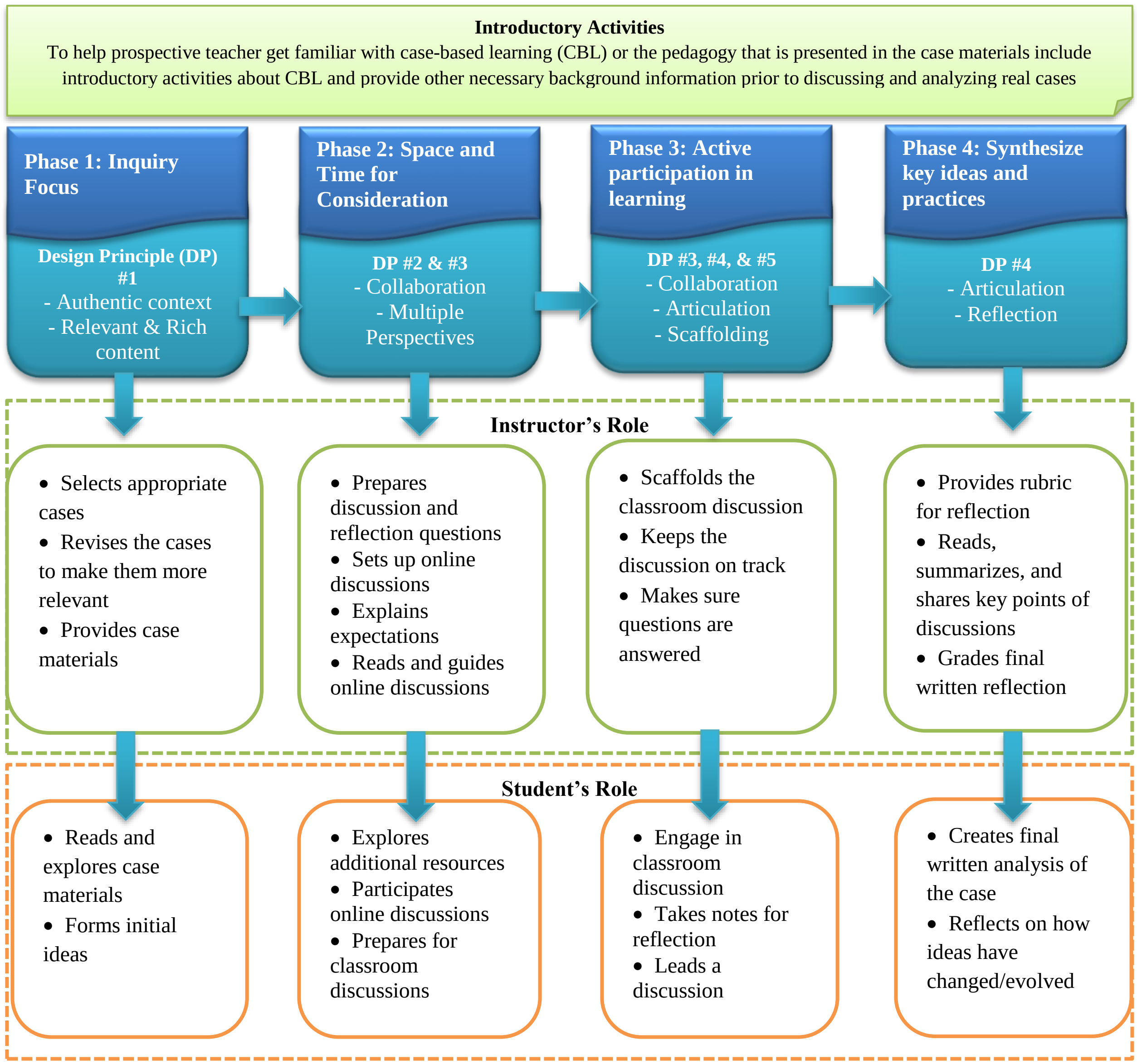


Figure 2.1. Instructional design model for a constructivist case-based learning environment

In line with the constructivist roots of case-based learning, inquiry-focused pedagogy requires collaboration between the instructor and students. Common strategies for use in a shared inquiry approach include: (a) time for individual reflection, (b) large and small group discussions, (c) sharing ideas, and (d) reflecting on the learning process (Hemphill, Richards, Gaudreault, & Templin, 2015). In the following sections, I explain how I integrated these strategies and case-based learning activities in the proposed model.

It is important to note: to be able to implement this model efficiently, the aforementioned challenges of case-based learning (e.g. unfamiliarity with pedagogy, lack of motivation for participation in case discussions, assessing discussions, lack of relevant case studies) should be taken into consideration and educators should spend the required time to find the resources and prepare for carrying out the learning activities. For example, I conducted an introductory case activity to model the steps that I expect our students to experience in shared inquiry process and excluded this activity from grading for the course and data analysis.

Phase 1: Inquiry Focus

The first phase of a shared inquiry process is selecting a focus for the inquiry. While the focus could be several different things, a case material can be used to initiate the shared inquiry (Harrington & Garrison, 1992). Harrington and Garrison (1992) asserted that, in order to promote shared inquiry, a case must: ‘‘provoke students of teaching to question how schools operate rather than to draw quick solutions to problems from their experience with schools or from what they learn in college classrooms’’ (p. 720).

To engage learners with sustained interest and motivation, case materials should be relevant and authentic (Morrow et al., 2003). Authenticity is increased when cases incorporate the tasks, knowledge, and problem-solving skills that reflect the way the knowledge will be used in real-life and apply in future practice (Brown, Collins and Duguid, 1989; Herrington & Oliver, 1995; Morrow et al., 2003). To provide authentic activities, the case-based learning environment should encourage learners to explore a resource with all the complexity and uncertainty of the real world. The learners would have a role in “selecting which information is relevant, and finding a solution which suits their needs” (Herrington & Oliver, 1995, p. 257).

Case materials should also provide “sufficient information” to identify the people, problems, situations, and tasks involved (Koehler, 2002; Levin, 1995). Morrow et al. (2003) states that to make a case content rich and complex, multiple correct responses, decision-making opportunities and explanation should be included.

Phase 2: Space and Time for Consideration

In phase two, open space and time should be given to students in order to consider possible reactions to the inquiry focus. Thus, in the proposed case-based learning environment, students are expected to prepare to discuss the cases prior to class time. They should spend enough time studying the case until they (a) are completely familiar with the facts and content of the case, (b) reflect on and identify obvious or potential problems within the case, and (c) reflect on potential solutions or plans of action. The course instructor should provide guiding questions for the case, and students should engage in online discussions to respond to those questions and share their opinions prior to class discussions.

A constructivist learning environment supports the collaborative construction of knowledge (Bransford, Vye, Kinzer, & Risko, 1990; Brown, Collins and Duguid, 1989). Thus, the proposed case-based learning environment is derived from collaboration between students who are required to prepare for, analyze, discuss a case, and then suggest a potential solution. This includes responding to other students’ online discussion posts to challenge their opinions and/or assumptions. Engaging in the online discussion and the classroom discussion, and the final analysis of the case also provide the learner with the opportunity to investigate multiple perspectives (Bransford et al., 1990; Brown, Collins and Duguid, 1989; Herrington & Oliver, 1995). Case materials and additional resources that I add at the end of the cases also allow learners to elicit information from multiple sources and examine problems from a variety of perspectives (Morrow et al., 2003).

Phase 3: Active Participation in Learning

In phase three, students should be included as valuable members of the inquiry process, which gives them an opportunity to shape their own learning. In the proposed design, students express their ideas either out-loud (in classroom discussions), or in writing (in online discussions and case reflection papers).

To provide well-written content for the cases is not sufficient for successful case-based learning. Tippins, Koballa, and Payne (2002) also suggested that case discussion facilitates the investigation of critical issues in teaching and learning through the taking on of multiple perspectives. Classroom discussion is really important because peer interactions are enriched by their prior knowledge, experiences and interests that the students bring to the process.

The collaboration between peers provides varied opportunities for students to examine their own thought processes (Goodman, Soller, Linton, & Gaimarie, 1998). To foster knowledge construction, the designed learning environment ensures that the cases are used within a social context; thus, students work in groups, discuss the issues, lead a classroom discussion session, and present multiple perspectives both from case content and online discussions. Through these activities, learners have the opportunity to articulate, negotiate, defend and evaluate their knowledge (Herrington & Oliver, 1995).

Phase 4: Synthesize Key Ideas and Practices

The instructor plays multiple roles in the proposed case-based learning environment. The instructor summarizes key issues and asks questions that help students identify issues and stay on track, but should not lead them to a specific conclusion during the application of proposed activities. Facilitating and scaffolding student discussion may appear to be simple, but in reality requires the teacher to use great skill in helping students explore and discuss the case in ways that maximize their learning (Blackmon, Hong, & Choi, 2007).

In the proposed design, subsequent to the case discussions, after class time, students construct a written reflection of insights, opinions, and potential solutions they have gather from their initial preparation as modified by the classroom discussion. General guiding questions should be provided such as to prompt prospective teachers to consider their final suggestions to the challenges that were faced by the teacher or the SSI; how would they act if they faced similar challenges; and how their initial ideas evolve after discussions.

Summary of how I address each phase in the current study is presented in Table 2.5.

Table 2.5

Four Phases in a Shared Inquiry Approach and their Application in the Current Study

Phases of a Shared Inquiry	**Applications in the Current Study**
Phase 1: Inquiry Focus	- Providing relevant and authentic cases for sustained interest and motivation. - Providing cases of real teachers' classroom experiences which include dilemmas of socio-scientific issue-based teaching and relevant SSI cases to students' daily lives (e.g. Zika virus)
Phase 2: Space and Time for Consideration	- Engaging students in online discussions to prepare to discuss the cases prior to class time. - Encouraging students to respond to other students' online discussion posts to challenge their opinions and/or assumptions. - Providing additional resources to help learners elicit information from multiple sources and examine problems from a variety of perspectives
Phase 3: Active Participation in Learning	- Including students as valuable members of the inquiry process, which gives them an opportunity to shape their own learning. - Providing students opportunities with expressing their ideas either out-loud (in classroom discussions), or in writing (in

	online discussions and case reflection papers). - Fostering active knowledge construction through using cases within a social context (e.g., students work in groups, discuss the issues, lead a classroom discussion session, and present multiple perspectives both from case content and online discussions).
Phase 4: Synthesize Key Ideas and Practices	- Summarizing key issues and asking questions that help students identify issues and stay on track, but not leading them to a specific conclusion - Providing general guiding questions such as what is their final suggestions to the challenges that were faced by the teacher or the SSI; how would they act if they faced similar challenges; and how their initial ideas evolve after discussions.

Summary

In this chapter, case-based learning has been discussed with a strong connection to constructivism to support prospective teachers' socio-scientific issue-based teaching and learning. Literature on case-based learning and socio-scientific issues in the teacher education context was reviewed and empirical research was explored to find current gaps in our understanding. A lack of effort to help prospective elementary teachers develop competencies necessary for using SSIs in their teaching is evident in the teacher education research. Developing and integrating appropriate training for teaching SSIs should be a part of teacher education programs.

Case-based pedagogy is used to enhance prospective elementary teachers' conceptualization of SSIs and SSI-based teaching in this study. Both McAninch (1993) and Lundeberg et al. (1999) stated that most evidence about the success of the case method in practice has been anecdotal, and this argument still seems true. This study aimed to fill some of these gaps by proposing an instructional model to support teachers' and curriculum designers' work toward creating case-based learning experiences to support SSI-TL and exploring what participants actually learned when they engaged in these kind of learning activities.

CHAPTER 3

METHODOLOGY

In this chapter, I first explain the purpose of the study and sampling procedures. Secondly, I describe the learning activities in a designed case-based learning environment. I then describe the design of the current mixed methods study including the paradigmatic stance, rationale, purpose, and type of the mixed methods design. I also describe the data collection and analysis methods followed by the trustworthiness of the study. I conclude the chapter with a discussion of the limitations of the study.

Purpose Statement

The purpose of this study was to (a) develop a feasible design framework for a case-based learning environment that incorporates cases related to socio-scientific issue-based teaching and learning and (b) apply the model to enhance prospective teachers' conceptualization of socio-scientific issues and SSI-based teaching in a science methods course for elementary education. A specific instructional model was used for seven weeks in a required undergraduate science methods course in Fall 2016. This study reports the data from the learning outcomes.

The inquiry in this study focused on one overarching question: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching? This study attempts to answer the following research questions:

1. To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSIs?

1.1. How does the CBLe support prospective elementary teachers' evolution of socio-scientific reasoning?

1.2. How do prospective elementary teachers' conceptualization of SSIs evolve during the SSI case activities?

1.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of socio-scientific issues?

2. To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSI-based teaching?

2.1. How do prospective elementary teachers' conceptualization of SSI-based teaching evolve during the pedagogy case activities?

2.2. How do prospective elementary teachers translate their understanding of socioscientific issue-based teaching into planning after experiencing CBLe?

2.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of socioscientific issue-based teaching?

Sampling Procedures

Sampling procedures in the social and behavioral sciences are often divided into two groups as probability and purposive sampling (Teddlie & Yu, 2007). Probability sampling techniques are primarily used in quantitatively oriented studies and involve ‘‘selecting a relatively large number of units from a population, or from specific subgroups (strata) of a population, in a random manner where the probability of inclusion for every member of the population is determinable’’ (Teddlie & Tashakkori, 2003, p. 713). Probability samples aim to achieve representativeness, which is the degree to which the sample accurately represents the entire population.

Purposive sampling is primarily used in qualitative studies and may be defined as selecting units (e.g., individuals, groups of individuals, institutions) based on specific criteria associated with answering a research study's questions. Maxwell (1997) defined purposive sampling as a type of sampling in which, "particular settings, persons, or events are deliberately selected for the important information they can provide that cannot be gotten as well from other choices" (p. 87).

Thus, in this study purposeful, criterion sampling (Patton, 2002) was used to reach participants from students who were enrolled in a science methods course for elementary teachers. The University of Georgia Institutional Review Board on Human Subjects approved all methods and procedures before any procedures with human subjects were initiated (see Appendix A). The class was comprised of 26 senior undergraduate students enrolled in the early childhood education program at a major public southeastern university in the United States. 25 students were female and one student was male, and all were in their early 20s. The course instructor introduced me to students during the first class meeting. I explained the purpose of my research and my role in the course. Among the 26 students, all of them gave their consent to use their course work (e.g. case reflection papers, online discussion posts, instructional resource designs and reflections), and 25 students gave permission to use their answers to Socio-scientific Issue Questionnaire (SSIQ) for my research.

I also asked students to voluntarily participate in interviews to share their experiences and thoughts about the instructional method after the implementation. Seven students initially volunteered for the interviews. I conducted interviews with all seven volunteers. However, because of the big amount of qualitative data I gathered throughout the semester, I decided to focus on one group of students which developed the "best instructional resource design," as judged by the instructor and voted by the students. Three members of the group initially volunteered for the interviews. I personally contacted one of the members via email to ask for her participation. The student agreed to participate in the interview along with other three interview volunteers. A total of four female students from the same group comprised the primary participants of the study (see Table 3.1. for details about the primary participants).

Table 3.1

Details about the Primary Participants

Participant	Gender	Prior SSI Experience - Grade Level		Prior CBL Experience
Alex	Female	Discussion of current issues (Not in-depth)	High school	None
Erica	Female	Discussion of social issues (Not in-depth)	College level pedagogy course	Inclusion of a short story in a class
Kyla	Female	None	-	None
Mary	Female	Discussion of current issues (Not in-depth)	College level pedagogy course	None

Design of the Case-based Learning Environment

In this section, I will explain the context of the study and the learning activities incorporated into the case-based learning environment.

Context

In the U.S., science education is part of the general training of prospective early childhood education teachers, but not a specific itinerary. Prospective teachers may have never heard about SSIs, even less about teaching SSIs. In this sense, their initial ideas on the topic were expected to be rather limited. Their inputs during the classroom meetings and interviews proved this assumption right.

The instructional model was implemented for in the required science methods course called Science for Early Childhood Education - ESCI 4420 (3 credits); this study reports the data from the learning outcomes. This is the only science methods course early childhood education students take during their undergraduate education. I, as the researcher, worked with the instructor of the course to integrate developed learning activities into the course. We devoted seven weeks of the course to implementation of learning activities in weekly sessions of 2 hours and 45 minutes each. Time devoted to case-based learning activities varied on different sessions (see Table 3.2).

Learning Activities

In this section, I provide a general overview of the learning activities that students engaged in the CBLe. I then describe each session including case materials in detail. All activities are structured into seven sessions (see Table 3.2) and were facilitated by the course instructor.

As discussed in Chapter 2, for many students, discussing and analyzing a case may be an unfamiliar experience. Mostert (2007) summarized several challenges regarding unfamiliarity and noted that students may have difficulty broadly adjusting their expectations of knowledge acquisition and their response modes to the relatively unfamiliar instructional setting when cases are used. For example, the flow and depth of the discussion may be disrupted by students being uncertain of how to respond to prompts from the case leader or other students; students might expect the instructor as instructional leader to give them the correct answer to a case problem; or class members might fail to assimilate the highly nuanced discussion and debate that case analysis often engenders, resulting in frustration or a growing disinterest with the topic and discussion at hand.

To overcome the challenges associated with no prior experience with case-based learning, a practice case was presented. Prior to data collection, during the first two weeks of the semester, the students read a pedagogy case and engaged in an online discussion activity. The instructor then led a whole-class discussion for this case. The purpose of this activity was to give students an opportunity to have an experience with technological tools (e.g. learning management platform) and to model a case-based learning activity. After this activity, I created a set of guidelines for online discussions and explained the rubric in detail (see Figure 3.1).

Let's Learn Together!

☆ Subscribe

Hide Description

Please check online discussion rubric before posting your sharing. Here is more explanation on the rubric:

1. What does "addressing some of the prompt's implications" mean?

   - Share your opinion on at least one of the questions, share your general takeaway and be clear and as detailed as possible.

2. What does "shows original thought that goes beyond the obvious" mean?

   - Google it! Look for additional resources to support your idea.

   - Do you know anything interesting about the topic, do you have an experience, a strong opinion? Share it!

   - A good example: S12 shared excellent insight into how to teach a similar topic in the future. Another good example: S25 connected her ideas to the big picture - to "theory". She mentioned how this example lesson connects to 'inquiry-based learning' and 'constructivism'. If you do not know what something is, just ask what it is!

3. What does showing concerted and honest effort to engage with others mean?

   - Respond to ideas in a way that advances discussion beyond the obvious: Saying "I agree with you" is a great way to share your appreciation but add more on that idea. Give an example, share your own insight, explain why it is an important point etc.

   - A Good Example: S5 shared her idea and focused on the positive side > S21 explained why she enjoyed her sharing and explained how this helped her to focus on positive side > S18 shared more specifically why she liked the point Brooke made about the fact that plants' insides and outsides look completely different and added more on this idea. Another good example: S26 wrote about the importance of giving rules and expectations > S4 agreed and gave an example to support this argument.

4. Respond if someone asks you something or states that he/she does not agree with you. Elaborate on your argument.

5. Go find diverse ideas, challenge each other's opinions, and make most out of this activity!

6. Ask for details if you do not understand something.

7. Feel free to not limit yourself to read only two posts. Online discussions will be a great learning opportunity only if you engage with each other! We will learn all together!

Figure 3.1. Guidelines for online discussions

Following the practice case, we implemented several learning activities including: (1) one introduction activity, (2) four case-based learning experiences, (3) one planning an instructional resource design activity and (4) one concluding activity. The time spent in-class on the activities differed across sessions. Implementation of the designed activities began in the third week of the course and finished in the tenth week. I will describe all learning activities for each session in depth in the following sub-sections (see Table 3.2 for an overview of all learning activities).

Table 3.2

Overview of the Learning Activities

	Date	Objective	Description	Time spent	Deliverables
Session 1 Introduction to SSI	August 30	- Conduct pre-SSIQ - Introduce the concept of SSI. - Model an hands-on SSI activity to introduce SSI concept.	- Students completed the pre- SSIQ - Students engaged in a hands-on activity related to Life sciences following an SSI discussion activity	2 hours and 45 minutes	Pre- SSIQ
Session 2: Case Activity #1 (To Spray or Not To Spray)	Sept. 6	- Support participants' SSR (RQ1)	- Students read an SSI case and engaged in online discussion before the session. - Students engaged in a classroom discussion led by a group then wrote a reflection paper after session ended as an assignment.	1 hour before classroom meeting (reading and online discussion) + 45 minutes classroom discussion + 1 hour for writing a reflection paper	- Online discussion posts - Researcher's observation notes - Case reflection papers
Session 3: Case Activity #2 (Selecting the Perfect Baby)	Sept. 20	- Support participants' SSR (RQ1)	- Students read an SSI case and engaged in online discussion before the session. - Students engaged in a classroom discussion led by a group then wrote a reflection paper after session ended as an	1 hour before classroom meeting (reading and online discussion) + 40 minutes classroom discussion +	- Online discussion posts - Researcher's observation notes - Case reflection

			assignment.	1 hour for writing a reflection paper	papers
Session 4: Case Activity #3 (I Like Spotted Owl Almost as much as Fried Chicken!)	Sept. 27	- Support participants' understanding of SSI-based teaching (RQ2)	- Students read a pedagogy case dealing with SSI-based teaching and engaged in online discussion before the session. - Students engaged in a classroom discussion lead by a group then wrote a reflection paper after session ended as an assignment.	1 hour before classroom meeting (reading and online discussion) + 55 minutes classroom discussion + 1 hour for writing a reflection paper	- Online discussion posts - Researcher's observation notes - Case reflection papers
Session 5: Case Activity #4 (The Day the Lobster Died)	Oct. 4	- Support participants' understanding of SSI-based teaching (RQ2)	- Students read a pedagogy case dealing with SSI-based teaching and engaged in online discussion before the session. - Students engaged in a classroom discussion led by a group then wrote a reflection paper after session ended as an assignment.	1 hour before classroom meeting (reading and online discussion) + 45 minutes classroom discussion + 1 hour for writing a reflection paper	- Online discussion posts - Researcher's observation notes - Case reflection papers
Session 6: Planning Activity	Oct. 11	- Demonstrate an SSI activity in elementary level. - Support participants' understanding of SSI-based teaching (RQ2)	- Session started with an SSI-based teaching activity - edible insects - Whole class discussion for reflection on issues of teaching SSI was held. - Students worked on their instructional resource designs for an SSI topic for elementary level classrooms	2 hours and 45 minutes	Participants' instructional resource designs
Session 7: Concluding Activity	Oct. 18	- Support participants' understanding of SSI-based teaching (RQ2) - Conduct post-SSIQ	- Students presented their lesson plans - Students completed the post-SSIQ.	110 minutes	-Instructional Resource Design Reflection Papers - Post- SSIQ

Session 1: Introduction to SSI. The first session started with an overall introduction to the nature of socio-scientific issues, followed by the implementation of the pre-SSIQ, and concluding with two SSI activities and overall discussion.

The first five minutes included a conversation about what students know about the concept. I reminded them that this is a part of my research, which explores their conceptualization of socio-scientific issues and teaching of those issues. I asked if anyone could explain the definition of a socio-scientific issue. Many of them stated that they have never heard the term. Only two students shared vague explanations such as “social issues that affect people” or “issues related to society and science”. The instructor shared the definition of SSI (See Definition of Terms section). We did not share any additional information about the nature of SSIs or how to teach those issues before students completed the pre-SSIQ.

The next 25 minutes was devoted to the pre-SSIQ. Students completed the questionnaire on their own laptops, individually. I answered students’ questions about how to log in or how to proceed. After completion of the pre-SSIQ, the introductory SSI activity began. In this methods course students engaged in activities that they could potentially use in their future classroom. For example, the topic of week 2 was earth science so they engaged in several activities related to water cycle, talked about ocean literacy and created their own paper-fishes to play a predator/prey game. Each week, the instructor shared materials (handouts, drawing tools etc.) and students left the class with materials of their own creation that they could use when they started teaching on their own. In this session, the instructor explained that we integrated SSI-based activities to enhance their understanding of socio-scientific issues. I intentionally found activities for higher-grade classrooms because the purpose of this session was to develop a basic understanding of SSIs before they engage in case-based activities. Thus, for this session, we integrated two activities related to oil spill (see Appendix B1) and vaccination (see Appendix B2).

Oil spill activity (90 minutes). We integrated this activity to highlight the complex nature of socio-scientific issues and how these issues affect different groups, involve personal decisions or depend on personal interests. This hands-on experiment provided students with an understanding of the issues that surround environmental cleanup. Students created their own oil spill, tried different methods for cleaning it up, and then discussed the merits of each method in terms of effectiveness (cleanliness) and cost.

The instructor started the activity by asking, “Do you remember when the most current oil spill happened?” After a short discussion, she mentioned about most known oil spills (e.g., Exxon Valdez, 2010 Gulf of Mexico) and explained oil spills, like most environmental issues, become very political situations. She explained how questions are asked and blame is given: Who is responsible for the pollution? Who should pay for the clean-up? How much should they pay? How should the spill be cleaned up? These and other questions are often highly debated issues. She explained that it is important to engage in this kind of an activity to be able to integrate these issues in their future classrooms. Following is the explanation of the hands-on activity:

> “Today, we are going to create a model of an oil spill. You are going to play the role of environmental engineers and use different technologies to clean oil from water. You will use booms and skimmers (used to contain the oil and avoid spreading); absorbents (used to soak up the oil and avoid spreading); and dispersants (chemicals used to break down the oil). You will collect data on oil removal and then look the clean-up methods used

from the viewpoint of both the environmental engineer and the oil company owner. Then we will evaluate alternative solutions and discuss how do you think they will feel about the oil spill cleanup?”

Students worked in groups of 4-5 people for this activity. After the hands-on simulation, the instructor asked general questions about different cleaning methods. We had a whole-class discussion about the methods and their possible flaws. After students tested all of the materials - both before and after dispersants were added – the instructor asked:

- Did any method completely remove the oil?
- What happened to the chemicals (dye)?
- Share some of the successes you experienced and some of the possible flaws that you see with these methods.

The course instructor shared how using detergent breaks up the oil and could harm the fish populations in the ocean, noting that this actually happened historically. She emphasized that these issues are complex, difficult to solve and there are always pros and cons to solutions. Then she explained how this example connects to the definition of socio-scientific issues and how it was relevant to science education. She emphasized that students may hear about an oil spill issue on news any time, providing a great opportunity to connect with the science classroom and enhance scientific literacy.

Finally, we provided the prospective teachers with an evaluation worksheet (see Appendix B1). Each group worked on an evaluation of alternative solutions to the problem “What should be done to reduce the amount of oil spilled into the oceans?” Each group worked on the worksheet for 15 minutes and then briefly shared their evaluations. The instructor summed up the activity and informed the students that they would start working on the second activity after a 10-minute break.

Vaccination activity (30 minutes). After the break, the instructor started the vaccination activity. The instructor shared current information on the vaccination issue. She showed a short video clip of an actor who defends his choice not to vaccinate his child and shared a story that she heard between an elementary teacher and a parent. The parent was also defending her decision not to vaccinate her child. However, she felt it was the teacher's responsibility to create a disease-free environment. The prospective teachers briefly discussed what they thought about these opinions and the importance of being able to use evidence-based decisions on these kinds of issues.

The instructor then pulled up the "Vaccination against Smallpox" story (see Appendix B2), and explained the activity. We read the short story of Jenner's discovery of the small pox vaccine together and assigned different roles to groups. Each group completed a set of questions to prepare them for their role and presented their character and his/her argument. Some students stated that it was difficult for them to present an opinion that they did not agree with and it was an important teaching moment for this session. We discussed why they felt uncomfortable with talking about *other* opinions, and the difference between debate and dialogue. We integrated this activity to highlight that engaging in socio-scientific issues requires the ability to consider multiple perspectives and that "when dealing with uncertainty it's not easy to make a decision / there is not a completely "good" or "bad" decision but better-reasoned decisions than others" (Espeja & Lagarón, 2015, p. 84). The instructor closed the session with reminding students the definition of SSIs (see Definition of Terms section) and reminded them to read the first SSI case and engage in online discussion before the next class.

Session 2: Case activity #1. The second session included the discussion of the first SSI case activity. The purpose of this session was for prospective teachers to experience the analysis and discussion of a real SSI topic related to their daily lives as students. Prior to the class meeting, students read a case about a socio-scientific issue, specifically the dilemma of using DDT for controlling the spread of the Zika virus (see Appendix C1). The original case from The National Center for Case Study Teaching in Science was related to use of DDT for malaria. Based on an expert's opinion, I modified this case to make the topic more relevant to the students' lives since Zika virus was a very current issue in the United States during the implementation of these activities. In this case, students faced with the complex issues surrounding the use of DDT to control the spread of Zika in the developing world. In their examination of the issue, students were expected to consider risk/benefit analysis and the precautionary principle, two techniques used when making policy decisions involving the impact of science and technology on society.

The students engaged in an online discussion activity (see details in the Data Collection section) to share their initial ideas and solutions for the case prior to the whole-class discussion. All students completed this activity prior to the class meeting. During this activity, my role as an insider was important since I had access to their online discussions in progress. Students needed additional guidance because this was the first online discussion activity of an SSI case. I noticed some students were simply responding to discussion questions instead of sharing their ideas. Thus, I sent out the email below (Figure 3.2).

Hello all!
I am really enjoying reading your posts on discussion forum! Please do not forget to look at "Let's Learn together" topic under "More Guidance about Online Discussions". We provided some examples from introduction case discussion to provide more insight on what is expected from online discussions.

Please do not limit yourself on responding the questions. You do not need to "answer" discussion questions. We want to hear your voice. We want to see what you are thinking about the topic, **what would you do if you were Mr. Sahriti?**

And Leading Group, you are expected to read all posts, take notes for the classroom discussion (takeaways, big ideas, key questions, conflicts etc.) and encourage people to engage in the discussion, ask questions, appreciate insightful posts. You do not need to respond all of the posts but feel free to do so if you have something important to say.

I hope this is helpful and you enjoy this learning opportunity! Do not forget to post your entry by Friday, Sept 2nd, 5 pm and respond to two other classmates by Monday, Sept 5th, 5 pm.

Figure 3.2. Email for additional explanation of the online discussion activity

In the class meeting, the students had 45 minutes to share their opinions, arguments and possible solutions to the issue. Five students formed the group discussion facilitators for the first SSI case activity and they were expected to read all online posts and encourage people to engage in the discussion, ask questions, and appreciate insightful posts during the classroom discussion. The instructor also facilitated the discussion, shared big ideas from online discussions and asked thought-provoking questions. For example, one of the students shared an additional resource about the issue on her online discussion post and the instructor remarked on her additional effort and brought the topic into the discussion. In addition, instructor asked for elaboration of ideas during the discussions. For example, one of the students stated “there is not enough data to say that DDT is harmful”, and the instructor asked “What do you mean by that? What constitutes data?” These strategies were all very well aligned with what was discussed previously in terms of the instructional design framework developed for this study.

At the end of the session, the instructor reminded the prospective teachers that their reflection papers were due before the next class session, and that they should focus on how their ideas evolved and what are their final suggestions for the case in their reflection papers.

Session 3: Case activity #2. The third session included the second SSI case activity. Prior to the class meeting, students read a case about a socio-scientific issue, specifically genetic testing (adapted from NCCSTS). The purpose of this session was for prospective teachers to experience the analysis and discussion of a real SSI topic which was very controversial. I chose this case to enhance their conceptualization of SSIs because I felt that genetic testing was such a current topic that some might have basic background knowledge of genetic engineering, IVF, stem cell research, and fertility medicine from movies and TV shows. I was very happy to see that students were able to relate to the topic and share knowledge from movies and TV shows that they watched in their daily lives. Many students shared that this case immediately reminded them of the movie My Sister's Keeper, and a student shared how she had watched a similar episode in a TV show, Private Practice.

In this case, students read about developmental disorders and considered the ethical issues of genetic manipulation and fertility treatments. The issues highlighted in this case involved genetic manipulation, advances in medical technology, and scientific ethics and were considered helpful to enhancing the prospective teachers' conceptualization of socio-scientific issues. I sent out a reminder email, similar to the one I did for case activity one, on the due date of the online discussion.

Students engaged in online discussion to share their initial ideas and solutions for the case before the whole-class discussion. In the class meeting, they had 40 minutes to share their opinions, arguments and possible solutions to issue. Classroom discussion was led by a group of students and facilitated by the instructor as similar to Case One. At the end of the session, the instructor reminded the prospective teachers that their reflection papers were due before next class session, and that they should focus on how their ideas evolved and their final suggestions for the case in their reflection papers.

Session 4: Case activity #3. The fourth session included the first pedagogy case dealing with a dilemma of SSI-based teaching. The purpose of this session was for prospective teachers to experience the analysis and discussion of a case including challenges of SSI-based teaching. Prior to the class meeting, students read a case about a first-year elementary teacher who attempted to make science instruction relevant to her students' everyday lives by having them debate a question: Should old-growth forests be logged for their valuable timber or should logging be stopped to preserve the habitat of the spotted owl? The teacher's efforts to use this emotionally charged issue to teach about the environment and ecology raised more controversy than she expected and she is left wondering whether the decision to hold the debate is a wise one. This case was originally created by Norman Lederman for the book *Cases in middle and secondary science education: The promise and dilemmas* (Koballa & Tippins, 2003), but again with an expert's guidance, I modified the context to reflect an elementary classroom and revised the text to make it age-appropriate and make the topic more relevant for students. I sent out a reminder email, similar to the one I did for case activity one about the due date for the online discussion activity.

The prospective teachers engaged in online discussion to share their initial ideas and solutions for the case before the whole-class discussion. In the class meeting, they had 55 minutes to share their opinions, arguments and possible solutions to the issue. Classroom discussion was led by a group of students and facilitated by the instructor as similar to Case One. At the end of the session, the instructor reminded the prospective teachers that their reflection papers were due before the next class session, and they should focus on how their ideas evolved and their final suggestions for the case in their reflection papers.

Session 5: Case activity #4. The fifth session included the second pedagogy case dealing with ethical treatment of animals in the elementary classroom. The purpose of this session was for prospective teachers to experience the analysis and discussion of a case dealing with a controversial issue and reflect on how to turn this into an SSI-based teaching activity. Prior to the class meeting, students read the case, which presents a story about a fifth-year elementary teacher who faced a number of dilemmas when the lobster cookout he has planned for the end of his oceanography unit takes an unexpected turn. I sent out a reminder email, similar to the one for the case activity one with the due date of the online discussion.

Students engaged in online discussion to share their initial ideas and solutions for the case before the whole-class discussion. In the class meeting, they had 45 minutes to share their opinions, arguments and possible solutions to the socio-scientific issue. Classroom discussion was led by a group of prospective teachers and facilitated by the instructor as similar to Case One. Since this was the last case-based activity before the prospective teachers planned their own instructional resource designs, I wanted to choose a case which was not explicitly about SSI-based teaching but would prompt them to consider how they might turn it into an SSI activity. Thus, at the end of the session, the instructor reminded the class that the reflection papers were due before next class session, and that they should focus on how their ideas evolved, their final suggestions for the case, and also specifically on this question: How would you turn this lesson into a socio-scientific issue activity?

Since the case was about ethical treatment of animals in science classrooms, I was expecting students to come up with topics such as animal rights. Students were very successful in about thinking about a variety of topics including animal rights, endangered species, different types of diets, and hunting regulations. Having this open-ended question helped me to explore their conceptualization of SSI-based teaching before they planned their own instructional resource designs.

Session 6: Planning activity (2 hours and 45 minutes). The purpose of this session was to introduce strategies to teach SSI in elementary classrooms and demonstrate an example elementary level SSI activity. I designed this session to provide prospective teachers an opportunity to experience an SSI related lesson as students and show the relevance of SSI for elementary level classrooms.

The sixth session started with an example SSI lesson for an elementary level classroom. The instructor modeled teaching a 5th grade SSI lesson on edible insects. A group of researchers (Evagorou et al., 2014; Espeja and Lagarón, 2015) developed and used this activity previously for a training program, which was designed based on results of research on professional development of prospective teachers. They used this activity to help prospective teachers reflect on teaching SSI: the reasons to incorporate SSIs in elementary classrooms and specific pedagogy when designing and implementing SSI activities. The activity was very well aligned with the purposes of this session so I contacted them to get permission to use their materials. The session included the following activities.

- For 50 minutes, the instructor acted like an elementary school teacher and followed a lesson plan (see Appendix D) to teach the topic of edible insects and controversies associated with that.
- The next 10 minutes was devoted to reflection on the lesson plan. The instructor shared the “edible insects” lesson plan with the students and the students were asked

to reflect in their groups on the 5E lesson plan and SSI teaching. The purpose of this task was for students to reflect on a lesson plan from the perspective of designing an SSI-based teaching activity and discuss the purposes of SSI-based teaching. The instructor asked “what would you like your students to learn when they engage in this activity?” Students’ responses included doing research, engaging in critical thinking, thinking about different perspectives, learning how to use scientific knowledge, engaging students in authentic scientific practices, and reflecting on their own values and attitudes, which are consisted with my analysis and the categories of purposes of teaching SSI found in the literature.

- The remaining time (~1 hour and 45minutes) was given to students to create an instructional activity for an SSI topic of their own choice for elementary level classrooms. The instructor explained the assignment and the rubric. They had time to finish this assignment in advance of the next class meeting.

Session 7: Concluding activity (110 minutes). The first 25 minutes of the session was devoted to the post-SSIQ. Students completed the questionnaire on their own laptops, individually. I answered students’ questions about how to log in or how to proceed. After completion of the SSIQ, each group had 15 minutes to present their instructional resource designs. The instructor encouraged students to leave at least 2-3 minutes for questions and comments, and their peers provided feedback for the designs. After the all presentations, students voted to select the *“best instructional resource design”*. They voted Group 6’s design as the best, which corresponded with my evaluation. Even though I did not analyze all students’ case reflections for this study, most of the students were able to evaluate the quality of an instructional resource design after they engaged in designed activities.

Mixed Methods Research Design

The purpose of this study was to explore prospective teachers' evolution of conceptualization of SSIs and SSI-based teaching when they engage in a case-based learning environment. In this section, I will explain my paradigmatic stance, rationale and purpose of the mixed methods design, and type of mixed methods design.

Paradigmatic Stance

Mixed methods research has been established as a third major research method over the past twenty years, complementing the existing traditions of quantitative and qualitative movements (Greene 2007; Teddlie & Tashakkori, 2009). This development has been accompanied by a search for an appropriate paradigm to provide a legitimation for the use of mixed methods comparable to the paradigms that have been widely accepted as justifying the use of quantitative and qualitative methods separately. Hall (2012) explained the background of this search as follows:

> The paradigm problem for mixed methods arises because of the so called 'paradigm wars' of the 1970s and 80s where the positivist paradigm of quantitative research came under attack from social scientists supporting qualitative research and proposing constructivism (or variants thereof) as an alternative paradigm (Reichhardt & Rallis, 1994). What has consequently been seen as a problem for mixed methods researchers is finding a rationale for combining qualitative and quantitative data in the face of seemingly incompatible paradigms. (p. 1)

To deal with this problem, a range of alternative approaches have been developed (Creswell, Plano-Clark, Gutmann, & Hanson, 2003; Greene, 2007; Teddlie & Tashakkori, 2003). The research methodology selected in this study was influenced by the alternative paradigm stance on pragmatism (Greene, 2007). Many members of the mixed methods community heavily favor alternative paradigm stance because this stance suggests that “historical philosophical incommensurabilities among paradigms are reconcilable through new, emergent paradigms, such as pragmatism, scientific realism, or transformation–emancipation” (Greene, 2008, p. 12).

Pragmatism has gained considerable support as a stance by a number of mixed methods researchers (e.g. Johnson & Onwuegbuzie, 2008; Morgan, 2007). It is oriented toward searching solutions to practical problems in the real world (Hall, 2012) and providing “workable improvements in our world” (Onwuegbuzie & Johnson, 2006, p. 54). Methodologically, pragmatism enables me to use mixed methods to find a middle position between quantitative and qualitative oriented questions, in this case to explore participants’ reasoning around socio-scientific issues and their conceptualization of SSI-based teaching in a case-based learning environment.

Rationale and Purposes of the Mixed Methods Design

Greene, Caracelli, and Graham (1989) examined published research and inductively identified the following five broad purposes or rationales of mixed methodological studies: (a) triangulation (i.e., seeking convergence and corroboration of results from different methods studying the same phenomenon), (b) complementarity (i.e., seeking elaboration, enhancement, illustration, clarification of the results from one method with results from the other method), (c) development (i.e., using the results from one method to help inform the other method), (d) initiation (i.e., discovering paradoxes and contradictions that lead to a reframing of the research question), and (e) expansion (i.e., seeking to expand the breadth and range of inquiry by using different methods for different inquiry components).

The purposes for this mixed methods study were triangulation and complementarity (Greene, 2007). With the triangulation intent, I used different methods (interviews, written artifacts, and questionnaire) to measure the same phenomenon (conceptualization of SSIs). Mixed methods methodology was also used for a complementarity purpose in this study. A complementarity mixed method study enabled me to use both quantitative and qualitative methods to seek “broader, deeper and more comprehensive social understandings by using methods that tap into different facets or dimensions of the same complex phenomenon” (Greene, 2007, p. 101). My central phenomenon for this study was conceptualization of SSIs and SSI-based teaching. I wanted to focus on how prospective teachers’ conceptualizations evolved with case-based pedagogy and how they perceived the value of CBLe on their development. Hence, complementarity purpose was also a focus of interest for this study.

In this study, I investigated the complex learning processes students experienced in the context of the designed unit. I focused on three aspects: (1) students’ reasoning around socio-scientific issues, (2) conceptualization of SSIs, and (3) conceptualization of SSI-based teaching. I also explored how they perceived the value of CBLe on their conceptualization of SSI-based teaching and learning.

Type of Mixed Methods Design

I employed a *concurrent triangulation design* in this study (Creswell et al., 2003). The purpose of this design is “to obtain different but complementary data on the same topic” (Morse, 1991, p. 122) to best understand the research problem. The intent in using this design was to combine the differing strengths and non-overlapping weaknesses of quantitative methods (e.g. larger sample size) with those of qualitative methods (e.g. small N, details, in depth) (Patton, 1990). This method enabled me to collect both quantitative and qualitative data concurrently while gaining different perspectives from different methods.

The rationale for choosing this design was twofold. 1) This design is used when a researcher wants to directly compare and contrast quantitative statistical results with qualitative findings or to validate or expand quantitative results with qualitative data (Creswell & Plano-Clark, 2007). With this design, I explored participants' reasoning around socio-scientific issues using both quantitative (SSIQ) and qualitative (online discussion posts, written reflection papers) data. 2) In a concurrent triangulation design, both types of data are collected during one phase of the research at roughly the same time. Each type of data can be collected and analyzed separately and independently, using the techniques traditionally associated with each data type (Creswell & Plano-Clark, 2007). Figure 3.3 is a graphical design of this study.

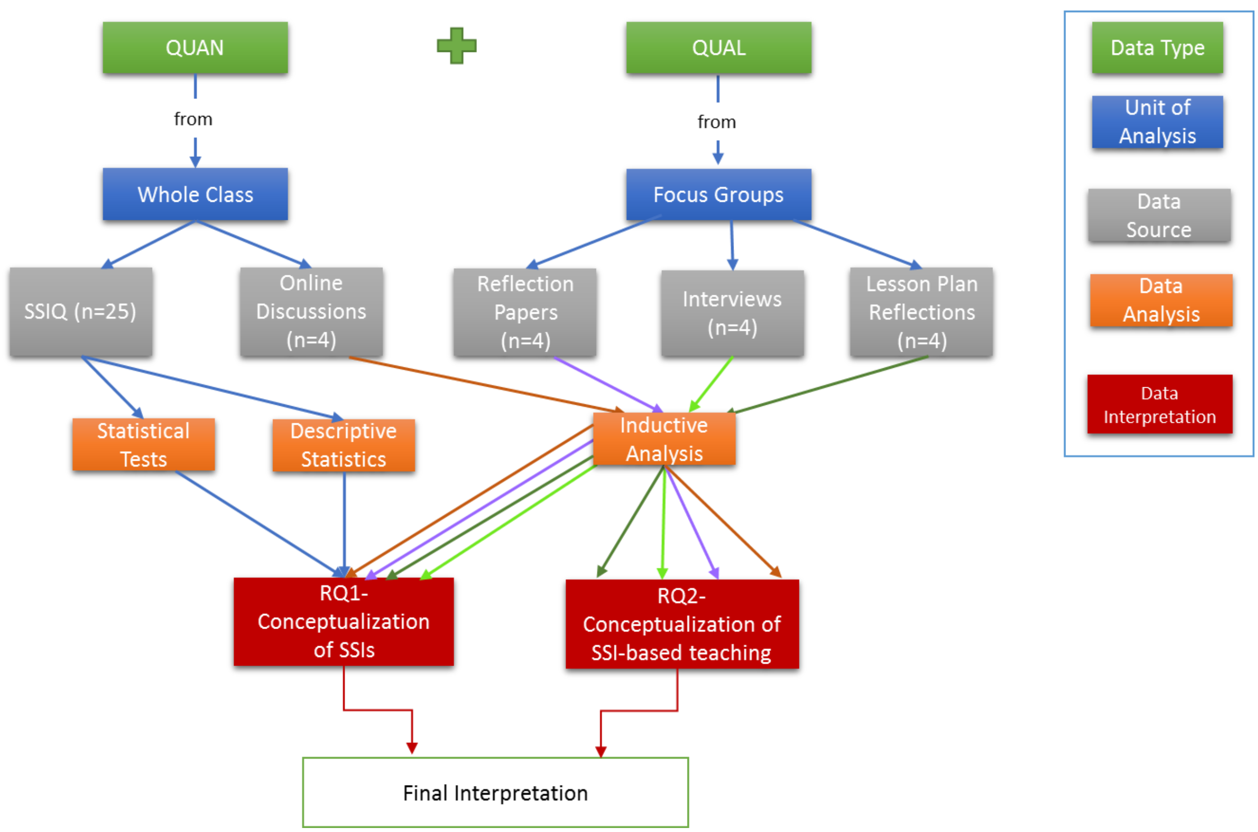


Figure 3.3. Graphical design of the *concurrent triangulation* mixed methods study

Teddlie and Tashakkori (2006) stated that a mixed methods study should include integration across stages. In Figure 3.3, a plus sign indicates that both QUAL and QUAN data were collected concurrently (Creswell & Plano-Clark, 2007). Mixing occurred during research questions, data collection, data analysis, and data interpretation stages. The Socio-Scientific Issue Questionnaire constituted a quantitative data source and collected from all participants (n=25); the primary participants' (n=4) reflection papers, online discussion posts, instructional resource design reflections and interviews constituted qualitative data sources for this study. In data analysis, I benefited from quantitative methods to answer the first sub-research question, and from inductive analysis for the other research questions. All findings were integrated and interpreted. In the next section, I provide a detailed description of the data collection process and instruments used for the study.

Data Collection Procedures and Instruments

The instructor introduced me during the first class meeting. I briefly explained the purpose of my research, and asked students for their consent to use their work for my research. I explained that I would not ask them to do any course work except volunteering for an interview at the end of the semester. I also explained that everything I used would be anonymous for my research. All students were assured that student participation was voluntary and would not influence their grades on assignments.

Students who consented chose to participate in pre- and post-questionnaire, interviews, and/or give the researcher access to their assignments related to course (e.g. online discussions, reflection papers). A consent form (see Appendix E) was provided in class and integrated into the online questionnaire. A learning management platform provided by the University was used to integrate case materials (text-based cases, discussion forums including guiding questions and explanation of the tasks under weekly folders). General functions of this platform and structures of the activities were explained during this introductory meeting along with the syllabus. I attended all classroom meetings to observe the students' in-class discussions and the implementation of other learning activities that we integrated into the course.

The pre-socioscientific issue questionnaire (pre-SSIQ) data was collected in the first week of the course, before the implementation of designed activities. I used a web-based survey creation tool, namely Qualtrics, to create the online questionnaire, and downloaded students' answers as pdf documents after class. Students engaged in weekly case-based learning activities (see Table 3.2) throughout the following six weeks. I downloaded and complied students' online discussion posts and written case reflection papers after each classroom discussion, and replaced any student names with pseudonyms for qualitative document analysis. Post-SSIQ data was collected right after the implementation of all activities during the tenth session of the course.

I also conducted individual interviews with participants after the implementation of all activities to better understand their impressions of and experience with CBLe regarding their conceptualization of SSIs and SSI-based teaching. Table 3.3 is a data matrix that indicates how the data collected related to each research question in this study.

Table 3.3

Data Matrix

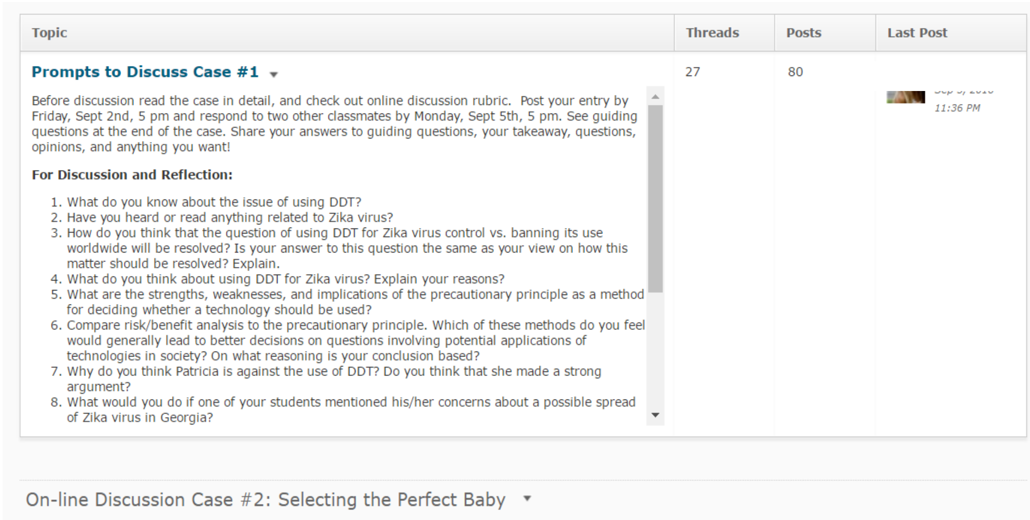
Research Question	Data Source					Data Analysis
	SSIQ	Online Discussion Posts	Case Reflection Papers	Interview	Instructional Resource Design & Reflection	
1.1. Evolution of socio-scientific reasoning	X	X	X	X		Statistical tests + Inductive analysis
1.2. Conceptualization of SSIs during case activities		X	X	X		Inductive analysis
1.3. Perceived value of CBL on conceptualization of SSIs		X	X	X		Inductive analysis
2.1. Conceptualization of SSI-based teaching during case activities		X	X	X	X	Inductive analysis
2.2. Translation of understanding into planning		X	X	X	X	Inductive analysis
2.3. Perceived value of CBL on conceptualization of SSI-based teaching		X	X	X		Inductive analysis

Socio-scientific Issue Questionnaire (SSIQ)

To assess prospective teachers' evolution of socio-scientific reasoning, I used the "Socio-scientific Issues Questionnaire" (SSIQ, see Appendix F) developed by Sadler, Klosterman, and Topcu (2011). SSIQ has an online, adaptive testing protocol that allows researchers to collect forced-choice as well as short-answer responses (Sadler et al., 2011). To reduce possible testing effects as a threat to validity, I used two equivalent scenarios developed by this group of researchers. Both scenarios were related to environmental pollution issues with economic implications and at least three clearly identifiable parties interested in the issue. Participants read and responded to one of the SSIQ scenarios prior to their experiences with CBLe and to the other after the implementation of the activities. The selection of scenarios (pre- versus post-intervention) was randomized.

Online Discussions

After reading each case and prior to class discussions, all students were required to respond to online discussion questions that prompted them to think critically about the readings. The online prompts stimulated students to comment on their understanding of the case and the specific SSI. Online prompts included the questions provided by the original case resources (e.g. National Center for Case Study Teaching in Science) and general reflection questions to explore students' conceptualization of the specific socio-scientific issue and/or SSI-based teaching. Questions for discussion and reflection were included at the end of each case and also on the discussion thread of the specific case. Figure 3.4.1 displays an example discussion thread; Figure 3.4.2 provides example questions from different cases.



Topic	Threads	Posts	Last Post
Prompts to Discuss Case #1	27	80	11:36 PM

Before discussion read the case in detail, and check out online discussion rubric. Post your entry by Friday, Sept 2nd, 5 pm and respond to two other classmates by Monday, Sept 5th, 5 pm. See guiding questions at the end of the case. Share your answers to guiding questions, your takeaway, questions, opinions, and anything you want!

For Discussion and Reflection:

1. What do you know about the issue of using DDT?
2. Have you heard or read anything related to Zika virus?
3. How do you think that the question of using DDT for Zika virus control vs. banning its use worldwide will be resolved? Is your answer to this question the same as your view on how this matter should be resolved? Explain.
4. What do you think about using DDT for Zika virus? Explain your reasons?
5. What are the strengths, weaknesses, and implications of the precautionary principle as a method for deciding whether a technology should be used?
6. Compare risk/benefit analysis to the precautionary principle. Which of these methods do you feel would generally lead to better decisions on questions involving potential applications of technologies in society? On what reasoning is your conclusion based?
7. Why do you think Patricia is against the use of DDT? Do you think that she made a strong argument?
8. What would you do if one of your students mentioned his/her concerns about a possible spread of Zika virus in Georgia?

On-line Discussion Case #2: Selecting the Perfect Baby

Figure 3.4.1. Example online discussion thread

1. How do you think that the question of using DDT for Zika virus control vs. banning its use worldwide will be resolved? (SSI case - Zika) a. Is your answer to this question the same as your view on how this matter should be resolved? Explain.	6. Some people in communities in Oregon and other Northwestern states believe that the spotted owl controversy is not science and should not be debated by students in elementary science. Do you agree or disagree? What are your reasons? (Pedagogy case – Spotted Owl)
2. What do you think about using DDT for Zika virus? Explain your reasons? (SSI case - Zika)	7. What should be done about those students not in Sandy's 5th grade classroom who have also expressed their concerns about the spotted owl controversy? (Pedagogy case – Spotted Owl)
3. What would you do if one of your students mentioned his/her concerns about a possible spread of Zika virus in Georgia? (SSI case - Zika)	8. Should fifth graders be protected from such life experiences? (Pedagogy case – Lobster)
4. What are some ethical issues related to the use of PGD? What do you think about those issues? (SSI case – Perfect Baby)	9. How might the lesson changed to avoid or soften the issues raised by the children's unexpected behavior? (Pedagogy case – Lobster)
5. What kind of additional research would you do before next meeting, if you were one of the research team members? (SSI case – Perfect Baby)	10. How would you turn this lesson into a socio-scientific issue activity? (Pedagogy case – Lobster)

Figure 3.4.2. Example questions from different cases

Students were also required to respond to two of their classmates' posts to support their exploration of multiple perspectives and alternative ideas. Each participant completed this activity for four cases. I downloaded and complied their online discussion posts after everybody completed the activity (see Figure 3.5 for the explanation of the online case discussion assignment.

> **<u>Assignment #2: On-line Case Discussion (15 points): (See rubric)</u>**
>
> Related to the case studies we will read in class, you will participate in the on-line discussion via ELC. The instructor or the teaching assistant will post a prompt for the case study for the week. All members of the class must write an *independent, individual* response to the prompt. Then, you are required to respond to two of your classmates' entries. Everyone is expected to "manage" your own thread/entry; for instance, if your peers pose a follow-up question, you are expected to respond to it, and etc. Discussion forums will be made available via ELC. In order to provide you with efficient feedback and grade, your first entry should be posted by **5pm Friday** before the following class. Your responses to two other classmates should be completed by **5pm Monday** before the following class.

Figure 3.5. Explanation of online discussion activity.

Written Case Reflections

Students read two cases on real-life, socio-scientific issues and two pedagogical cases that presented the dilemmas of teaching and learning of socio-scientific issues in the classroom. Participants wrote case reflections after completion of online and in-class discussions for each of the four cases. The instructor explained that students had to write four case reflections, and she would grade all four case reflections. However, she would incorporate the two highest grades of the four reflections into their final grade. She also reminded them that I had access to their work but my evaluation of the assignments had no bearing on their grades.

We provided one week after in-class discussion for submission of reflection papers to help students reflect deeply on how their initial ideas evolved after discussions and do additional research if they needed to do so (see Figure 3.6 for the explanation of the case reflection assignment).

Assignment #1: Case Discussions/Reflections (30 points): (See rubric)

During this course you will read a variety of "cases" (5 cases total) that address socio-scientific issues in science teaching and learning. You should read **all** assigned cases and participate in online discussions for all cases. Of the cases #1, #2, #3, and #4 you and your group will serve as the discussion leader for **one** of these cases. The leader group should peruse the on-line discussion forum and incorporate the salient topics emerged from the on-line discussion in class.

You will also develop an *individual* written reflection for all four cases. Introductory case is *excluded* from writing a reflection. In total, you will write **four** case reflections, and all four case reflections will be graded. However, the two highest grades of the four reflections will be incorporated into your final grade. Your response should demonstrate insight and in-depth reflection (see rubric). The reflection assignment is an *independent, individual assignment*. Case reflection should be completed *after* the class discussion in class. This assignment is **due** 5pm on Monday before class. (See Assignment #2 for the on-line discussion related to the case studies)

You should be prepared to contribute deep insights to class discussion of all cases.

Figure 3.6. Explanation of case reflection assignment.

Instructional Resource Designs (Designing a Learning Activity) and Reflections

As a concluding activity, after the implementation of all case activities and example SSI-based teaching activity (edible insects), the prospective teachers were asked to prepare their own instructional resource designs to teach a socio-scientific issue of their choice as an assignment. During the first meeting of the course, they formed groups and signed up for several different assignments. Designing the instructional resource design activity was also a group project. The prospective teachers formed groups of four or five (six groups in total) for this assignment. They had time in one of the class sessions (See Session 6: Planning activity section) to work on this assignment and to ask questions of the course instructor. They had one week to finish their instructional resource designs and prepare for presenting their designs during the subsequent class meeting. They were asked to include some necessary components such as subject, target grade level, background knowledge related to SSI, possible difficulties in teaching (see Appendix

G) but were encouraged to add more. Student were also expected to write a one-page reflection in which they discussed:

1. Which socio-scientific issue is being addressed via the instructional resource design?
2. Multi-dimensional nature of SSI (i.e., how does the selected topic for the lesson plan fit the definition of SSI?).
3. An in-depth discussion of the science content in the activity and its relation to society.
4. How the selected topic can be connected and integrated to the national curriculum.

I used this data (primary participants' instructional resource designs and reflections) to answer the one of sub-questions of the second research question.

Interviews

The interviews served a triangulation function to gain insight into the perceived impact of CBLe on participants' conceptualization of SSIs and SSI-based teaching. Example questions include: (a) What is your understanding of SSIs? (b) In what ways did CBL help or hinder your understanding of socio-scientific issues? (c) What do you think about the role that SSIs might play in your future classroom? (d) How did your experiences in the course influence your beliefs about learning and teaching of SSI? Through exploring their experiences and perceptions, I was able to analyze their challenges, activities that enhanced their conceptualization of SSI-based teaching and learning, as well as the effects of personal characteristics on their perceptions of case-based learning.

Before conducting the interviews, I formulated my questions using a semi-structured interview design which "covers a common set of themes but allows for changes in the sequencing of questions and the forms of questions, enabling the interviewer to follow up on the interviewees' answers" (Suzuki et al., 2007, p. 311). With the semi-structured interview approach, I was able to have a natural conversation flow and to use probes seeking further detailed descriptions (Roulston, 2010; Suzuki et al., 2007).

Merriam (1998) defined the semi-structured approach as a mix of open-ended and structured questions. She suggested that questions should be carefully considered, as they are the key to the door of data. Following these suggestions and approach, I have created both open-ended and structured questions. Two experienced qualitative researchers and one doctoral student from my cohort revised the first draft of my interview questions. They checked my interview guide for clarity. They suggested some additional questions and we changed the language for some questions that asked about negative experiences. I took into consideration their revisions, making the appropriate changes to my interview guide (see Appendix H).

To recruit participants for interviews, I included a specific checkbox on the consent form and explained the purpose of the interview during the introductory session. As indicated earlier seven students initially volunteered for the interviews. I asked for possible new volunteers after the completion of learning activities in class and asked them to send me an e-mail if they were willing to participate. I contacted my initial volunteers via e-mail and explained the purpose of the interview in a more detailed way. I explained that if they were still willing to participate on the interview, I would email them again to schedule a date, time and place to conduct the interview.

I personally contacted one of the students via email to ask for her participation because she was one of the group members who developed the *best instructional resource design* and the other three students from that group were already volunteers for the interview. She agreed to participate in the interview, making a total of four female students who comprised the primary participants of the study.

I conducted all of the interviews toward the end of the semester. The duration of the interviews varied between 30 and 45 minutes. I audio-recorded all interviews with the participant's permission. A professional transcribed the interviews verbatim for analysis. I reviewed all transcriptions for accuracy, added missing text, and revised misspelled areas of the transcripts in preparation for data analysis. The next section provides a detailed description of the analysis of all study data.

Data Analysis

Diverse types of data were gathered during the implementation of activities aiming at analyzing prospective teachers' conceptualization of SSIs and SSI-based teaching. I collected the following data:

1) Students' pre- and post-Socio-Scientific Issue Questionnaires (SSIQ),
2) Students' online discussion posts and reflection papers for four cases,
3) Students' instructional resources designs and reflection papers for their designs, and
4) Audio recordings of the interviews with volunteer students.

After the completion of data collection, I analyzed the data through data reduction, transformation, and integration (Onwuegbuzie & Teddlie, 2003). The data analysis process was aided by the use of a qualitative data analysis software called Atlas.ti (version 7.5.15). In this software, special stacks are designated to hold and organize data (see Figure 3.7). Using Atlas.ti I was able to create, change, add and delete codes and categories for my data. In Atlas.ti, data can be searched for codes, words or phrases and this enabled me to identify, retrieve, group and regroup meaningful data for analysis. The following sub-sections explain these processes in detail.

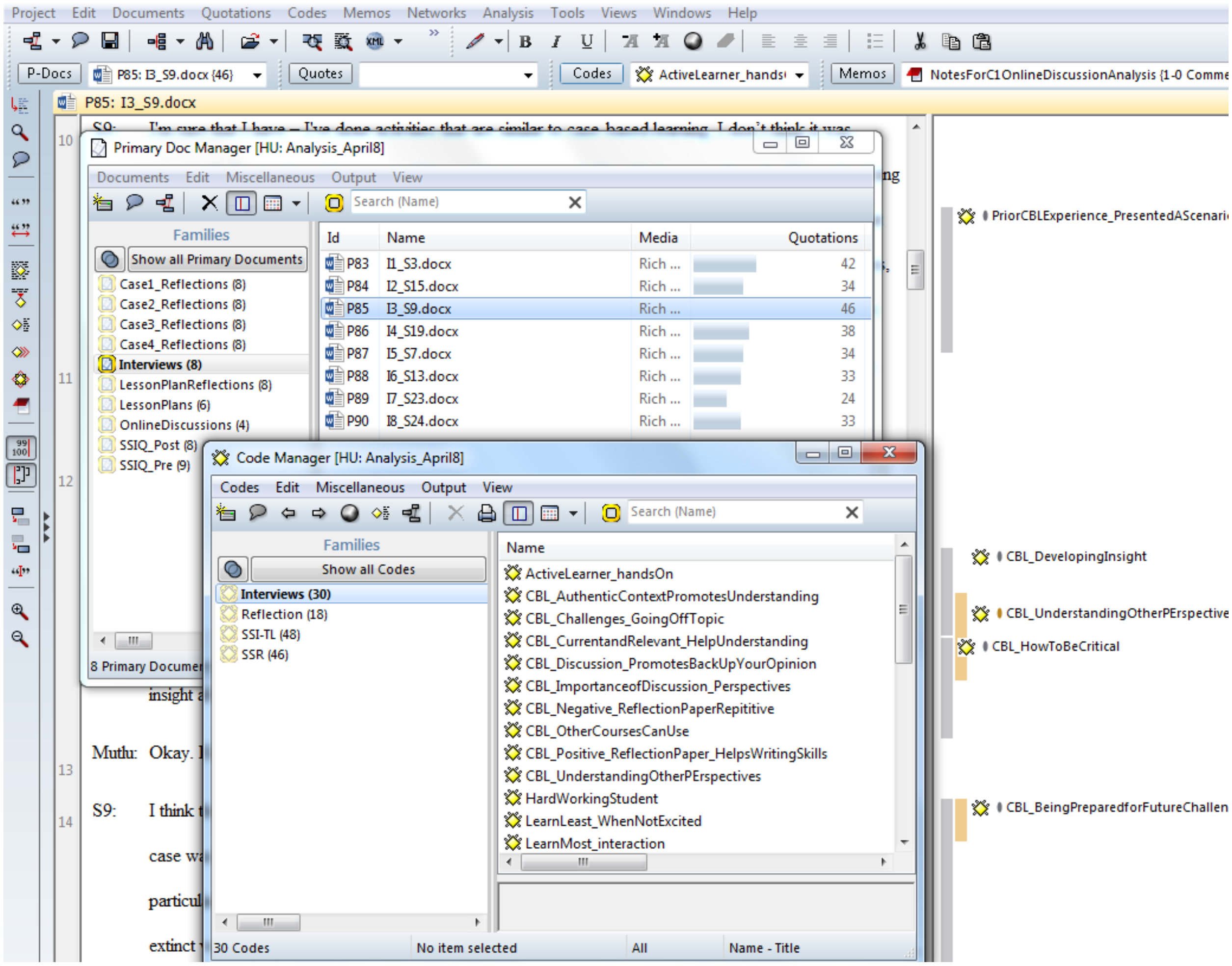


Figure 3.7. Example screen shot of Atlas.ti

Data reduction. Data reduction is necessary to eliminate irrelevant information from data and have the data in manageable pieces. At the beginning of the analysis, data from the students who would not give consent were excluded from the data set. This first applied to the SSIQ. One pre- and one post- questionnaire were eliminated because one of the prospective teachers did not give consent to use her questionnaire for the research.

All students (n=26) gave consent to use their course work (e.g. online discussion posts, reflection papers). The sample used for this study were the students who also participated in the interviews (n=4). The four students' online discussion posts, case reflections, instructional resource designs, design reflection papers, and interview transcripts were included in the analyses. This new data set was considered the consolidated subset of qualitative data.

Data transformation. Although data reduction was applied to all the data, *data transformation* was performed on qualitative SSIQ data only to be able to conduct statistical tests. Using Sadler et al.'s (2011) rubrics (see Data Analysis section), participants' answers to open-ended questions on the SSIQ were scored and qualitative data was quantitized (Tashakkori & Teddlie, 1998) to explore the improvement of students' SSR.

Data integration. The final step in the analysis was *data integration*. This process was aimed at weaving the bulk of findings into a coherent piece to depict participants' conceptualization of socio-scientific issues through case-based learning phenomenon. Descriptive statistics, statistical tests, categorization of case reflections and online discussions were interpreted to answer the first research question.

Based on the results of the consolidated data, online discussions, case reflections, and instructional resource design reflections were integrated to answer the second research question. Inductive analysis of interview transcripts were conducted to support findings from other data and to answer the third sub-research question for both research questions. Finally, all data was compared and integrated to write a final interpretation in order to give a holistic picture of the prospective elementary teachers' conceptualization of socio-scientific issues and SSI-based teaching. In the following sub-sections, I will explain specific analyses that were conducted for different data sources.

Analyses of the Socio-scientific Issue Questionnaire

As mentioned earlier, socio-scientific reasoning is a theoretical construct designed to "uniquely capture the array of practices fundamental to the negotiation of SSI" (Sadler et al., pp.

377-378). This group of researchers had completed several conceptual and empirical works that had been done in conceptualizing socio-scientific reasoning and its sub-constructs. Sadler (2014) explains this process as follows:

1. Initial work in the area of socio-scientific reasoning used interviews to document variation in student practice associated with the four aspects of socio-scientific reasoning (Sadler et al., 2007).
2. Next attempt to assess socio-scientific reasoning came in the context of an intervention study conducted in local classrooms. Building on what they had learned in the initial interview-based study, they developed the "Socio-scientific Issues Questionnaire" (SSIQ), an online, adaptive testing protocol that allowed researchers to collect forced-choice as well as short-answer responses (Sadler, Klosterman, & Topcu, 2011).
3. Finally, Sadler et al. (2011) developed five-point ordinal scales for each SSR aspect and used the rubrics to score the SSIQ data. Each had five levels (0–4). The first level (0) indicated that a student did not understand a particular socio-scientific reasoning sub-construct. The next level (1) indicated that a student understood the basic idea but could not offer an example in support of that idea. The three highest levels (2–4) offered more detailed descriptions of the sub-construct.

The most recent version of the rubrics (Sadler, 2014) was used to analyze pre and post SSIQ data in this study. See Table 3.4 for examples of how I scored participants' answers. To explore the students' evolution of SSR, I conducted Wilcoxon Signed-Ranks test (pre vs. post) for each of the SSR aspects. Average scores and standard deviations for the pre- and post-intervention SSR assessments as well as the p values are presented in the results chapter.

Table 3.4 *Rubric for scoring the four aspects of socio-scientific reasoning.*

	Levels			
SSR Aspect	**1**	**2**	**3**	**4**
Complexity	**Offers a very simplistic or illogical solution without considering multiple factors.**	**Considers pros and cons but ultimately frames issue as being relatively simple with a single solution.**	**Construes issue as relatively complex because of a lack of information. Potential solution tends to be tentative or inquiry-based.**	**Perceives general complexity of the issue based on different stakeholder interests and opinions. Potential solutions are tentative or inquiry-based.**
Exemplar quote	I think that the Branville Bay situation could be solved easily. The reason I think this is because there are still areas in the bay that the Native Americans could fish. (BR)	There should be another way for the ships to transport their cargo because I'm confident the ships are the problem. After all, it is only recently that the city became a major shipping port and wildlife authorities just now started reporting declines in populations and water quality (BR)	Although wind power not only helps the environment vs using fossil fuels for power and can also bring up the employment rate, the birds would become endangered. Although I do not know exactly why birds are an important part of the environment at this moment, I am sure that birds are very important to preserve. Maybe the leaders can figure out a way that birds would not go into the wind panels. (WF)	Any time that there is an issue that more than one party feels strongly about, coming to a conclusion can be difficult. The best option for one group is not necessarily the best option for another group, and because of this there are bound to be disagreements. I would also like to know the number of farm families affected and the endangered animals in the area that the opposition is scared would be affected. (WF)

	Levels			
	1	**2**	**3**	**4**
Perspectives	**Fails to carefully examine the issue.**	**Assesses the issue from a single perspective or only assesses some of them correctly**	**Can examine a unique perspective when asked to do so.**	**Assesses the issue from multiple perspectives.**
Exemplar quote	I think all the problems could be avoided if the Windfarm was not constructed. (WF)	I think that I would need to know where the wind farm is going to be located and if there is a better spot that we could put it to make everyone happy. (WF)	The Port Authorities, Native Americans, and Wildlife Managers are all going to have different opinions because they each want something different and do not want harm being done to their business/group. (BR)	Because the wind farm people probably have more money and power, I would have them make sure to hear out the farmers and the refuge and their needs. I would have a meeting with all three people to start to discuss their wants and needs, as well as get the facts from them. (WF)
Inquiry	**Fails to recognize the need for inquiry.**	**Presents vague suggestions for inquiry.**	**Suggests a plan for inquiry focused on the collection of scientific or social data.**	**Suggests a plan for inquiry focused on the collection of scientific <u>and</u> social data.**
Exemplar quote	Move the animals as much as possible- the port is needed and helps make the area money. The ships need to keep using it. (BR)	I would test the water and see if there is any change that could be effecting the fish. (BR)	I would talk with environmentalists. I would try looking for an alternative solution instead of using wind power or try figuring out a way to keep birds from flying into the wind panels. This is effective because I still want the city to do well but not at the cost of the birds. (WF)	I would need to know where exactly each part of the wind farm would be as well as how close it is to the wildlife areas. I would also need to know why the farmers would need to drastically change their farming practices. I would also want to research if there were any other locations that would work better for this. (WF)

	Levels			
	1	**2**	**3**	**4**
Skepticism	**Declares no differences among stakeholders.**	**Suggests that differences likely exist among stakeholders.**	**Describes differences among stakeholders.**	**Describes differences among stakeholders and discusses the significance of conflicting interests.**
Exemplar quote	It seems as though the Port Authorities and Native Americans share the same view that their reasons for using the bay area (exporting/importing and fishing) as more important than protecting the wildlife of the area. (BR)	They have differing opinions on the proposed Refuge Windfarm. (WF)	Each want a different thing while it satisfies the wildlife managers, the farmer will lose land and then the city officials may lose jobs. (WF)	They all have a different view on what is "good" based on their individual and group needs. The farmers are thinking about their crops and business whereas, the Wildlife Managers are thinking about the wildlife and the birds. The City Leaders are thinking about the whole city's energy resource and creating jobs. None of these motives is wrong, but they will think that a certain decision is a "bad" or a "good" one based on their biases and needs. (WF)

Note. “BR” indicates that the comment was excerpted from discussions of the Branville scenario (Pre-SSIQ). “WF” indicates that the comment was excerpted from discussions of the Windfarm scenario (Post-SSIQ).

Analyses of the SSI Case Reflection Papers and Online Discussions

To investigate prospective teachers' reasoning around socio-scientific issues, their reflection papers for the SSI cases, which incorporate narratives about real socio-scientific issues that present complex arguments from multiple perspectives in a story format, were analyzed inductively. Two reflection papers of each interview participants (n=4), considered units of analysis, were categorized using a categorical system built from the characteristics of SSI included in the literature (Espeja & Lagarón, 2015; Sadler, 2014) in addition to others emerging from data.

The theoretical and empirically based categories about the conceptualization of SSIs were distributed in four dimensions: Characteristics of Topic (T), the Nature of controversy (C), the Nature of Uncertainty (U), and the Perspectives (P). For each dimension (T, C, U or P), I adapted Espeja and Lagarón's (2015) category system ordered from lower (level 1) to higher (level 4) level of understanding of SSI (level 0 when it is not mentioned). For example, regarding the idea C, level 1 was given to those who identified the controversy in general terms (i.e., different opinions on an issue), while level 4 was given to those who identify that it was a conflict of ideas between different social groups or within science (see Table 3.5).

Table 3.5 *Categories of Prospective Teachers' Conceptualization of SSIs.*

Category	Level	Idea	Description of the Category/Level
Topic (T)	Level 1	Identifies 1 aspect of the topic (relevance, complexity, consequences, implications, ...)	Mentions one of the aspects of the topic: - it is a current or relevant topic, - it is a problematic or a complex topic, - it affects different people/groups/sectors, - it implies personal decisions or depends on personal interests…
	Level 2	Identifies 2 - 4 aspects of the topic **OR** identifies it is a topic with social or scientific implications	Mentions 2-4 of the aspects included in T1 **OR** mentions that the topic has social or scientific implications
	Level 3	Identifies 2 - 4 aspects of the topic **AND** identifies it is a topic with social or scientific implications	Mentions 2-4 of the aspects included in T1 **AND** mentions that the topic has social **or** scientific implications
	Level 4	Identifies 2 - 4 aspects of the topic **AND** identifies it is a topic with socio-scientific implications	Mentions 2 - 4 aspects of the topic **AND** identifies it is a topic with socio-scientific implications
Controversy (C)	Level 1	Identifies controversy in general terms	Mentions that there are different opinions or points of view on an issue. It is seen as a conflict of ideas in general terms.
	Level 2	Identifies controversy in general terms with a reason	Mentions controversy as a conflict of ideas in general terms and provides one reason for this conflict.
	Level 3	Identifies controversy between different social groups/disciplines **OR** within science	Mentions the controversy as a diversity of points of view between different disciplines or social groups (i.e. politics, economics, ethics, ecology, etc.) **OR** within science (scientific community)
	Level 4	Identifies controversy between different social groups **AND** within science	Mentions the controversy as a diversity of points of view between different disciplines or social groups (i.e. politics, economics, ethics,

			ecology, etc.) **AND** it can also be within science (scientific community)
Uncertainty (U)	Level 1	Identifies uncertainty in general terms	Mentions that the information available is not clear and precise (but diffuse, complex, open, without a unique answer/solution...) / or that we do not know the possible/long-term effects
	Level 2	Identifies the implications of uncertainty when making a decision	Mentions ideas related to Level 1 **AND** mentions that when dealing with uncertainty it's not easy to make a decision / there is not a completely "good" or "bad" decision
	Level 3	Identifies at least one reason for uncertainty	Mentions ideas related to Level 1 **AND** gives one reason for uncertainty: there is a lot (quantity) or not correct enough (quality), it has different origins (source), it is under construction or without consensus (lack of knowledge)
	Level 4	Identifies the implications of uncertainty when making a decision **AND** one reason for uncertainty	Mentions ideas related to Level 1, identifies implications **AND** gives at least one reason (included in Level 3).
Perspectives (P)	Level 1	Assesses the issue from a **single** perspective	Assesses only one side of the argument, problem and/or controversy.
	Level 2	Assesses only **two** of the perspectives correctly	Assesses the issue from two different perspectives but does not mention about other perspectives.
	Level 3	Assesses the issue from **multiple** perspectives evident in the case.	Assesses the issue from multiple perspectives evident in the case but does not mention about other possible perspectives.
	Level 4	Assesses the issue from multiple perspectives **and** mentions about other perspectives	Assesses the issue from multiple perspectives and mentions about other perspectives.

Due to the size of the course (26 students), I included only the reflections of participants who also participated in interviews in this analysis but I also downloaded other students' reflections and replaced their names with pseudonyms to analyze separately in a future study. I used a different analysis method for reflections rather than the instructor's grading. SSI case reflections helped me to explore students' socio-scientific reasoning around different real-life issues to answer the first research question and pedagogy case reflections were used as triangulation data to answer the second research question. We developed a rubric to assess students' written case reflections for the course (see Figure 3.8).

ASSIGNMENT #1
CASE REFLECTIONS GRADING RUBRIC
(15 POINTS for each case; 30 POINTS TOTAL)

Component	Points
Catchy title for the case study reflection	1
In-depth insight and reflection	10
Should include **at least eight** of the following elements: 1. Your interpretation of the dilemmas/challenges presented in the case 2. Any current events or issues that may pertain to the case 3. Theories about science teaching and learning 4. The solutions you recommend or your evaluation of solutions found in the case 5. An explanation of why you think the solutions are viable or your justification of other solutions 6. Your own experiences as a student, teacher or parent 7. Common sense vs. scientific literacy 8. Any morals or lessons you think you can draw from you reading and interpretation of the case 9. Experiences of friends, colleagues or relatives 10. How could the case study be applied in your own classroom considering socio-scientific issues 11. References to any components of the case itself 12. Your big take-away from this case for your future teaching career.	
Typed and Submitted on Time (required)	1
Lead Case Discussion or Participation in Class DI	3
Total Points Possible (15)	

Your written case study reflection should be approximately 1 page, single-spaced in length (approximately 500-750 words). This reflection should be completed *after* our in-class discussion.
You must put your name, class information, and title on the *cover page only*.
Due 5pm on Monday before class

Figure 3.8. Case reflections grading rubric.

I also analyzed students' online discussion posts but used a different analysis method for online discussions, consistent with my analysis of reflection papers, rather than the grading of students' online discussions. A rubric was used to assess students' engagement in online discussions for the course (see Figure 3.9).

ASSIGNMENT #2
ON-LINE CASE STUDY DISCUSSION GRADING RUBRIC
(20 POINTS total for all 4 cases; 5 POINTS per case)

Component	Evaluation		
	Excellent	Average	Poor
In-depth insight and reflection	3 points Discussion post: • Shows serious contemplation of readings • Shows original thought that goes beyond the obvious	2 points Discussion post: • Indicates reading was completed • Addresses some of the prompt's implication	1 point Discussion post: • Suggests reading assignment scanned but not read carefully • Rehashes ideas from other posts
Engagement with others (Responded meaningfully to two students)	2 points • Shows concerted and honest effort to engage with others • Responds to ideas in a way that advances discussion beyond the obvious	1 point • Offers little interaction with other posts in the thread • Mostly summarizes what others have said without adding to discussion	0 point: • Ignores other posts in thread • Does not engage with others (at least two students)
Total points possible (5)			

Your first entry should be posted by 5pm Friday before class.
Your responses to two other classmates should be completed by 5pm Monday.

Figure 3.9. Online discussion grading rubric.

Analyses of the Pedagogy Case Reflection Papers, Online Discussions, and Instructional Resource Design Reflections

Students' reflection papers for the pedagogy cases, which incorporated dilemmas of socioscientific issue-based teaching, and their reflections on the instructional resource designs were analyzed inductively. Two reflection papers of each interview participants (n=4) and their reflections on the instructional resource designs, considered units of analysis, were classified using a category system built from the reasons to teach SSI included in the literature in addition to others emerging from data.

To inform the analysis, I identified four main purposes for teaching SSIs: (1) making science more relevant, (2) developing higher order thinking skills (i.e., critical thinking), (3) learning of science (i.e., scientific information) and (4) learning about science (i.e., scientific literacy). Considering these ideas, I adapted Espeja and Lagarón's (2015) four categories of analysis when appreciating the purposes of teaching SSIs (P).

The four categories from Espeja and Lagarón's (2015) work are exclusive and ordered from the lowest (level 1) to the highest (level 4) appreciation of purpose. For example, in level 1 participants only identified some apparent purposes for teaching SSIs (i.e., being informed), while in level 4 they identified all main purposes of teaching SSI (i.e., making science more relevant, development of HOTS, learning of science and learning about science) (see Table 3.6).

Table 3.6

Categories of Prospective Teachers' Conceptualization of SSI-based Teaching

Category	**Level**	**Description of category**
Making science more relevant	Level 1	Mentions ideas such as: - Being informed about current issues, - Being connected with real-life topics (i.e., understanding the world around them), - Learning the topics that are relevant for them, - Being involved in the community, - Connecting with other subjects (integrated curriculum).
Developing HOTS	Level 2	Mentions at least one idea related to "HOTS" (Higher Order Thinking Skills), such as: - Critical thinking about real-life issues, - Creating/Challenging/Articulating their own ideas, values and attitudes, - The ability to consider a wide range of information and perspectives,

		-Learning how to discuss.
Level 1 and/or Level 2 + learning about or learning of Science	Level 3	**A.** Mentions at least one idea of making science more relevant (included in Level 1) **OR** one idea of "HOTS" (included in Level 2) **AND** one idea related to **learning ABOUT science**: - Understand the importance of science in everyday life. - Promote scientific literacy. - Learn how to use scientific knowledge (e.g., argumentation). - Confront the uncertainty of scientific knowledge. - Understand the nature of science (e.g., tentativeness). **OR** **B.** Mentions at least one idea of making science more relevant (included in Level 1) **OR** one idea of "HOTS" (included in Level 2) **AND** one idea related to **learning OF science**: - Understanding and articulating scientific information. - Make science more real and practical to integrate science content in the social context. - Engage students in authentic scientific practices (i.e., doing research, doing experiments).
Level 1+2+3	Level 4	Mentions at least one idea of "making science more relevant", one idea of "HOTS", one idea of "learning ABOUT science" **AND** one idea of "learning OF science" (included in Level 1, 2 and 3)

I used the same analysis method for pedagogy case reflections and instructional resource design reflections rather than the instructor's grading. We developed a rubric to assess students' instructional resource designs for the course (see Figure 3.10).

ASSIGNMENT #4:
INSTRUCTIONAL RESOURCE DESIGN
(15 POINTS)

EXCEEDS EXPECTATIONS	MEETS EXPECTATIONS	BELOW EXPECTATIONS
1. Neatly constructed—professional looking 2. Includes all materials needed 3. Accurate science content based on background research 4. Very creative--evidence of strong creativity in the design of the instructional resource 5. Includes 1-2 page, single spaced reflection that addresses the points listed below	1. Neatly constructed—professional looking 2. Includes all materials needed 3. Accurate science content based on background research 4. Creative but somewhat lacks "WOW" factor 5. Includes 1-2 page, single spaced reflection but does not thoroughly addresses all points	1. Neatly constructed—professional looking 2. Includes all materials needed 3. Some inaccuracies with respect to science content 4. No evidence of creativity or originality 5. Lacks a 1-2 page reflection paper
Points 12-15	Points 9-11	Points 0-8

Figure 3.10. Instructional resource design grading rubric.

Analyses of the Interviews

I analyzed the interview transcripts to explore how elementary teachers perceived the value of the designed CBLe for their conceptualization of socio-scientific issues and SSI-based teaching. I used a combination of inductive analysis and the constant comparative method (Lincoln & Guba, 1985; Straus & Corbin, 1994). This process requires the researchers to compare individual pieces of the data to the entire dataset in an effort to identify common themes. First, I coded interview transcripts to identify emerging themes about students' perceptions of their experiences with CBLe. Once independent analysis was completed, another researcher (critical friend) independently coded sample qualitative data (two interview transcripts) and the researchers discussed their emergent findings collectively with the aim of coming to consensus on a common set of themes. The analysis of the interview transcripts also highlighted extracts and quotes in which participants expressed their appreciation of purposes of teaching SSIs. The extracts selected were used as triangulation data to explore participants' conceptualization of SSIs and SSI-based teaching.

Trustworthiness

Trustworthiness was ensured using several techniques to enhance credibility (Lincoln & Guba, 1985) in this study. Prolonged engagement on the site for 4-5 months, as well as triangulation of both data collection methods and theoretical frameworks established the credibility of the research (Bentz & Shapiro, 1998).

Researcher triangulation by having multiple investigators with different perspectives code and discuss the data in order to create the final set of themes (Lincoln and Guba, 1985) was another technique that I built into the design of the study. The course instructor served as the critical peer for researcher triangulation. She analyzed sample qualitative data from all data sources (one reflection paper for each case, two examples of instructional resource design reflections, and two interviews). Most of the discrepancies with coding were quickly resolved and ascribed to simple misinterpretations and we agreed on the final set of themes and categories.

A trained qualitative researcher not involved in the coding of the data was involved in peer-debriefing by reading the emerging themes and providing feedback related to the degree to which they could be logically derived from the data. Finally, thick description (Patton, 2002) was used to provide a transparent process for data collection and analysis to enable better transferability.

Limitations

This study has several limitations. First, in order to fully explore the evolution of students' reasoning around socio-scientific issues, one would need more time and practice in the context. However, participants in this study did not have any prior learning experiences with socio-scientific issues, thus I was able to explore their evolution of SSR by having pre- and post-measures of the phenomenon. On the other hand, the sample size was small, which limits the possible statistical analyses of quantitative data.

Another limitation of the study was that the instructor of the course had no prior experience with case-based pedagogy and it was her first time to teach the course. However, she was avid and open-minded for integrating new pedagogies and activities into the course, which helped me have enough time for implementing the designed model in the classroom setting. We regularly met during the planning of the course and talked about the strategies we would employ to enhance students' experience with the case-based learning environment. The core study participants' (n=4) perceptions on positive effects of CBLe on their learning suggest that we were able to overcome this limitation.

There are also several limitations in terms of the study design. Although concurrent triangulation design is the most popular mixed methods design, it is also probably the most challenging one (Creswell & Plano-Clark, 2007) and has its own limitations. Much effort and expertise is required, particularly because of the concurrent data collection and the fact that equal weight is usually given to each data type. I attempted to overcome this issue by including researchers with both quantitative and qualitative expertise on the graduate committee for this dissertation study. I, as the primary researcher of this study, am also trained in quantitative, qualitative and mixed methods research. In addition, a critical friend, who was also the instructor of the course, served the purpose of researcher triangulation.

Ratner (2002) stated that qualitative methodology recognizes that the subjectivity of the researcher, which guides everything from the choice of topic that one studies to formulating hypotheses to selecting methodologies and interpreting data is intimately involved in scientific research. Thus, I think my personal attitude toward the effectiveness of case-based pedagogy experiences might have affected my observations and interpretations, and limited my ability to think about any negative interpretations. However, strategies I used for trustworthiness, being aware of my own assumptions and beliefs, and presenting thick description of my subjectivity helped me to overcome these limitations.

CHAPTER 4

FINDINGS: CONCEPTUALIZATION OF SSIs

The purpose of this study was to (a) develop a feasible design framework for a case-based learning environment that incorporates cases related to socio-scientific issue-based teaching and learning and (b) apply the model to enhance prospective teachers' conceptualization of socio-scientific issues and SSI-based teaching in a science methods course for elementary education.

The inquiry in this study focused on this overarching question: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching? This chapter reports the findings of the first research question: To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSIs?

The first question included three sub-questions. To explore the first sub-question regarding prospective teachers' evolution of SSR, I analyzed all participants' answers to pre- and post- Socio-Scientific Issue Questionnaires (SSIQ) and reported the statistical analysis of pre- and post-SSIQ scores.

The second sub-question explored how the participants' conceptualization of SSIs evolved during the SSI case activities. Primary participants' online discussions and reflections to SSI cases and their answers to related interview questions provided triangulated data for the exploration of the second sub-question.

The third sub-question explored how the participants perceived the value of CBLe on their conceptualization of socioscientific issues. I will present findings for these sub-questions in the following sub-sections.

Research Question 1.1: Evolution of SSR

To explore the issue of change in socio-scientific reasoning (SSR) associated with the CBLe, I scored students' answers to pre- and post-SSIQ using the most recent version of the rubric by Sadler (2014) (see Data Analysis section for details). Data used for this analysis was restricted to 25/26 students who had responded to both scenarios and gave permission to use their answers for this research.

In order to explore the evolution of participants' SSR, I presented descriptive statistics of the data, then tested the data for normality and conducted a Wilcoxon Signed- Ranks test (pre- vs. post-) for each of the SSR aspect. The alternative hypothesis argues that there will be significant difference between participants' socio-scientific issue questionnaire scores before and after they engage in designed CBLe. In other words, participants' post-SSR scores are expected to be significantly higher than their pre-SSR scores after they participate specifically designed case-based activities in a science methods course. Descriptive statistics of the data are presented in Table 4.1.1 and Table 4.1.2.

Table 4.1.1

Distribution of Scores for SSR Aspects on the Pre- and Post-SSIQ

SSR Aspect	**Pre-SSIQ**				**Post-SSIQ**			
	Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 4
Complexity	5	4	10	6	3	3	3	16
Perspectives	4	6	13	2	2	4	7	12
Inquiry	1	11	13	0	1	6	6	12
Skepticism	5	11	9	0	6	7	6	6

According to descriptive statistics, forty-two percent of responses in the pre-SSIQ regarding the complexity and perspective aspects of SSR were scored at a Level 1 or Level 2 in the current study. Similarly, fifty percent of responses regarding the inquiry aspect were scored at a Level 1 or Level 2 and sixty-five percent of responses regarding the skepticism aspect were scored at a Level 1 or Level 2. However, participants of this study improved their SSR scores in the post-SSIQ responses after engaging in the case-based learning environment, supporting the efficacy of the model to enhance prospective teachers' evolution of SSR. Figure 4.1 presents a graphical representation of the distribution of scores for SSR aspects on the pre- and post-SSIQs.

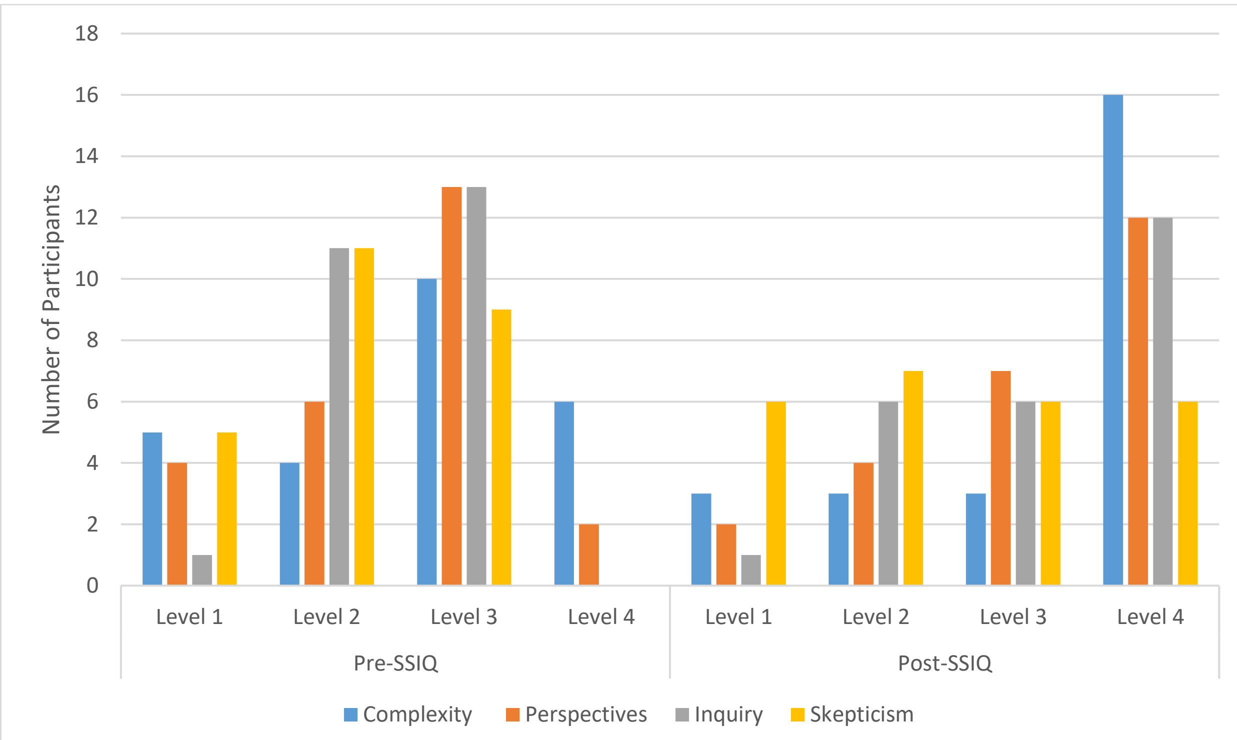


Figure 4.1 Graphical representation of the distribution of scores for SSR aspects on the pre- and post-SSIQ

Descriptive statistics also reported that the participants' post-questionnaire mean scores were higher than their pre-questionnaire mean scores for each aspect (see Table 4.1.2).

Table 4.1.2

Descriptive Statistics of Pre- and Post- SSIQ Scores

SSR Aspect	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
Pre-Complexity	25	1	4	2.68	1.069
Pre-Perspectives	25	1	4	2.52	.872
Pre-Inquiry	25	1	3	2.48	.586
Pre-Skepticism	25	1	3	2.16	.746
Post-Complexity	25	1	4	3.28	1.100
Post-Perspectives	25	1	4	3.16	.987
Post-Inquiry	25	1	4	3.16	.943
Post-Skepticism	25	1	4	2.48	1.122

To be able to conduct appropriate statistical tests, participants' pre- and post-questionnaire scores were tested to determine normality of data. According to the Kolmogorov-Smirnov test, participants' SSR scores were not normally distributed for all aspects ($p< .005$). Similarly, the Shapiro-Wilk test results showed that scores were not normally distributed ($p< .005$) (see Tables 4.2 and 4.3).

Table 4.2

Tests of Normality for Pre- and Post-SSIQ Scores

	Tests of Normality					
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Complexity	.258	25	.000	.853	25	.002
Pre-Perspectives	.309	25	.000	.838	25	.001
Pre-Inquiry	.333	25	.000	.721	25	.000
Pre-Skepticism	.230	25	.001	.805	25	.000
Post-Complexity	.384	25	.000	.679	25	.000
Post-Perspectives	.283	25	.000	.794	25	.000
Post-Inquiry	.293	25	.000	.797	25	.000
Post-Skepticism	.186	25	.026	.865	25	.003

a. Lilliefors Significance Correction

Because the data was skewed for all of the variables a Wilcoxon Signed-Ranks test was run and the output indicated that participants' post-SSIQ scores were statistically significantly higher than pre-SSIQ scores for three of the four constructs: (1) complexity aspect of SSR, Z= -1.97, p<.048; (2) perspectives aspect of SSR, Z=-2.498, p<.012; and (3) inquiry aspect of SSR, Z=-2.707, p<.007.

Table 4.3

Wilcoxon Signed-Ranked Test Statistics

Test Statistics[a]

	Post-Complexity – Pre-Complexity	Post-Perspectives – Pre-Perspectives	Post-Inquiry – Pre-Inquiry	Post-Skepticism – Pre-Skepticism
Z	-1.975[b]	-2.498[b]	-2.707[b]	-1.191[b]
Asymp. Sig. (2-tailed)	.048	.012	.007	.234

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Results indicated that participants' post-skepticism scores were not statistically significantly higher than their pre-skepticism scores, Z= -1.191, p< .234.

It is important to note that skepticism was one of the aspects in Sadler et al.'s (2007) original work that was completed in conceptualizing socio-scientific reasoning. However, in their later work, while designing the SSIQ and the rubrics used for scoring responses; they merged the perspectives and skepticism constructs. Sadler (2014) explained this change as follows:

> We did make one distinct change relative to the initial formulation: the skepticism and perspectives components were combined into a single sub-construct. Conceptually, both of these components relate to students' abilities to anticipate how parties with different

> interests might react to a particular issue; therefore, we decided to combine these as a single measure. (p. 108)

I found the original formulation more proper for my data analysis. I noticed that some of the participants were able to assess the issue from multiple perspectives but for their answers to the last question on the SSI, they were not able to declare differences among stakeholders. Thus, I decided that the assessment of these aspects require further exploration as separate measures.

To further explore participants' reasoning around socio-scientific issues, I focused on four participants' pre- and post-SSIQs in detail: Alex, Erica, Kyla, and Mary. These four female students comprised the primary participants of the study because they were the group members who developed the *best instructional resource design* and volunteered for the interviews. In the following sub-sections, I will present the primary participants' profiles and their evolution of SSR based on the SSIQ.

The Primary Participants' Evolution of SSR

Alex. Alex was one of the higher performers in the class; she attended all class sessions, completed all assignments and was one of the group members that developed the *best instructional resource design* at the end of the semester. During the interview, she stated that she had limited experiences with science classes. She shared that in college she only took ecology and weather and climate since those were the required courses for the early childhood education program. She explained her previous learning experiences with SSIs and CBL as follows:

> S*cience isn't really my strong suit. In high school, we would have little science experiments and they would kind of give like a little bit of a back story, but it was just like, you're a scientist and you want to see what happens when you mix these two*

chemicals, it was never – until this class, I had never really talked about issue-based scientific learning at all.

Even though Alex mentioned that *science is not really her strong suit* and she had no experience with socio-scientific issues before this class, her pre-SSIQ scores were high compared to her peers (Complexity: 3, Perspectives: 4, Inquiry: 3, Skepticism: 3). Only two students were able to assess the issue from multiple perspectives in their responses to pre-SSIQ, and Alex was one of them. She was also able to improve her scores on the post-SSIQ (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 4). Alex's pre- and post-high *perspectives* scores and evolution of each SSR aspect were evident in her SSI case reflections as well. Analysis of the online discussion posts and reflections for the SSI cases will be presented in the Research Question 1.2 section for each participant. Excerpts from her post-SSIQ and scores of her answers are presented in Table 4.4

Table 4.4

Alex's responses to Pre- and Post-SSIQ and Associated Scores

SSR Aspect	**Pre-SSIQ Related Response**	**Pre-Score**	**Post-SSIQ Related Response**	**Post-Score**
Complexity	[She assessed the issue as complex because of lack of knowledge] The story says that there are laws around the area, it may be helpful to know the specifics of these laws. Also, it may help to know if the Native Americans that are fishing in the area are changing their fishing habits since this decline has begun.	Level 3	Any time that there is an issue that more than one party feels strongly about. Coming to a conclusion can be difficult. The best option for one group is not necessarily the best option for another group, and because of this there are bound to be disagreements.	Level 4
Perspectives	She assessed the issue from multiple perspectives correctly before being asked to do so. [When assessing her proposed	Level 4	She assessed the issue from multiple perspectives correctly before being asked to do so. [In her suggestion as the next step] As	Level 4

	approach] My approach would take time, and during this time the ecosystem would continue to worsen and affected parties, like the Native Americans, Port Authorities and others may become inpatient.		a next step in this process, I would hold a public vote and provide two options as to how to resolve the situation. The results of this vote could be very telling about just how opposed to this situation the city is.	
Inquiry	If I was responsible for resolving this situation, I would set up a system to monitor boat activity and observe the bay's sensitive water areas. Once I found an action that I believed would most likely cause the effects that we have been observing, I would research those actions further.	Level 3	I would like to know if there are other options for the location of the Windfarm. I would also like to know the number of farm families affected and the endangered animals in the area that the opposition is scared would be affected. (This response also informs the *Perspectives* aspect)	Level 4
Skepticism	Each group has different views on the situation to begin with, so it would be hard to find a solution that all would respond to the same way.	Level 3	Each group wants a situation that best aligns with their group's interests. The interests of these groups do not align, so their responses to the proposed suggestion will never be the same.	Level 4

Erica. Erica was one of the most engaged students throughout the semester and she described herself as a *quick learner***.** She was also one of the group members that developed the *best instructional resource design* at the end of the semester. She always brought different perspectives to online discussions and wrote in-depth reflections.

She shared that she is from a small town but she had *access to a good variety of resources outside of our school, not necessarily nearby***.** However, she shared some negative science learning experiences in her first case reflection as follows: "…*in the past, I have not particularly enjoyed anything related to science. I'm not sure if this had to do with my teachers or the expectations for the class, or something entirely different."* She explained her previous learning experiences with SSIs during college as follows:

The EDEC classes that we have each semester were really the classes that focused the most on what's going on right now. I don't think they necessarily were socio-scientific, I feel like they were probably the closest thing to socio-scientific in that they really looked at social issues that were going on today and how that will affect our classroom, how that will affect our teaching, how it affects our students. None of them were necessarily socio-scientific so I don't think I really have had any socio-scientific learning experience.

Erica was able to make a distinction between social and socio-scientific issues supporting her better conceptualization of SSIs after engaging in the designed activities. To further explore her experiences with these social topics, I asked her to explain the nature of the activities in the college course; she stated:

There wasn't really any exploration or research involved with it, I think it was mostly just professors integrating that into their lecture or the lesson for the day. And we probably had discussions on it, but there wasn't – it's not like we came to class prepared for a discussion like we did with this class. I think it was merely just this is something to think about and then we would have a few questions or discuss it and then move on. It wasn't very in-depth.

When I asked her about her previous learning experiences in high school or before, she also stated that she did not have any SSI-based learning experiences that she could remember even though she took courses that could benefit from SSIs.

Let me try to remember… I took biology my freshman year of high school. We probably were exposed to something during that biology class, maybe something along the lines of the perfect baby [genetic testing] *case. Nothing in chemistry my sophomore year, nothing really in physics my junior year. I took forensics my senior year, so that was a great* *opportunity but I don't know if something was brought up but I'm not remembering. And like middle school is probably the same with life science, physical science, earth science. I feel like I probably have but nothing really specific is coming to mind.*

Erica's previous learning experiences also supported that the integration of SSIs is rare in today's classrooms especially at the middle and elementary level. Aligned with her limited experience with SSIs, her pre-SSIQ scores were lower than the average of the classroom for complexity and inquiry aspects (Complexity: 2, Perspectives: 2, Inquiry: 3, Skepticism: 3).

However, she was also able to improve her scores in the post-SSIQ to the highest levels except the skepticism aspect (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 1). Again, it was interesting to see that one more participant had a lower score for the skepticism aspect in the post-questionnaire, supporting the difficult nature of assessing this sub-construct. Excerpts from her post-SSIQ and scores of her answers are presented in Table 4.5.

Table 4.5

Erica's responses to Pre- and Post-SSIQ and Associated Scores

SSR Aspect	Pre-SSIQ Related Response	Pre-Score	Post-SSIQ Related Response	Post-Score
Complexity	I think it should be easy to solve. The Native Americans have been in this area for a longer period of time compared to the city of Branville and the huge ships that sail around the port (even if they aren't going into the sensitive waters).	Level 2	This situation cannot be solved easily because there are two very sensitive aspects to this case: renewable energy/decrease unemployment and farm destruction/ecological risks. All of these issues are important so who is to say one should be preferred over another?	Level 4
Perspectives	She assessed the issue only from Native Americans' perspective. She stated "There should be another way for the ships to transport their cargo	Level 2	[In her suggestion as the next step] I think it would be smart to take a step back and evaluate all of the factors individually. Each one of them brings something to the	Level 4

	because I'm confident the ships are the problem…The Native Americans have little to do with the issues at hand.”		table, and also requires a sacrifice. I think it's critical to look at each one individually and in relation to the other factors at hand.	
Inquiry	[Her proposed approach included inquiry about Port authorities] I would need to know: how far the ships are coming into the bay, how deep the water has to be for the ships to sail effectively, different options for transporting the goods on the ship, the money that the city of Branville is willing to spend to solve the problem.	Level 3	I would need to know the parameters of both the proposed wind farm and of the wildlife refuge. I think it would also be helpful to know the locations of the family farms that are in question. So basically a map of everything that has to do with this project. I would also want to know about how many jobs this would create as well as about how much energy would be produced. I think it would be beneficial to know the costs of producing the wind farm. Other information that might be needed to make a decision would be information of the family farms in question (crop yield, number of employees, etc.). (This response also informs the *Perspectives* aspect)	Level 4
Skepticism	They are all worried about different things: the Port Authorities are concerned with money and businesses, the Native Americans are concerned with continuing their sustainable way of life, and the Wildlife Managers are concerned with the well-being of the environment and how to restore it properly.	Level 3	Although they represent different perspectives, I think moving the farm out of the city would be a situation that would make most of the citizens there content.	Level 1

It is important to note here, scoring of the different aspects were not mutually exclusive, and different parts of their answers informed several aspects. In general, I explored the skepticism aspect through their answers to the last two questions on the SSIQ. In Erica’s responses to the post-SSIQ, her high level of reasoning was apparent for all aspects except the skepticism. She declared no differences among stakeholders and suggested that "The City Leaders, Farmers, and Wildlife Managers would have similar responses to the proposed suggestion." However, she explicitly stated that these groups represent different perspectives and she assessed the issue from multiple perspectives correctly before being asked to do so.

It was an interesting and conflicting finding that she had a lower score for the skepticism aspect in her post-questionnaire. This may be related to the nature of the skepticism aspect of the questionnaire. To better explore this construct, I used a different category system for the analysis of case reflections since the original rubric did not provided enough details to analyze the data that the participants provided for this study. Uncertainty and controversy categories and levels associated with them were highly related to the skepticism construct.

Supporting her low level of skepticism, Erica had lower scores for the uncertainty and controversy aspects compared to other aspects in her second SSI-case reflection. Like other participants, Erica's conceptualization of different aspects of SSIs were further explored through her online discussion posts and case reflections for the SSI cases in the Research Question 1.2 section.

Kyla. Kyla was one of the most engaged and unique students. She was also one of the group members that developed the *best instructional resource design* at the end of the semester. She explicitly shared her excitement for the cases and for SSIs during classroom discussions. Supporting my observation about her engagement and her sharing about her excitement, when I asked her "How do you describe yourself as a learner?" she stated that:

I'm quick to learn if it's something I'm really interested in or if it's something that I think is valuable, it's easy for me to just jump in and want to learn. I enjoy learning, I enjoy seeking out knowledge and understanding more…

When I asked about her previous learning experiences with SSIs, she stated that *"Probably not that much. Yeah, really not that much. I can't think of a time specifically."* Then, I asked more questions to explore her experiences in elementary or high school. She, again, shared that she could not remember anything specific but had some positive memories from her fifth-grade science class in which they *did many hand-on projects*. I also added a question on participants' previous learning experiences with SSIs at the beginning of post-SSIQ specifically: "Do you have any previous experience with socio-scientific issue-based teaching and learning? (Before ESCI 4420)". Kyla answered this question as follows: *"I have not had any previous experience with socio-scientific issued-based teaching before this class. It has been a great experience so far!"*

Although, Kyla did not mention any experiences with SSIs from her college courses or before, she was able to get the highest score for the complexity aspect and her scores for other aspects were higher than the average of the class in the pre-SSIQ (Complexity: 4, Perspectives: 3, Inquiry: 3, Skepticism: 3). She was also able to improve her scores in post-SSIQ to the highest levels for all aspects (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 4). Her post-SSIQ was labeled as the best example in my analysis memos since she had the most detailed responses to questions. Excerpts from her pre- and post-SSIQ and scores of her answers are presented in Table 4.6.

Table 4.6

Kyla's responses to Pre- and Post-SSIQ and Associated Scores

SSR Aspect	Pre-SSIQ Related Response	Pre-Score	Post-SSIQ Related Response	Post-Score
Complexity	There are two sides of the situation, the Port Authorities and the Native Americans. The only voice that is being heard is the Port Authorities… The Native Americans were there before the port and so it becomes a sticky situation. There is no right or wrong and there is no actual proof of which group is causing the fish decline.	Level 4	I do not think it [Windfarm situation] can be solved easily because there are many sides of the story and different perspectives. The wind farm may be good for creating new jobs and creating clean renewable energy, but there is a lot of risk and consequences if this does happen. The wildlife refuge and the farmer would both be affected negatively.	Level 4
Perspectives	She assessed the issue only from one perspective until she was asked how other stakeholders would respond to her suggestion. [In her suggestion as the next step] I would want to give the Native Americans a voice and here what they have to say about their fishing. I would want to hear how they fish and how often.	Level 3	She assessed the issue from multiple perspectives correctly before being asked to do so. [In her suggestion as the next step] Because the wind farm people probably have more money and power, I would have them make sure to hear out the farmers and the refuge and their needs. The wind farm people could just ignore the neighboring areas, but that would be unwise. I would have a meeting with all three people to start to discuss their wants and needs, as well as get the facts from them.	Level 4
Inquiry	I would hear the Native American's out and I would make sure to monitor how both parties fish and come in and out of the waterway.	Level 3	I would need to know where exactly each part of the wind farm would be as well as how close it is to the wildlife areas. I would also need to know why the farmers would need to drastically change their farming practices. I would also want to research if there were any other locations that would work better for	Level 4

			this.	
Skepticism	The Port Authorities, Native Americans, and Wildlife Managers are all going to have different opinions because they each want something different and do not want harm being done to their business/group.	Level 3	They all have a different view on what is "good" based on their individual and group needs. The farmers are thinking about their crops and business whereas, the Wildlife Managers are thinking about the wildlife and the birds. The City Leaders are thinking about the whole city's energy resource and creating jobs. None of these motives are wrong, but they will think that a certain decision is a "bad" or a "good" one based on their biases and needs.	Level 4

Kyla's online discussion posts and reflections for all of the cases were also exemplary. The instructor and I agreed on appreciating her effort and success on assignments, and shared her posts as appropriate examples during classroom meetings on many different occasions. Further exploration of her online discussions posts and reflections will be presented in the Research Question 1.2 section.

Mary. Mary was also one of the group members that developed the *best instructional resource design* at the end of the semester. Her reflections were always detailed and she was engaged during classroom discussions. However, she did not create detailed online discussion posts and she was late for several sessions.

During our interview, she shared that she is not a morning person and thus sometimes was late for the sessions but *discussing the cases helped her to wake up!* Mary's higher level understanding of the cases was evident in her comprehensive reflection papers. This finding supported that classroom discussions were helpful for Mary more than other activities (e.g., online discussions). When I asked about her previous learning experiences with SSIs, similar to

Erica, she shared that they experienced the integration of some current issues in their pedagogy courses. She stated that:

> *I think those are brought up more in our EDEC courses, so we use those because we're just always, as teachers, supposed to be thinking about how we can create more of a global community in our classroom and just students who are informed on different issues and not only teaching them the standards but teaching them those standards in a fun way that's applicable to the world around them.*

I also asked about her learning experiences before her undergraduate education, and similar to all other participants, she did not have any in-depth experiences. She shared that:

> *In science class in high school, we would do that in biology, I know specifically of a teacher who would pull in some science or scientific issues and then we would take sides on it and discuss it or experiment with it and see the different sides. So, I did experience some of that in high school. Not a whole, whole, whole lot but some of it….*

She also stated that she could not remember anything from elementary or middle school like Kyla and Erica, supporting the rareness of SSIs in elementary or middle schools. Although, Mary shared that she had limited experiences with SSIs, her pre-SSIQ scores were higher than the average of the classroom for all aspects of SSR except skepticism (Complexity: 4, Perspectives: 3, Inquiry: 3, Skepticism: 1). Excerpts from her pre- and post-SSIQ and scores of her answers are presented in Table 4.7.

Table 4.7

Mary's responses to Pre- and Post-SSIQ and Related Scores

SSR Aspect	**Pre-SSIQ Related Response**	**Pre-Score**	**Post-SSIQ Related Response**	**Post-Score**
Complexity	I feel that it will be very difficult to convince either side of this conflict to realize their part in the decline of fish in the area. And even if it is easy to prove that one side or the other is at fault it will be difficult to have them change their ways because both sides seem very set in their ways.	Level 4	I do not think it [Windfarm situation] can be solved easily because the idea of a refuge windfarm could affect many people's lives in the area positively or negatively.	Level 4
Perspectives	She assessed the issue from two perspectives (Port authorities and Native Americans) and from Wildlife Preserve's perspective when she was asked to do so.	Level 3	She assessed the issue from multiple perspectives correctly before being asked to do so. [In her suggestion as the next step] I would conduct a survey around the local area on how different people from different parts of the community feel about the proposed wind farm. This would be an effective strategy because it would help us see if we need to further pursue the issue and possibly give us more insight into the issue	Level 4
Inquiry	I would need to know more about both sides. How often are the Native people are using the waters, boats and fishing, if there is any way the boats at the bay are still effecting the waters even if they are not in the protected areas and if there are any other outside factors we can explore. (This answer also informed the perspectives aspect).	Level 3	I would like to know how much the unemployment rate has affected the community- I would like to know how the rest of the community feels about this idea (not just farmers and wild life people) - how many birds would actually be hurt potentially by the windfarm- is that actually a very real concern.	Level 4

Skepticism	She did not declare differences between stakeholders and suggested that “they would probably be especially mad if they did not think they were at fault”	Level 1	Because they all have different interests and goals they want met by the windfarm.	Level 3

Mary was able to improve her scores on the post-SSIQ to higher levels for all aspects – even for the skepticism (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 3). It is important to note here, Mary was able to declare differences among different stakeholders but her explanation was not in-depth. She answered the question “Explain why you expect City Leaders, Farmers, and Wildlife Managers to have different responses to the proposed suggestion” (She selected that they would have different responses in the previous question) as follows: *“Because they all have different interests and goals they want met by the windfarm.”* She did not mention anything related to skepticism aspect in her other answers, thus I scored this aspect as Level 3. Despite her low Pre-SSIQ skepticism score, her ability to consider controversy among different groups and skepticism was evident in Mary’s case reflections even in the first one. I will present her online discussion posts and reflections in the following section.

Similar to statistical analysis, qualitative evidence indicated that participants’ conceptualization of SSIs evolved after engaging in several activities in the designed learning environment. I will present triangulated data for the second sub-research question in the following section.

Research Question 1.2: Conceptualization of SSIs during the Case Activities

To further explore how prospective elementary teachers’ conceptualization of SSIs evolved during the SSI case activities, primary participants’ online discussion posts and reflection papers for the SSI cases, which incorporate narratives about real socio-scientific issues that present complex arguments from multiple perspectives in a story format, were analyzed inductively. Two online discussions posts and reflection papers of each participant (n=4), considered units of analysis, were categorized in a category system built from the characteristics of SSIs included in the literature (Espeja & Lagarón, 2015; Sadler, 2014) in addition to others emerging from data. I will present findings from primary participants' online discussion posts and reflections for the SSI cases in the following sub-sections.

Findings from the Primary Participants' Online Discussions and Reflections for the SSI Cases

Alex. Alex engaged in all activities for SSI cases, including the online discussions, classroom discussions, and writing reflections. I will present her reasoning around these cases in the following sections.

The first SSI case. For the first SSI case, students read a case about a socio-scientific issue, specifically the dilemmas of using the DDT for controlling the spread of the Zika virus (see Appendix C1). During the interview, Alex shared that these SSI cases helped her to understand the current and relevant nature of SSIs. She stated that:

> *This class really helped me to kind of talk about the issues and talk about the Zika virus and talk about genetic testing but realize that it also is happening, it's not just some story, it's happening and a lot of our conversations ended with, what can we do about that? So not only are these things happening, but our actions can affect it in a negative or positive way. And I think that's something that really stood out to me about the SSIs.*

<u>Online discussion.</u> On her online discussion post, Alex considered some pros and cons but ultimately framed the issue being relatively simple with a single solution. She responded to

the online discussion question "What do you think about using DDT for the control of the Zika virus? Explain your reasons?" as follows:

While I am not especially fond of chemicals being sprayed into the air for us to breathe, DDT has yet to show any proven harm to humans. It has, however been proven to rid the environment of insects that carry deadly disease. Because of this, I support the use of DDT for the Zika virus.

She was able to assess the issue from multiple perspectives mentioned in the case when asked to do so (Perspectives - Level 3). She evaluated one of the characters' argument and stated that:

Patricia is against the use of DDT because she is worried about its possible implications on the environment. I think that she did make a strong argument, her ideas made me consider my opinion and allowed me to see the merits of the other side of the argument.

She also identified controversy as a diversity of points of views between different disciplines or social groups (Controversy - Level 3). She answered the online discussion question "How do you think that the question of using DDT for Zika virus control vs. banning its use worldwide will be resolved?" as follows:

Unfortunately, most decisions that are made by the government and other officials usually do not end in compromise. I think that with the world the way that it currently is, very concerned with the environment, that DDT will be banned. This could cause many more lives lost that do not necessarily need to be.

Alex did not mention any other aspects of the topic (e.g. being current or complex), did not present any suggestions for additional inquiry, and did not identify uncertainty explicitly on her online discussion post.

Case reflection paper. In her reflection paper, Alex was able to identify several aspects of the topic (Level 2). She explicitly stated that case reading and discussion helped her to understand the current and relevant nature of topic. She explained this as follows:

> *I did not previously have much knowledge about the Zika virus and DDT, reading this case and discussing it in our class helped me to understand an issue that is currently relevant in society. I had previously heard about the Zika virus, and understood that it was transmitted to humans by mosquitos, similar to Malaria.*

In her reflection paper, she successfully explained different perspectives evident in the case, but she did not mention about other possible perspectives. Thus, I categorized the perspectives aspect as Level 3 based on the following excerpt.

> *Three of these individuals had their own personal opinions on the use of spraying DDT to treat the recent outbreak of the Zika virus. The WHO tropical disease specialist and the Brazilian ambassador agreed that use of DDT would lessen the occurrence of the Zika virus. While there may be some negative effects, there is not enough proof in their eyes to discontinue the use of DDT. The Sierra Club representative disagreed. She was in favor of the "precautionary principle"*

Alex was able to identify controversy as a diversity of points of views between different social groups in her online discussion post. In addition to that, she identified controversy within science on her written reflection (Level 3). She mentioned that:

> *DDT has previously proven to control mosquito populations and lesson occurrences of malaria, so the same would most likely occur to treat Zika. While there may be consequences to the environment, these have not been proven, and the reduction of the Zika virus is more vital than preventing unproven risks.*

In addition to mentioning that consequences to environment has not been proven, Alex also mentioned that "*there is no way that one person can make the decision of whether or not DDT should be banned or allowed".* This statement suggested that Alex was able to identify that when dealing with uncertainty it is not easy to make a decision. Thus, I categorized the uncertainty aspect as Level 2.

The second SSI case. For the second SSI case, students read a case about a socio-scientific issue, specifically genetic testing (see Appendix C2). The purpose of this session was for prospective teachers to experience the analysis and discussion of a real SSI topic, which was very controversial and current by the time of the implementation.

<u>*Online discussion.*</u> Supporting the relevance of the topic, Alex's first sentence on her online discussion post was about a movie with a similar topic (My Sister's Keeper). She was able to describe the current and relevant nature of the topic and how it implies personal decisions, so I categorized her answers as Level 2 for the topic aspect on her online discussion. However, it is important to note here that she framed the issue in relatively simple terms with a single solution, and stated that "*I think that the team should go ahead with IVF and implantation of matching and Falconi anemia-free eggs for the family. Their daughter Sally will otherwise have a very low possibility of a bright future."* She also identified uncertainty only in general terms (Level 1). She mentioned that:

> *There are many risks with this process. June Shannon would need to go through hormone therapy, which can have complications, and there is a chance that this would not work. Many couples go through IVF, but the Shannon's case is a little different because they are looking for not only a viable embryo, but also an embryo that has specific genetic qualities.*

On the online discussion post, Alex was not able to think about multiple perspectives. She assessed the issue only from one perspective and focused on saving the existing child (Level 1). She stated that:

> *The reason that this case is controversial is because they are planning on, "selecting for a specific combination of genetic traits, a combination that will not benefit the planned child but will save an existing child." It is important to note that the planned child would not be harmed in any way. The umbilical cord blood from this second child, which is not otherwise used is all that is necessary.*

In the excerpt above, Alex mentioned that the topic is controversial but did not elaborate on any kind of conflict of ideas. Thus, I concluded that the controversy aspect was not evident in her online discussion post.

Case reflection paper. Even though Alex's online discussion post yielded low levels for all categories, she was able to improve her understanding of the issue in her reflection paper. First of all, she was able to identify that the issue implies moral and ethical decisions and has scientific implications. Accordingly, I categorized the topic aspect as Level 3. She stated that:

> *The team came across many ethical questions. How far can science go in controlling the life of a potential human? Are they okay with going through with this case to essentially create a "donor baby"? What type of precedent would this set for the scientific community?*

These were the questions that arose during classroom discussions. This suggests that the discussion activities helped participants to better understand SSIs. This excerpt also informed the decision I made for her uncertainty level (Level 3), along with the fact that she provided a reason for uncertainty (lack of knowledge). She stated that *there have not been many cases just like this* *one to which the team can refer*. She was also able to make personal connections, think about different perspectives (Level 4) and identify controversy as a diversity of points of view between different groups (Level 3). She stated that:

> *I have a personal connection to parts of this case. My mother was sick while she was trying to get pregnant, and as a result she had many of her eggs harvested and frozen…. There are several individuals who fight the concept of IVF and say it is unnatural, but in my opinion, this is a method that can be super helpful for couples that are struggling with pregnancy. The Shannon's case debates more than just IVF, and after discussing with my classmates and reading their posts, I am able to more fully understand the arguments that people against continuing with the Shannons case have.*

Improvement of Alex's conceptualization of the SSI after online and in-class discussions proposes important implications for the effectiveness of the model, which will be discussed in the Research Question 1.3 section. Alex's categories for the first and second SSI case reflections are presented in Table 4.8.

Table 4.8

Alex's Categories for SSI Case Reflections

SSI Case	**Data Source**	**SSI Aspect**			
		Topic	**Controversy**	**Uncertainty**	**Perspectives**
Case 1 (Zika)	Online Discussion	Level 1	Level 3	Level 0	Level 3
	Reflection Paper	Level 2	Level 3	Level 2	Level 3
Case 2 (Perfect Baby)	Online Discussion	Level 2	Level 0	Level 1	Level 1
	Reflection Paper	Level 3	Level 3	Level 3	Level 4

Erica. Erica engaged in all activities for SSI cases, including the online discussions, classroom discussions, and writing reflections. She did not explicitly talk about her experiences with SSI cases in her interview but during it she explained her general experiences with CBL, stating that she found all of the cases as *fairly interesting*. When I asked about any challenging experiences with CBL, she stated that:

> *If I came across something that I wasn't familiar with, I just took the initiative to – I don't want to make this discussion post without knowing what I'm talking about so like for the perfect baby case, I went and did more research on PGD beforehand. I wasn't necessarily familiar with all of the terminology that was used, but that wasn't an issue for me because it was interesting, I was fine with going and doing more –a little bit more research, at least in that particular one.*

The first SSI case. Erica's engagement in the case activities and her initiative to conduct further research were evident in her online discussion post and reflection for the first SSI case. I will present findings from her online discussion and case reflection in the following sub-sections.

<u>Online discussion.</u> Erica stated that she did not know much about DDT and Zika virus before reading the case and engaging in the online discussion. She mentioned that:

> *I learned what I know about DDT from the additional resources provided below the prompt questions and from the case study itself. The most recent thing I've seen related to the Zika virus or DDT was in the news this morning. There was a story about flooding in south Florida from the recent tropical storm… South Florida has seen over 500 cases of the Zika virus in the past year, according to the CDC. I also saw a story about millions of bees dying in South Carolina after an aerial insecticide was distributed over a county after they realized four residents had contracted the virus.*

It is important to note here, by sharing this story, I believe Erica affected many of her classmates with respect to changing their ideas towards the use of DDT to control Zika Virus. However, she was in favor of using DDT both in her online discussion and in her reflection. On the other hand, this excerpt suggests that she identified the current and relevant nature of the topic and that she was interested in finding additional resources to better understand the topic. She did not explicitly mention the complex/problematic nature of the topic. She considered how this issue affects different groups however ultimately framed the issue as being simple with a single solution. Thus, I categorized the topic aspect as Level 2. She stated that:

> *After reviewing the resources and reading the case study, I am definitely leaning towards using DDT for Zika virus control. There will be unintended consequences (as in the case of the millions of bee deaths) and probably some consequences that were predicted (mainly by the representative for the Sierra Club in the case study). But I think we should be able to regulate use and exposure in a way that will take control of the situation and pose a minimum threat to our environment.*

Erica was able to assess the issue from two different perspectives evident in the case (Level 2). However, she did not mention other possible perspectives. She stated that:

> *I believe that the precautionary principle is a double-edged sword: you could be saving lives and the environment, but by not attempting to use DDT (in a controlled and precise manner) you could be ending even more lives than you save.*

To support her argument on using DDT, she suggested that instead of exercising "*the precautionary principle, representatives/scientists need to sit down and investigate what they do know about DDT and the effects that it has on everything in the environment (plants, animals, and people).*" When she was elaborating on her ideas about precautionary principle, she identified uncertainty in general terms (Level 1) but she implied that we have enough data to look at. She stated that:

> *We know for a fact that DDT repels and exterminates mosquitoes that transmit the Zika virus, and we are able to look at data collected for decades to show that more lives were lost after we discontinued use of the chemical.*

She was also able to identify controversy in general terms in her post. She mentioned that "*in my opinion, Patricia basing her argument off of a principle that, at its core, revolves around uncertainty proved unconvincing compared to data provided by her opponents."* However, she did not include any details suggesting controversy between different groups or within science. Thus, I categorized the controversy aspect as Level 1.

Case reflection paper. In her case reflection, Erica shared some of the same ideas from her online discussion post but improved on some of the aspects. She mentioned more than two characteristics of the issue (e.g. being complex, current). And, she was able to identify the social implications of the issue. Accordingly, I categorized the topic aspect as Level 3. The following excerpt informed my decision:

> *Since our discussion, I found a news story printed on the website of Forbes that talks about a study done with genetically modified adult mice (to simulate human adults), and how it was found that the Zika virus actually affected cognition in these mice… If more research is done and this idea proves to be true, this will mean that adults can be negatively affected on a much more severe level by the virus in addition to unborn children that develop cognitive and physical defects.*

In her reflection, she elaborated on her ideas of controversy and was able to identify controversy within science (Level 3). She stated that:

One argument was made using the precautionary principle, which is centered around the idea that since we are not 100% sure of what could happen in the long term if we used DDT that we should refrain from putting it back to use. On the other hand, the rebuttal was that DDT controlled the mosquito population in the past, thus preventing thousands of cases of infection with the Zika virus.

She also improved her understanding with respect to the uncertainty aspect. In addition to identifying uncertainty in general terms, Erica gave reasons for uncertainty (lack of knowledge, being from different sources) and implications of them in her reflection. She stated that:

I believe a big lesson I learned from this case was that even when you're leaning one way or another regarding a dilemma, things are almost never just black and white. There are benefits and negative consequences that will be experienced with every decision that is made and that's important to remember when formulating your argument/providing evidence for why you believe what you do… Personally, I think that if you believe there is a correlation between environmental deterioration and the use of DDT, you should have more concrete evidence than the Sierra Club representative had. How do we know that DDT is causing what the Sierra Club says it's causing? To me, the precautionary principle is valid is many situations but the risk of contracting Zika virus is too great to take this precaution.

In the excerpt above, Erica presented one of the most comprehensive considerations of the uncertainty aspect. Thus, I categorized the uncertainty aspect as Level 4. Throughout her reflection, Erica was also able to assess the issue from multiple perspectives evident in the case but did not mention about any other possible perspectives. Thus, I categorized the perspectives aspect as Level 3.

The second SSI case. Similar to Alex and Cathy, Erica engaged in the topic thanks to its current nature and relevancy to real life. She did not mention any previous experiences related to this issue in her online discussion post but she shared a learning experience from high school in her reflection, and stated that she remembered this during the classroom discussions.

Online discussion. In her online discussion post, Erica was able to identify that the issue was problematic and implied the need for personal decisions (Topic: Level 2). She was able to consider the ethical dimensions of the topic and stated that:

> *One of the ethical issues related to IVF is that often viable embryos are being disregarded and thrown out, and therefore lives are being taken. This issue connects to a major ethical issue related to PGD: if embryos (fertilized eggs) are being thrown out because they are either carriers of diseases that are unwanted by the parent(s) OR do not have the characteristics that are wanted by the parent(s) (blue eyes, brown hair, male, etc.), then they are being voluntarily destroyed without any say in the matter. My personal opinion is that ANY human life is inherently valuable, therefore throwing out eggs that are fertilized is unethical to me.*

Similar to the Zika Virus case, Erica was the first student who brought a very unique perspective into the discussion: *disregarding the viable embryos*. This idea was also discussed in class and some students shared that they only thought about this after they read Erica's post. This excerpt also informed my categorization with respect to the controversy. Since Erica was able to identify controversy in general terms, I categorized this aspect as Level 1.

Erica focused on other ethical issues related to the case in her online discussion post. She stated that:

> *If a baby is being born from an IVF and PGD procedure, a third ethical issue relates to that child's rights if they are being born to save a sibling. Treatment might consist of one procedure, but it could also result in dozens of procedures throughout the child's life. Your second child might feel valuable in that they were the reason their sibling lived, but then there is the great possibility that they believe they are alive for no other reason and how tragic is that?*

Base on this excerpt, it appears that she was able to consider multiple perspectives evident in the case and was also able to consider the second child’s perspective. Hence, I categorized the perspectives aspect as Level 4. Any discussion related to the uncertainty aspect was not evident in her post.

<u>Case reflection paper.</u> In addition to mentioning some aspects in the online discussion post, Erica shared a learning experience from her high school years and identified current nature of the topic in her reflection paper. She shared the experience of watching a movie in her freshman biology course in high school about genetic testing. She stated that:

> *The film talked about a society where only the best traits were passed on, and it centered around the story of a guy who was conceived outside of this normal genetic process. I remember watching the film and thinking how crazy this idea was… Now the idea doesn’t seem very far-fetched considering that geneticists have reached a point in science where they are able to distinguish genetic traits from one another.*

She was also able to improve her understanding of the controversy aspect in her reflection. She did additional research regarding the growth of PGD due to the idea of creating "savior siblings" and mentioned controversy as a diversity of points of view between different disciplines (Level 3). She mentioned that:

> *I believe this (referring the research article she included) shows just exactly how important of an issue we're dealing with, medically and morally. Decisions should be made so precedents can be set. Do I think there will be laws made or policies enacted to make this process easier? I'm not sure there will be enough agreement among lawmakers for that to happen, but it's not an impossible idea.*

The following excerpt informed my categorization with respect to the topic and the uncertainty aspects. Throughout her reflection and in the following excerpt, Erica was able to identify that the issue involved socio-scientific implications. Thus, I categorized the topic aspect as Level 4. In addition, she mentioned that no decisions are completely good or bad, thus I categorized the uncertainty aspect as Level 2. She stated that:

> *The team needs to research as much as possible before moving any further. They needed to research both procedures and turn them inside out to determine any risks to the embryos and to the mother during this whole process. My big take-away from this case is that every decision you make, you are ensuring something and giving something up. If these doctors decide to go through with this procedure and determine a perfect genetic match for the Shannons, there is a great chance they will throw away viable embryos that have the potential to develop into healthy, loved children.*

Erica had a very striking end for her reflection and connected the issue to teaching. She stated that "*If I decide to skip out on discussing an issue like this in class, I'm giving up an important discussion but I have the freedom to fill instructional time with something else that needs to be done. What are we willing to give up?*" Even if the first two cases were not specifically related to teaching, I added guiding questions at the end of the SSI cases to encourage prospective teachers to reflect on how to teach about similar issues in their future classrooms. Since Erica did not know anything related to SSI-based teaching prior to taking the methods class, her reflections on how to teach these issues were rather limited in the first two cases. Erica's categories for the first and second SSI case reflections are presented in Table 4.9.

Table 4.9

Erica's Categories for SSI Case Reflections

SSI Case	**Data Source**	**SSI Aspect**			
		Topic	**Controversy**	**Uncertainty**	**Perspectives**
Case 1 (Zika)	Online Discussion	Level 2	Level 1	Level 1	Level 2
	Reflection Paper	Level 3	Level 3	Level 4	Level 3
Case 2 (Perfect Baby)	Online Discussion	Level 2	Level 1	Level 0	Level 4
	Reflection Paper	Level 4	Level 3	Level 2	Level 4

Kyla. Kyla engaged in all activities for the SSI cases, including the online discussions, classroom discussions, and written reflections. She explicitly demonstrated her engagement in the case activities throughout the semester and in her written work. During the interview, she shared that her favorite case was the *Lobster Case* (last pedagogy case, see Appendix C4). When I asked her opinions about the SSI cases, she shared that:

> *I loved those, they were good. The Zika one was interesting. I really liked learning about that one and I liked being able to research it myself... I really liked the genetic testing one because everyone is kind of trying to please everybody and you can't really do that in science and you have to think about the whole masses, and just like the Zika virus. And so*

it's very controversial and it was hard for me to make a full assumption or decision about it and so a lot of times, again, I would catch myself: I feel this but also I could agree with this…I kept kind of going back and forth…

In the excerpt above, Kyla shared that she enjoyed the learning experience and she was able to appreciate the uncertain nature of these issues and the argumentation process throughout the discussion of them. Kyla did not know much about the Zika virus issue and had to conduct research about it. Actually, she stated that she enjoyed *being able to do research about it by herself.* Kyla's posts and reflections were shared as exemplary works for the first SSI case by the instructor. The following sub-sections present the conceptualization of these cases.

The first SSI case. Kyla was able to identify the complex nature of the Zika virus case beginning with her initial reasoning around the topic, and did not arrive at a simple solution. She also improved her conceptualization of the issue in her reflection paper. The findings from her online discussion post and reflection paper are presented in the following sub-sections.

<u>Online discussion.</u> In her online discussion post, Kyla shared a conversation indicating the current and relevant nature of the topic. She shared that she did not know much about the topic until she read the case. She stated that:

I honestly had little to no information about DDT before this case. From reading the article I learned that it is a pesticide for mosquitos, and that it is in debate on whether it should be banned or not in order to stop the Zika virus from spreading. One of the mentor teachers in my grade made a joke about the Zika virus this past week and I asked what it was. She and the other teachers were shocked that I didn't hear anything. When they explained it to me I remembered that I had heard about it, but I didn't look into it more at the time.

Although Kyla did not do research about the topic after she had this conversation with her mentor teacher, she was able to look into different resources online to better understand the topic for the analysis of the case. She stated:

> *I did some digging and saw the correlation between the Zika virus and underdeveloped brains in babies. It is scary and we still don't know all that the Zika virus will affect in peoples' health all around the World. I was also interested in finding more about DDT, so I looked into it more on the Pesticide Action Network website and it talked about how DDT was used a lot after World War ll and how we are still seeing negative health affects today. Other articles share about how we can save more people with just a little dose of the drug then if we ban it and keep letting people die from Malaria and the Zika virus.*

Kyla was one of the few students that was able to identify controversy in the online discussion post. This excerpt suggested that Kyla was able to identify controversy within science in her online discussion post. Accordingly, I categorized the controversy aspect as Level 3. She was also able to identify several aspects of the topic (e.g., current, complex, affects different groups) and the social implications of the topic. Thus, I categorized her topic aspect as Level 3. The following excerpt informed this decision as well as Kyla's ability to consider multiple perspectives from the case (Level 3). She stated:

> *This situation is not going to be an easy decision and will not be resolved quickly or easily. There are always many sides to the story, and I even find myself being on the fence about it when I read all of the information given. My thought is that we should be thinking not just about our Nation, but the rest of the World who would be majorly affected if we do ban DDT. Mr. Ricupero makes a good point in the case by saying that*

most of the Malaria and Zika deaths are happening in underdeveloped places, but that is changing.

Kyla's ability to identify reasons for and implications of uncertainty was exemplary in her online discussion post (Level 4). In the excerpt above, she mentioned how it was not easy to make a decision since the information presented was not always clear. She talked more about the reasons for uncertainty and stated that:

My question is what is best for everyone? I care about the future of our environment, but I cannot stand to see people die when we have an answer. It is like cancer in a way. In order to be cancer free, you have to go through treatments that have awful side effects. Some people can even die from the side effect itself. I know there are people who already are trying to find a cure for Zika and for Malaria, but right now people are dying and DDT can help while we continue to seek more answers.

Considering this was the first SSI activity that Kyla had participated in, her ability to identify all aspects of a SSI was extraordinary. Her profound conceptualization of the issue was also evident in her reflection as presented in the next section.

<u>*Case reflection paper.*</u> In her online discussion post, Kyla did not arrive at a single conclusion, but rather stated that *she was on the fence.* She was slightly in favor of the idea of *using DDT*. In her reflection paper, she stated that *"I am more against it now then I was before the in-class discussion, and I want to refocus the conversation to find other cures rather than give a DDT ultimatum."* She elaborated on the idea of finding other solutions and suggested that the issue was under construction. Thus, I categorized the uncertainty aspect as Level 4. The following excerpt informed this decision.

I realized after our discussion in class that the argument is very pointed on these two options: ban DDT or use DDT to stop Zika from spreading. There aren't as many voices advocating for alternative options. I know that the CDC is running low on research money, but I know that there are people who want to find a cure or vaccine for Zika. I think that we should be funding more research so that we don't have to pick between killing people now or killing people later through long term DDT affects.

In addition to identifying that the complexity of the topic and its effect on different groups, Kyla was able to indicate that the issue has socio-scientific implications. Hence, I categorized the topic aspect as Level 4.

Although there has not been an official death caused by DDT, I know that it will affect human health to some degree in the future and it will harm our environment as well. It is very hard for me to pick saving the environment later over saving lives now, but I do know that there are some consequences of using DDT now that can cause even more deaths later on.

In her online discussion post, Kyla was able to identify controversy within science. Even though she did not discuss the controversy as a diversity of points of views between different social groups explicitly, she was able to identify the importance of considering different groups (e.g. developed or undeveloped countries) when making decisions. Thus, I categorized the controversy aspect as Level 4. The following excerpt informed this decision.

I would hate to have the responsibility to decide to ban or not ban DDT. With either decision, there are significant consequences. I hope that whoever does decide what to do in this situation considers the whole World and the needs of all people and not just the more developed countries. This is something that I have noticed about most current *events. Americans freak out about an epidemic once it is on U.S soil. Malaria has been killing thousands of people in undeveloped countries, and can be repelled by using DDT. This issue hasn't come into conversation as much as a benefit for using DDT because it doesn't directly affect America as highly as Zika does.*

Kyla's ability to consider multiple perspectives was evident throughout her reflection paper and she explicitly stated the importance of thinking about different perspectives when dealing with controversial issues. She concluded her reflection as follows:

It is a tough decision that I don't think will be solved easily or fairly. We have to decide if we want to risk the side effects of using DDT, or any other vaccine that we find, in order to stop the spread of Zika. I hope that I can teach my students to think about different perspectives and options when controversial topics come up. A lot of times there is not a wrong decision, but just different perspectives. I am quickly learning that with any decision you make, there will always be a cost.

It is important to note here, this excerpt suggests that Kyla's ability to identify purposes of teaching SSIs was very limited at the beginning of the semester. She identified one reason related to higher order thinking skills (thinking about different perspectives) but did not mentioned other purposes. I will present the evolution of her conceptualization of SSI-based teaching in Chapter 5.

The second SSI case. During the interview, Kyla shared that she had very strong emotions about the second SSI case. She stated that:

It was hard for me to make a full assumption or decision about it…but I think at the end, with the genetic testing one, I really felt strongly about not opening it up to just people being able to modify a baby any way they want. Or even just the fact that doctors can *have the hands of taking away something really specific in differentiation in our whole world and that freaked me out...*

She also stated that *this case made her think the most*. Supporting her profound thinking about the case, Kyla's conceptualization of all aspects of the issue was evident both in her post and reflection paper. She developed a very detailed online discussion post and she was one of the students who shared a previous medical case that they watched on a TV show named "Private Practice" during the classroom discussion. She brought a different perspective on the case (money side of these procedures) into the classroom discussion but never mentioned it in her written works. The analysis of her online discussion post and reflection paper is presented in the following sub-sections.

Online discussion. With her interest in the case, Kyla was able to identify several aspects of the topic in her online discussion post. She mentioned that the issue is current and also a problematic one that includes ethical dimensions. She stated that:

While reading this case study, I was reminded of how truly technologically advanced our generation is then those of the past. The thought of being able to make the "perfect baby" is mind blowing to me. Of course PGD and IVF sounds like a no brainer if you can prevent your child from getting certain diseases, but genetic engineering can push limits and cross ethical lines very quickly.

While she was reflecting on her thinking process to suggest a solution, she shared that her initial instinct was to let the research team do the procedure because the issue implies personal decisions. However, she added that the topic has many other socio-scientific implications. Accordingly, I categorized the topic aspect as Level 4. She stated that:

If the research team goes ahead with this case, they are opening the door to hundreds of other cases involving concerned parents who want to not just modify for health reasons but also to modify other qualities or possibilities of the child. I think the research team needs to think about how their decision will not just affect the Shannon case but also the future of PGD. Instead of just taking away "bad" genes, they have to power to eliminate qualities and characteristics of a baby that make them unique. How would this decision affect diversity within humanity?

It appeared that Kyla identified uncertainty in general terms when she was discussing how we do not know *the effects of this decision on diversity*. Hence, I categorized the uncertainty aspect as Level 1. Additionally, Kyla identified controversy in general terms (Level 1) and assessed the issue from multiple perspectives including ones that were not evident in the case (e.g., unborn child) (Perspectives Level 4). All of these aspects were also evident in Kyla's reflection paper as discussed in the next sub-section.

Case reflection paper. In addition to all other aspects of the topic she mentioned in the online discussion post, Kyla elaborated on her ideas about having socio-scientific implications and the potential for loss of diversity in her reflection paper. She stated that:

…who is the deciding factor of what a harmful or undesirable trait is? There is a lot of power behind this process, and when it is handled in the wrong hands there could be serious consequences. I personally have friends who have a child with down syndrome and they feel like it is their purpose to embrace this child and help them thrive in the best way that they can. Being different is not a bad thing, and I am fearful that if we open the door to being able to genetically modify the perfect child, then many diverse traits of many different cultures and races may be wiped out completely.

This excerpt suggested that Kyla was also able to identify uncertainty that could lead to serious consequences. While she was explaining her solution, she also mentioned that it was not easy to arrive at a decision. Thus, I categorized the uncertainty aspect as Level 4. She also identified possible controversy between different disciplines. She stated that:

> *I am not even fully against preimplantation genetic diagnosis, but if it were to happen, I would hope there would be more laws and restrictions about it so that it could not get out of hand. Even with law making, there is no way to get everyone's side and perspective apart of the decision-making… politics, doctors, researchers will all have different opinions on the issue.*

Accordingly, I categorized the controversy aspect as Level 4. Kyla was also able to consider multiple perspectives throughout her reflection paper. She concluded her reflection as follows:

> *Another factor I had not thought about until Erica brought it up, is the other embryos that don't make the cut. It saddens me that all lives that are being risked to save this one girl's life are not thought about. After discussion in class and hearing other opinions, I still feel just as strongly about not letting the process of preimplantation genetic diagnosis move forward in the Shannon's case. With that being said, I am not a parent and I cannot imagine seeing my child slowly die and feel helpless about it.*

Since she mentioned perspectives that were evident in the case and other possible perspectives from class discussions, I categorized the perspectives aspect as Level 4. Similar to Alex, improvement of Kyla's understanding of the controversy and uncertainty aspects after the classroom discussions suggests some implications for the effectiveness of the model which will be discussed in the final chapter. Kyla's categories for the first and second SSI case online discussions and reflections are presented in Table 4.10.

Table 4.10

Kyla's Categories for SSI Case Reflections

SSI Case	Data Source	SSI Aspect			
		Topic	**Controversy**	**Uncertainty**	**Perspectives**
Case 1 (Zika)	Online Discussion	Level 3	Level 3	Level 4	Level 3
	Reflection Paper	Level 4	Level 4	Level 4	Level 4
Case 2 (Perfect Baby)	Online Discussion	Level 4	Level 1	Level 1	Level 4
	Reflection Paper	Level 4	Level 4	Level 4	Level 4

Mary. Mary engaged in all activities for the SSI cases, including the online discussions, classroom discussions, and written reflections. During the interview, she explicitly shared that she liked the *Zika Virus Case* and the *Lobster Case* (see Appendix C1 and C4). I will present her conceptualization of the Zika Virus case in the following sub-sections and the Lobster Case in Chapter 5.

The first SSI case. Like Kyla, Mary was able to identify the complex nature of the Zika virus case since her initial reasoning around the topic. However, she did not write a detailed online discussion post and concluded her post with providing a simple solution. On the other hand, she demonstrated improved understanding of the topic in her reflection paper. The findings from her online discussion post and reflection paper are presented in the following sub-sections.

Online discussion. Mary was able to identify current and relevant nature of the topic in her online discussion post, since she also had a personal connection to the topic. She shared that she heard about the Zika virus in the recent news but had never heard about DDT before reading the case. She stated that:

> *Patricia's argument truly did make me think critically about what it could mean to use a pesticide that could potentially have so much negative damage later on. I would hate to try and solve a problem and end up making more people suffer. In conclusion, I definitely see both sides to this argument have very valid points.*

Based on the excerpt above, I categorized the topic aspect as Level 2 since Mary was able to identify that the problematic nature of the topic and its social implications. The excerpt suggested that she was able to identify the controversy in general terms, thus I categorized the controversy aspects as Level 1. She was able to assess the issue from two perspectives but did not consider other possible perspectives, thus I categorized the perspectives aspect as Level 2. Mary also noted that we do not know the possible/long-term effects of the issue and that it is not easy to make a decision when there is not completely a good or bad position. Thus, I categorized the uncertainty aspect as Level 2.

> *It does make me very nervous that DDTs long term affects are unknown and that it may be bad for the environment and humans. That being said, it is also very unnerving that Zika is spreading so quickly. It has actually personally affected my family being that my sister's boyfriend just returned from Mexico with Zika like symptoms. AND my aunt is currently trying to get pregnant. Being that this issue is so close to home I definitely hope that they are able to resolve it in the best manner possible.*

Even though Mary was able to identify that this was a complex and problematic issue; not having prior knowledge about DDT and having a personal connection affected Mary's initial ideas and led her to arrive at a single solution. She stated that "*If I was forced to make a* *recommendation I believe that I would NOT ban DDT and go ahead and solve the current issue. But also I am definitely not an expert."* She was able to improve her conceptualization of the issue in her reflection paper as described in the next sub-section.

Case reflection paper. After engaging in the classroom discussion, Mary changed her idea with respect to not prohibiting DDT, and stated that "*I realize that Zika virus is horrible and is causing problems internationally but I believe it is too soon to release such a stable chemical with unidentified effects into our atmosphere"* in her reflection paper. This statement suggests that she was able to give one reason for uncertainty (lack of knowledge). Thus, I categorized the uncertainty aspect as Level 3. In this statement and throughout her reflection she identified several aspects of the topic such as being controversial and affecting different people and noted the scientific implications of the issue. Thus, I categorized the topic aspect as Level 3.

Mary was able to identify controversy within science while she was assessing the issue from multiple perspectives that were evident in the case. She assessed the issue from each character's perspective, and stated that:

> *After reading the case in its entirety and still being unsure of where I stood on this issue I looked more into the background of our participants…Dr. Caravan was the only person present who was an expert on the chemical in question. Though Mr. Ricupero and Dr. Lund both make good arguments for the use of DDT, I cannot help but side with an expert on the chemical who has deemed it unsafe to release back into the world.*

Based on this (shortened) excerpt, I categorized the controversy and perspectives aspects as Level 3. Mary improved her understanding of all aspects in her second SSI case reflection as discussed in the next sub-section.

The second SSI case. Mary did not share her experiences with the *Perfect Baby* case during her interview. In her online discussion, she shared that she had a personal connection and that she *"actually have had a family member who had trouble getting pregnant who used IVF as a possible solution."* But then she added that *"I had no idea they could test the genetic material prior to putting the eggs back into the body and identify if a child will have a disease or what blood type the child will be (PGD)"* She also had strong emotions about the case and evaluated this process (PGD) as *playing God* in her reflection paper. The findings from her online discussion post and reflection paper are presented in the following sub-sections.

<u>Online discussion.</u> Similar to the Zika virus case, Mary did not create a comprehensive online discussion post for the second SSI case. Her basic understanding of some aspects of the topic was evident in her short online discussion post. She stated that:

> *Upon realizing what the scientists were planning to do, I was shocked. I love that technology allows people who may not be able to conceive an alternate opportunity but I feel that by selecting which embryos to specifically use for the opportunity to create a child with specific traits is pushing the limits of technology too far. But this case makes it difficult to provide a definitive answer because it gives us a specific instance of a family with a sick child who could possibly be helped by this process.*

This except suggested that Mary was able to identify the complex and problematic nature of the issue although she did not mention other characteristics of the topic or its social/scientific implications. Thus, I categorized the topic aspect as Level 1. She was also able to assess the issue from one of perspectives (the parents' perspective) that was evident in the case but did not mention other possible perspectives (e.g., unborn child) resulting in the classification of

Perspectives aspect as Level 1. While she was presenting her solution for the case, she emphasized how we do not know the possible/long-term effects of the issue. She stated that:

> *I completely understand the Shannon's desperation to choose their perfect child but if the scientists allow them to choose for this trait then what is stopping other people to choose their children based on more superficial traits?*

This excerpt suggested that Mary was able to identify uncertainty in general terms, thus I categorized the uncertainty aspect as Level 1. Even though she had not assessed the issue meticulously for aforementioned categories and did not mention controversy in her online discussion post, Mary demonstrated her improved understanding for all of the categories in her case reflection paper as discussed in the next sub-section.

Case reflection paper. Mary identified several aspects of the topic throughout her reflection and stated that the topic has socio-scientific implications. She started her reflection as follows: "*The case was very messy and complicated. The family would like the scientists to only replant the embryos who would be a perfect donor to their first-born child. This request brought up some big issues, moral and medical."*

In addition to medical (scientific) implications, as she was explaining her stance on the topic, she stated that the topic also had social implications such as causing people to want to choose the traits of their children. She stated that:

> *I mainly disagreed with using PGD to choose a child's specific bone marrow type because its causes scientists to play "God" and define what is a "good" or "bad" embryo. By giving science this power it has potential to have a snowball effect and cause people to want to choose even more traits about their children. That is where this debate*

gets messy. How can scientists have the power to choose what is a good trait and what is a bad trait.

Accordingly, I categorized the topic aspect as Level 4 since Mary was able to mention the socio-scientific implications of the issue. She also identified controversy as a diversity of points of views between different people with different moralities. Hence, I categorized the controversy aspect as Level 3. She mentioned that:

Each year there are about 6,000 children born with Downs Syndrome (CDC). Some people consider this a disorder and some people consider it a blessing. One use of PGD could be to detect this chromosome defect (Downs Syndrome) and abort the child (Google). Morally, I do not agree with this decision. I believe all children have a right to life but that is only my opinion. The issue is that I think abortion is the wrong course of action and someone else may think it is right. Who can tell one of us we are wrong?

This excerpt suggested that Mary was able to consider other possible perspectives related to the issue (e.g., use of PGD for identification of Down syndrome, abortion), and assess the issue from multiple perspectives that were brought up during our classroom discussion. Thus, I categorized the perspectives aspect as Level 4. Mary also mentioned that when dealing with uncertainty there is not a completely "good" or "bad" decisions and in this issue, in particular, there would be no consensus. Accordingly, I categorized the uncertainty aspect as Level 3.

Who can define what a "good" trait in a child is and what a "bad" trait is? Who has the power to tell some people they can genetically choose their child and tell others they cannot because they do not agree with their motives? The lines are too susceptible to being blurred if we allow this one couple, The Shannon's, to choose their perfect baby.

Similar to Alex and Kyla, improvement of Mary's conceptualization of the controversy and uncertainty aspects after the classroom discussions suggests some implications for the effectiveness of the model which will be discussed in the final chapter. Mary's categories for the first and second SSI case reflections are presented in Table 4.11.

Table 4.11

Mary's Categories for SSI Case Reflections

SSI Case	**Data Source**	**SSI Aspect**			
		Topic	**Controversy**	**Uncertainty**	**Perspectives**
Case 1 (Zika)	Online Discussion	Level 2	Level 1	Level 2	Level 2
	Reflection Paper	Level 3	Level 3	Level 3	Level 3
Case 2 (Perfect Baby)	Online Discussion	Level 1	Level 1	Level 1	Level 1
	Reflection Paper	Level 4	Level 3	Level 3	Level 4

Research Question 1.3: Experiences with CBLe for Conceptualization of SSIs

To explore how prospective elementary teachers perceived the value of the designed CBLe for their conceptualization of socio-scientific issues, I conducted inductive analysis of interviews with primary participants. Other extracts and quotes from online discussions and reflection papers, in which participants expressed their appreciation, provided triangulated evidence for this research question. Results from the inductive analysis indicated that the primary participants appreciated the designed CBLe as they interpreted the learning experiences as a way to enhance their conceptualization of SSIs for several reasons that I will present in the following sub-sections.

Importance of Authentic Context

Importance of having authentic context for cases was discussed in the theoretical framework section and participants' expressions of their experiences with the cases supported this idea. All of the primary participants mentioned ideas related to "the benefits of the current and relevant nature of the cases" (e.g., promoting understanding, making learning interesting, enhancing engagement). For example, with respect to making learning more interesting, Alex shared that:

> *Because I'm such an interactive learner, current nature of cases helped me to interact with the topic. You know it is happening or recently happened, it's not just fact, fact, fact, and it gives you some background and makes it more interesting to learn.*

During the interview, in response to my question *"In what ways did case-based learning help your understanding of social scientific issues?"* Alex mentioned how authentic context promoted her conceptualization of SSIs. She stated that:

> *I think it helped to kind of wrap my mind around the real life of the issues. You learn about history as history and you don't kind of put it in a real-life perspective. And so, I think the case-based learning – and this class really helped me to talk about the controversial issues and talk about the Zika virus and talk about genetic testing but realize that it also is happening. It's not just some story, so our actions can affect it in a negative or positive way. And I think that's something that really stood out to me about the case-based learning.*

All of the primary participants shared their appreciation for the authenticity of the cases, especially for the SSI cases, which was discussed earlier in the Research Question 1.2 section. For example, during the interview Kyla shared that she found the Zika Case (the first SSI case) very interesting and she liked *being able to research it herself since it is currently happening.* She also shared that she thought the case activities were more helpful for her understanding of SSIs than other activities (e.g., in-class activities).

Mary also mentioned how she was personally connected to the first SSI case and the case experience inspired her as a teacher to bring current topics into her class in the future. During the interview, when asked *"In what ways did case-based learning help or hinder your understanding of social scientific issues?"* she shared that:

> *The Zika virus activity was really helpful…. I think we discussed this in class: We are living in a bubble in the United States. And then the case caused us to explore outside of the United States and we realized that it was affecting so many other countries and people way more directly than it was affecting us… and how it was being blown up in our news now because we have a few reported cases in the United States. I think that helped me see just as a future teacher to not take everything in our news as face value when pulling in a social scientific issue into the classroom and making sure that our students are exploring those other perspectives. So that one was helpful in that way.*

This excerpt suggested that the current and relevant nature of the Zika Virus topic inspired Mary as a teacher to discuss these issues in the future. She shared how helpful the case was in improving her understanding of different perspectives and the importance of enhancing her future students' understanding of other perspectives when she teaches these issues. Participants' conceptualization of SSI-based teaching will be further explored in Chapter 5 but this excerpt suggested that Mary was able to translate her understanding of SSIs into planning to teach those issues and she appreciated the purpose of supporting higher order thinking skills (e.g., thinking about different perspectives).

The prospective teachers also explained that the current nature of the cases enhanced their understanding as they engage in online discussions and reflection papers. For example, one of the prospective teachers mentioned that "*I didn't really pay attention to the news about the virus but learned a lot through reading the case"* during the online discussions for the first SSI case. Students shared their interest in the second SSI case (Genetic Testing) and expressed that the authenticity of the case made it more engaging. For example, many students shared that the case reminded them of a modern movie (My Sister's Keeper – released in 2009) and stated that it was interesting to see that issues related to genetic testing were currently happening on a daily basis. All of the points highlighted here suggest that the current and relevant nature of the cases enhanced participants' conceptualization of SSIs.

Benefits of Discussion Activities

All of the primary participants shared their appreciation for the discussion activities we had for each case. Many other participants expressed their opinions about discussions (online or in-class) and how those activities helped them to improve their conceptualization of the issues and/or further develop their initial ideas. Primary participants mentioned many ideas related to "the benefits of discussions" (e.g., promoting understanding, encouraging exploration, importance of discussion to understanding other perspectives) throughout the interviews.

For example, regarding the benefit of understanding other perspectives, Alex shared that "*Some of the discussions and things we had brought up challenges that I didn't originally anticipate. So having a lot of different brains going around and those discussions and having the online discussions are super helpful".* Kyla also mentioned that she learned from her peers and discussions helped her to think about other perspectives. She shared that:

I've liked the discussions we've had, I thought it has been helpful to understand how other people learn and how other people take things. And there's a lot of times where I'd leave the discussion and I would be able to take what someone else said and add that to my reflection which was good to know that I'm learning from my peers and not just my teacher so it's been good.

Mary also elaborated on the importance of discussions, focusing on the in-class discussion. She stated that not having the discussions would affect the efficacy of the instructional model. She shared that:

I liked that we were able to do it individually at first and form our own opinions… and then I would go into the classroom and kind of see how other people's opinions differed from my opinions. So I enjoyed being able to talk about the case with other people because my initial reaction on how I think I would have solved it normally changed after all of those discussions. I think it would be not efficient if we just got the case and had to give you our response ourselves.

This excerpt suggested that discussion activities were helpful for enhancing students' initial conceptualization of the cases. Regarding the importance of in-class discussions, Alex mentioned ideas related to considering other perspectives and backing up your opinions. She stated that:

I think the most helpful for me was the in-person class discussions. It was not only giving you the opportunity to share your point of view, but to hear others' points of view. And it also helped with the social skills of just being able to have a conversation and being able to back up opinions while still respecting other people's opinions.

Erica also shared this developing social skills feature and mentioned ideas related to hearing and respecting other points of views. She appreciated discussions as a learning experience and stated that:

> *I also like the discussion in class because I get to hear other points of view that are not necessarily my own and that's always a learning experience in itself. I guess seeing where they're coming from and being able to like respect what they're saying. Yeah, I feel like the discussions in class and the online posts that we made were both very helpful.*

Kyla mentioned that having online discussions was helpful in summarizing her initial opinions and feelings, and preparing for in-class discussions. She stated that:

> *Well, for me specifically, online discussions were kind of forced you to actually read the entire case before class because I think without that, a lot of us, we would have just came – just skimmed over the case and then talked about it. And so I thought that was good to add what I was thinking and my summary of kind of what I feel about it, like all the discussion questions to talk about, and then being able to talk with the group was good...*

On the other hand, similar to Alex and Mary, Kyla mentioned that she appreciated in-class discussions more than online discussions and shared that:

> *[being able to talk with the group was good …] That was probably my favorite part, I didn't really care as much talking online about it necessarily, it was still good but I caught myself just kind of catching the limit of it: I have to comment on two [*peer's post*]. Instead of in class where you're just talking and it becomes a discussion. So that was probably the most helpful for me.*

These excerpts suggested that participants enjoyed the in-class discussion activities more than online discussions because they were able to hear all of their classmates' opinions, and it was a more active learning experience. However, they also expressed their appreciation for online discussions and stated that they found online discussions beneficial for several reasons. For example, Kyla stated that *"I guess backtracking, online discussions was good for me to write a post because it was good for me to formulate my thoughts, so that was like probably initially the best thing."* Thus, I concurred that even though participants expressed that they favored in-class discussions, they were able to identify the importance of having online discussions. Erica also shared that:

> *I really liked the online discussions and that I had some specific questions at the end of each case that were like concentrate on these for reflection. I think that helped guide my thinking… even if I might have been stuck at the beginning on how to get my words out. I think that was nice.*

This excerpt suggested that online discussions were important in helping the prospective teachers prepare for classroom discussions and written reflections. Mary also elaborated on this idea and stated that:

> *I like the online discussion, just posting and having to not only read it and think about your answer but actually physically type out the answer and how you are thinking about it, it kind of made me further my thoughts before classroom discussions. So I enjoyed the online discussion and it did make you really think about what you were going to say later.*

Other participants also shared that writing the online discussion posts helped them to formulate their thoughts and further their opinions in their posts or reflections. One of the participants shared the following excerpt in her first SSI case reflection:

> *Having the online discussion really did help and like being encouraged to explore more and look up other articles that pertain to this case that could also help support your*

argument. I feel like without that, discussion may not have been as stimulating or interesting because no one would have gone out of their way to explore more upon this case.

These findings suggest that participants viewed their experiences with discussion activities as beneficial and important for several reasons, and appreciated having both online and in-class discussions. The difference between the level of primary participants' online discussion posts and reflections papers also suggests that discussions were helpful in promoting prospective teachers' conceptualization of SSIs.

Triangulation of Findings for Research Question One

All primary participants of this study had the highest scores for three of the four aspects of SSR; (1) complexity; (2) perspectives; and (3) inquiry in their post-SSIQs. Their scores for the skepticism aspect showed a difference in terms of their post-SSIQs. A summary of findings for research question one from all data sources in relation to each participant is presented in this section (See Table 4.12 for a summary).

As mentioned earlier Alex had no experience with socio-scientific issues before this class, however her pre-SSIQ scores were high compared to her peers (Complexity: 3, Perspectives: 4, Inquiry: 3, Skepticism: 3). Only two students were able to assess the issue from multiple perspectives in their responses to the pre-SSIQ, and Alex was one of them. Her ability to consider multiple perspectives was also evident even in her first online discussion post. Her second SSI case reflection was categorized as the highest level (Level 4) for the perspectives aspect and as Level 3 for other aspects. She was also able to improve her scores on the post-SSIQ (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 4).

Table 4.12

Summary of Findings for Research Question One

Participant	**Data Source**					
	Pre-SSIQ*	Post-SSIQ*	SSI Case 1 (Zika Virus)**		SSI Case 2 (Genetic Testing)**	
			Online Discussion	Reflection	Online Discussion	Reflection
Alex	C3P4I3S3	C4P4I4S4	T1C3U0P3	T2C3U2P3	T2C0U1P1	T3C3U3P4
Erica	C2P2I3S3	C4P4I4S1	T2C1U1P2	T3C3U4P3	T2C1U0P4	T4C3U2P4
Kyla	C4P3I3S3	C4P4I4S4	T3C3U4P3	T4C4U4P4	T4C1U1P4	T4C4U4P4
Mary	C4P3I3S1	C4P4I4S3	T2C1U2P2	T3C3U3P3	T1C1U1P1	T4C3U3P4

* For SSIQ, letters indicate SSR aspects, numbers indicate levels: Complexity (C), Perspectives (P), Inquiry (I), and Skepticism (S) (e.g., C3 indicates Complexity Level 3).
** For SSI Case 1 or Case 2, letters indicate categories, numbers indicate levels: Topic (T), Controversy (C), Uncertainty (U), and Perspectives (P) (e.g., T4 indicates Topic Level 4).

Supporting Erica's high post-SSIQ scores for all aspects except the skepticism (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 1), her second SSI case reflection was categorized as the highest level for the topic and perspectives aspects (Level 4), Level 3 for the controversy aspect and Level 2 for the uncertainty aspect. It was interesting to see that the level for the controversy aspect stayed the same in both of her case reflections (Level 3) but the uncertainty aspect was higher in the first reflection.

Erica's low level of the uncertainty aspect may also possibly be explained by her insufficient background knowledge with respect to the second case. She shared that she did not know anything about the issue (e.g. PGD, IVF) and thus she conducted research on the topic. Since the first case was very current during the time of implementation, she was able to find conflicting information on the internet; and thus she was able to identify implications and reasons for uncertainty. However, it appeared that, Erica spent more effort on understanding the basics of the second case issue and could not develop her understanding of the uncertainty aspect.

Kyla also had high scores in the pre-SSIQ (Complexity: 4, Perspectives: 3, Inquiry: 3, Skepticism: 3), and her conceptualization of all aspects of the topic was evident and comprehensive even in the first online discussion and case reflection. She was also able to improve her scores on the post-SSIQ to highest levels for all aspects (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 4).

Mary's pre-SSIQ scores were higher than the average of the classroom for all aspects of SSR except skepticism (Complexity: 4, Perspectives: 3, Inquiry: 3, Skepticism: 1). Supporting her high scores for the complexity and perspectives aspects in pre-SSIQ, Mary was able to identify several aspects of the topic (e.g., complexity, relevancy, affecting different people) and assess the issue from multiple perspectives even in her first SSI case reflection. She also extended her conceptualization of these aspects in her second SSI case reflection. Her levels for the uncertainty and controversy aspects stayed the same in her both SSI case reflections. However, she was also able to improve her scores on the post-SSIQ to higher levels for all aspects – even for skepticism (Complexity: 4, Perspectives: 4, Inquiry: 4, Skepticism: 3).

Participants' low levels of conceptualizations for all aspects in online discussions posts compared to reflection papers supported the idea that in-class discussions were more effective in supporting their conceptualization of SSIs. All primary participants explicitly expressed that they found classroom discussions as the most valuable learning activity since they were able to hear their peers' perspectives and evolve their initial ideas of the cases. Difference between the levels of online discussions and reflection papers will be discussed in Chapter 6.

Findings suggested that all primary participants presented a more comprehensive conceptualization of SSIs in their second SSI case reflection and improved their scores in post-SSIQ after engaging in the activities. Key findings for the first research question regarding the extent the CBLe influences prospective elementary teachers' conceptualization of SSIs can be summarized as follows:

- Prospective elementary teachers in this study had lower conceptualizations of inquiry and skepticism aspects in their pre-SSIQs and of controversy and uncertainty aspects in their SSI case online discussions and reflections.
    - » Developing the conceptualization of these aspects are more difficult compared to developing perspectives and complexity aspects.
- Prospective elementary teachers started with lower conceptualizations for all aspects in their online discussion posts.
    - » In-class discussions were more effective in supporting prospective teachers' conceptualization of SSIs.

Chapter 5 presents the results related to the second research question: To what extent does CBLe influence prospective elementary teachers' conceptualization of SSI-based teaching?

CHAPTER 5

FINDINGS: CONCEPTUALIZATION OF SSI-BASED TEACHING

The purpose of this study was to (a) develop a feasible design framework for a case-based learning environment that incorporates cases related to socio-scientific issue-based teaching and learning and (b) apply the model to enhance prospective teachers' conceptualization of socio-scientific issues and SSI-based teaching in a science methods course for elementary education.

The inquiry in this study focused on this overarching question: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching? This chapter reports the findings of the second research question: To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSI-based teaching?

The second question included three sub-questions. The first sub-question explored how the participants' conceptualization of SSI-based teaching evolved during the pedagogy case activities. For this sub-question, I analyzed primary participants' online discussions and reflections to the pedagogy cases. Their answers to related interview questions also provided triangulated data for the exploration of this research question.

The second sub-question explored how the participants translated their understanding of socioscientific issue-based teaching into planning after experiencing CBLe. Primary participants' instructional resource design reflections and their answers to related interview questions provided triangulated data for the exploration of the second sub-question.

The third sub-question explored how the participants perceived the value of CBLe on their conceptualization of SSI-based teaching. The findings for these sub-questions are presented in the following sub-sections.

Research Question 2.1: Conceptualization of SSI-Based Teaching during the Case Activities

To explore how the designed case-based learning environment enhanced prospective teachers' conceptualization of SSI-based teaching, participants' online discussions and reflection papers for the pedagogy cases, which incorporate dilemmas of socioscientific issue-based teaching, were analyzed inductively. Two reflection papers of each primary participants (n=4), considered units of analysis, were categorized in a category system built from the reasons to teach SSI included in the literature (Espeja & Lagarón, 2015) in addition to others emerging from data. Findings from primary participants' online discussion posts and reflections for the pedagogy cases are presented in the following section.

Findings from Primary Participants' Online Discussion Posts and Reflections for the Pedagogy Cases

Alex. Alex engaged in all activities for the pedagogy cases, including the online discussions, classroom discussions, and written reflections. Her conceptualization of SSI-based teaching as reflected in her discussions and reflections are presented in the following sub-sections.

The first pedagogy case. I included the first pedagogy case with the purpose of providing an opportunity for prospective teachers to experience the analysis and discussion of a case, including challenges of SSI-based teaching. Prior to the class meeting, the prospective teachers read the case which depicts a first year elementary teacher who attempts to make science instruction relevant to her students' everyday lives by having them debate a question: Should old-growth forests be logged for their valuable timber or should logging be stopped to preserve the habitat of the spotted owl? (see Appendix C3).

Online discussion. In her online discussion post, Alex was able to identify some apparent purposes for teaching SSIs (i.e., making science more relevant) but she also shared some negative opinions about integrating a controversial topic that is too relevant to students' lives. She stated that:

> *In my opinion, I would not continue with the debate, because I think that the topic that she choose to talk about is too relevant to the community. I am supportive of debates in the classroom however when a topic comes this close to home and is already controversial in the community, it may be difficult to conduct a debate in the classroom without negative input from parents and the community.*

However, she also shared a pedagogical strategy to avoid this challenge and mentioned that:

> *I think that the conversation of this topic and lessons surrounding it could happen in the classroom, but a debate may not be smart with this lesson. If Sandy decides to go on with the debate, I think parents should be allowed to watch the debate, as long as they do not comment or object while the students are talking. If they have problems, they should be allowed to discuss them with Sandy before and after the debate.*

Alex elaborated further on her idea of not having a debate and identified another reason for teaching this topic (being informed about current issues) as she was responding to a guiding question for the online discussion,. The question was framed as follows: *"Some people in communities in Oregon and other Northwestern states believe that the spotted owl controversy is* *not science and should not be debated by students in elementary science. Do you agree or disagree? What are your reasons?"* Alex stated that:

> *I would not go so far as to not call it science. I think that any topic involving animals or any other topic in a science curriculum would be considered science. I think that students not in the class who have become interested about the spotted owl debate should be required to investigate the topic further so that they are informed about an issue in their community.*

This excerpt suggested that Alex identified the purpose of learning science and also mentioned one more idea related to the making science more relevant category (e.g., learning the topics that are relevant for them).

<u>Case reflection paper.</u> In her case reflection, Alex demonstrated an expanded understanding of strategies that could be used to teach this issue and shared a deepened understanding of the purposes of teaching SSIs. She suggested an alternative end-task and mentioned several ideas related to developing higher order thinking skills (HOTS). Thus, I categorized her reflection as Level 2. She stated that:

> *I think that learning about the spotted owl is a relevant and age appropriate lesson for the class to learn, but the final assessment for the lesson does not have to be a debate. Debates on these kinds of topics help students to think critically and consider other's opinions, however with a topic this close to home, a better option to end this unit may be having the students write an opinion piece about either saving the local economy or saving an endangered species.*

These issues were all brought up in online and classroom discussions and Alex was able to elaborate on these ideas in her reflection. One other issue we discussed in class was the length of the unit. Many of the students thought that creating such a lesson was too time-consuming and may not be feasible in their future classrooms. Alex was also able to connect this issue to her own learning experiences and suggested the idea of creating an integrated curriculum which is compatible with one of favorable features of SSI-based teaching and relates to the making science more relevant category. She shared this experience as follows:

> *As part of our EDEC class, I took a trip to visit an alternative school [name of the school is deleted]. At this school, the students choose a topic that they would like for their unit to be focused on. The teacher then creates integrated lessons for a three to five-week unit on that topic. If Sandy developed her unit in this way and integrated the spotted owl conversation with other subjects, I would be more supportive of such a long unit.*

However, Alex was not capable of identifying other purposes of teaching SSIs (e.g., learning of science or learning about science). Thus, her reflection was categorized as Level 2.

The second pedagogy case. The second pedagogy case dealt with ethical treatment of animals in the elementary classroom. The purpose of this session was for prospective teachers to experience the analysis and discussion of a case dealing with a controversial issue and reflect on how to turn this into an SSI-based teaching activity. Prior to the class meeting, the prospective teachers read the case, which featured a story about a fifth year elementary teacher who faces a number of dilemmas when the lobster cookout he planned for the end of his oceanography unit takes an unexpected turn (see Appendix C4).

<u>Online discussion.</u> This was the last case activity where the prospective teachers were expected to engage in online discussion and develop a written reflection. Accordingly, I kept guiding questions as open-ended as possible. Some of the participants (e.g., Kyla) were able to give details about their conceptualization of SSI-based teaching on their discussion posts but

many students required more guidance to focus on how to turn the lesson into an SSI activity. Alex was one of them, thus she did not mention much about this on her online discussion post. She only stated that *"this case could be transformed into a more socio-scientific based activity by discussing where more of our food comes from and discussing whether or not our food is being prepared humanely."* However, she did not identify purposes of teaching SSIs.

Case reflection paper. Alex did not develop a detailed reflection paper for the second pedagogy case. She was only able to identify one idea related to the making science more relevant (e.g., being connected with real world) and one idea related to learning of science (e.g., understanding scientific information) in her reflection for the second case. She concluded her reflection as follows:

> *Instead of a debate, by using this end of unit time as a reflection of what the students have learned and a call to socio-scientific action, the class time would be much more beneficial to the student's understanding of the importance of this lesson in context with their life. Students should understand after the lesson is concluded that every species in and out of the ocean is critical to the survival of any other species.*

Accordingly, I categorized her case reflection as Level 2. Alex improved her understanding after the example SSI-based teaching activity (edible insects) and the experience of designing her own instructional resource. She was able to mention several ideas related to all categories in her instructional resource design reflection and during the interview. These findings will be presented in the Research Question 2.2 section.

Erica. Erica engaged in all activities for the pedagogy cases, including the online discussions, classroom discussions, and written reflections. During the interviews she shared that reading these cases helped her to prepare for future challenges. While she was describing her experiences with the case-based learning activities, she stated that:

> *I think they were very interesting. Some of them were very like local to the area, like the spotted owl case; we wouldn't necessary have that issue here, but that would certainly happen with other species of animals that could be going extinct versus popular industry in our area. I think they're relatable in the sense that we could be challenged with something similar. So I feel like that was really helpful, just like for preparation sake and just having more knowledge about that.*

Aligned with her positive opinions about the cases, she developed comprehensive online discussion posts and reflections for the pedagogy cases. Her conceptualization of SSI-based teaching as reflected in her discussions and reflections ae presented in the following sub-sections.

The first pedagogy case. As stated earlier, Erica's reflections on how to teach SSIs were rather limited in her reflections on the first two SSI cases. Unlike Alex, she did not share any details about her understanding of the purposes of teaching SSIs until the first pedagogy case online discussion post, as presented in the next sub-section.

Online discussion. Erica's online discussion post was marked as the most comprehensive post in my memos during the analysis. She was able to identify different purposes for teaching SSIs related to all categories. She started in her online discussion the following:

> *I believe that Sandy thinks the students will learn the importance of being scientific literate and the importance of seeing multiple perspectives of issues (controversial or not). I think the debate should take place as planned because I feel it's a valuable learning experience for the students (as well as the parents).*

This sentence suggests that Erica was able to mention one idea related to the learning about science (e.g., scientific literacy) and one idea related to HOTS (e.g., ability to consider multiple perspectives) even in her first sentence about the case. She was the first participant who mentioned the idea *"confronting the uncertainty of scientific knowledge"* which relates to learning about science category. She stated that:

> *I realize it's a controversial debate and a topic that quite literally hits home. There will eventually be a point in your life where you will have to make a hard decision, a point where you've got to weight the benefits with possible consequences and make a judgment call.*

This excerpt suggested that Erica was able to identify the reason of "*making science more real and practical to integrate science content in the social context"* which relates to the learning of science category. Moreover, she mentioned one more idea related to the making science more relevant category such as *"connecting with other subjects"* (i.e., integrated curriculum) and provided more details than Alex. She stated that:

> *The students will have the opportunity to learn more about logging and the spotted owl (more than they already know from home/their community), they will develop important learning strategies related to research and will hone their skills/knowledge in areas like debate/formulating opinion pieces, vocabulary, writing, science literacy, history, not to mention valuable social skills like patience, empathy, respect, and tact.*

In the excerpts above, it is evident that Erica was able to identify all main purposes of teaching SSIs (i.e., making science more relevant, development of HOTS, learning of science and learning about science); therefore, I categorized her discussion post as Level 4. Erica also shared many positive opinions about the importance of having these kind of learning activities and strategies in her online discussion post.

Case reflection paper. Erica's reflection paper included almost the same information as her online discussion post. I believe that this was because she developed a very detailed post and did not change her ideas after the classroom discussion. The only idea she mentioned that reflected the evolution of her thinking is illustrated in the following excerpt:

> *In my original discussion post, I said that since the students had been working on preparing for this debate for such a long amount of time, I thought it should continue with some ground rules… After listening to my peers discuss this issue in class, I still believe some sort of dialogue or discussion should be had about the issue but I am no longer 100% confident that the debate is the right way to go.*

Erica shared strategies for fostering a dialogue rather than debate, in part due to the nature of the classroom discussion on this issue. She even identified an additional idea related to learning of science (e.g., engaging in authentic scientific practices) and created some questions to encourage students research such as "*What would we do if we logged all of the forests nearby?" "What would our community look like if we did not have the logging business?" "Besides people losing jobs, what else might happen if logging was no longer allowed near our community?"*

Erica's online discussion post included ideas related to all main purposes of teaching SSIs, and she shared an additional idea related to learning of science in her reflection. This was the first instance in which a prospective teacher had the highest level of conceptualization in her online discussion post and did not change the nature of her written response in the reflection paper.

The second pedagogy case. Similar to the first pedagogy case, Erica did not change her written reflection too much from her online discussion post. However, she developed a less comprehensive post compared to the one she developed for the first pedagogy case. This might be related to her general reflection on the instructional model that she shared during the interview. She shared that she found writing the reflection papers "*a little repetitive*" and added that: "*I felt like I had already said everything that I needed to say in between the discussion we had in class and the original discussion post. I felt like I had already exhausted everything.*"

Moreover, this was the last case activity and it was designed to be very open-ended in nature. Thus, the prospective teachers needed to define an SSI and design a short activity based on this issue. Erica was able to choose a related topic but she did not include any details about the purposes of teaching SSIs in her online discussion post. Her conceptualization of the case is presented in the following sub-sections.

<u>Online discussion.</u> In her online discussion, Erica stated that "*I would try to turn this lesson into a socio-scientific issue centered on animal rights by asking students what they knew about human rights and animal rights.*" Although, animal rights is a suitable topic for turning the lesson into an SSI activity, she did not include any details about what she aimed to teach through this issue.

She also shared some age-appropriate resources but did not designed an active learning experience. She simply mentioned that "*PETA has great age-appropriate resources (literature and videos) that can be shown to students, as well as The Humane Society.*"

<u>Case reflection paper.</u> Erica elaborated on her idea of choosing the topic of animal rights, and identified some purposes for teaching about this issue in her case reflection. She stated that:

One aspect of animal rights that you can choose to bring into your classroom is ethically raised meat (wild-caught, grass-fed, etc.). This concept could spark a discussion on how many people think it is okay to consume meat if we are treating it the right way (including raising animals and the process we go through in killing them).

In the excerpt above, Erica was able to mention one idea related to HOTS (e.g., the ability to consider a wide range of perspectives). She also discussed the importance of hearing students' feelings and stated that:

I think it is important to hear how each student feels about this issue so I would give them time to express their concerns and questions and research them as a class or give small groups questions to be in charge of answering. I think a critical part of this lesson is to give them the truth but in a way that is not all blood and guts, and for them to be able to form their own opinion about consuming animals.

In the excerpt above, Erica mentioned ideas related to learning of science such as providing opportunities with doing research and forming opinions based on *truth* (i.e., understanding and articulating scientific information). She did not mention any ideas related to other categories in her case reflection, thus I categorized her second pedagogy case reflection as Level 3.

Kyla. Similar to Erica, Kyla's reflections on how to teach SSIs were rather limited in her reflections on the first two SSI cases. She did not share any details about her understanding of the purposes of teaching SSIs except the following excerpt that she wrote in her first SSI case reflection (Zika Virus case):

I hope that I can teach my students to think about different perspectives and options when controversial topics come up. A lot of times there is not a wrong decision, but just *different perspectives. I am quickly learning that with any decision you make, there will always be a cost.*

Based on this statement, I interpreted that Kyla was able to identify one idea related to HOTS (i.e., ability to consider different perspectives) at the beginning of the semester, after our first case-based activity. However, she did not have a profound conceptualization of SSI-based teaching.

The first pedagogy case. During the interview, Kyla shared that the *Lobster case* (the second pedagogy case, see Appendix C4) was her favorite. She stated that:

> *I really liked the lobster one because that one probably is what I got the most out of because it challenged me to think about even just the activities I'm doing and how I'm treating animals and then treating your students. I mean, they could be vegetarians, all these different things, and you should know your students. So that one was probably the hardest for me to figure out, but I really enjoyed that one.*

Supporting her appreciation of the pedagogy cases, Kyla developed comprehensive online discussion posts and reflections for both of the pedagogy cases, especially for the second one. Her conceptualization of SSI-based teaching as evidenced in her discussions and reflections are presented in the following sub-sections.

<u>Online discussion.</u> Kyla was able to identify two purposes for teaching SSIs in her online discussion post. She supported the idea of revising the debate activity and provided suggestions to solve the problems highlighted in the case. Kyla expressed the importance of not making students uncomfortable and thus providing an option to attend to the debate. But, she also emphasized the importance of discussing the issue and suggested that students should "*write an*

opinion piece about the side they were supposed to defend" if they chose not to attend to the debate. She stated that:

> *I think that the children need to be able to think for themselves and develop their own opinion (separate from their parents). Debating or talking about this issue scientifically using facts will help them form that opinion.*

This excerpt suggested that Kyla was able to mention one idea related to HOTS (e.g., creating their own ideas). Throughout her online discussion post, she suggested ideas to change the debate activity and she identified another idea related to HOTS (e.g., ability to consider different perspectives) and one idea related to learning of science (e.g., engaging in authentic scientific practices). She stated that:

> *A way that Sandy could have eased the tension between the either-or issue is to explain that it was not the logging industry vs. the spotted owl but really a discussion and awareness about the cause and effects between two different things. We must, like scientists, discover and observe all perspectives to piece the whole story together and understand deeper. We talk about in class that science starts in the classroom. Science is observation, discovery, and can sometimes deals with controversial topics.*

Therefore, I categorized Kyla's online discussion post as Level 3.

Case reflection paper. Kyla did not add new ideas related to the learning about science category in her case reflection but she discussed more fully her conceptualization of other categories that she mentioned previously in her online discussion post.

She elaborated on the idea of *developing their (students) own ideas* that she mentioned in her online discussion post. She stated that:

> *I am a huge believer of teaching children to think for themselves. That is why I think students should be exposed to controversial topics without their parent's opinion being involved. It is so important for students to think for themselves and be able to learn about the World around them from different perspectives.*

There were several ideas Kyla emphasized in this statement. She identified one idea related to making science relevant (e.g., understanding world around them) and HOTS (e.g., ability to consider different perspectives). She also elaborated on her idea of *science starts in the classroom*, and added *"I would much rather have children talk about controversial topics in a safe place where it is regulated and based on self-discovery and facts instead of on the playground with someone's random opinion."* She concluded her reflection in a positive manner and she was the first participant that mentioned the idea of *challenging students' thinking* in relation to HOTS. She stated that:

> *This case has taught me that as a teacher I need to be strategic on how I bring up controversial topics, but I should by no means try to avoid them. I shouldn't try to force children to participate in something that would make them feel uncomfortable, but I can challenge them to step out of their comfort zones and help them see from other perspectives.*

Since Kyla did not mention any ideas related to learning about science, I categorized her reflection as Level 3. She was able to include all of these ideas in her second case reflection when she was discussing how to turn the lesson from the case into a SSI activity.

The second pedagogy case. As stated earlier, the second pedagogy case (i.e., the lobster case) was Kyla's favorite one. The analysis of her online discussion post and reflection paper for this case are discussed in the following sub-sections.

Online discussion. As stated earlier since this was the last case activity, the case did not include an explicit SSI but the prospective teachers were expected to turn this lesson into an SSI issue-based activity. Kyla's interest in the problems depicted in the case was very high and she wrote a very detailed online discussion post. Her analysis of the case was exemplary, thus I find it worthy to share here:

> *Although I agree that having a "Lobster Cookout" funny way to end a Marine Life Unit, I think it is inappropriate. I can understand his educational intention with this cook out was to tie in how marine life affects our economy, but why would you cook a live animal in front of your students? Our students come from all types of backgrounds. Some may be vegetarians and believe in no animal cruelty and others may be sons and daughters of hunters who kill animals all the time. The point is that we must leave our choice of how we treat animals outside of the classroom. Who knows! Because of this, I don't think that Stan should continue with the Lobster cookout.*

She was also able to share ideas on how to turn this lesson into an SSI activity in her online discussion post. Kyla was not able to mention any ideas related to learning about science in her first pedagogy case reflection or online discussion, but she included an idea related to this category (e.g., a research activity to make her students use scientific facts) in this second activity. She stated that:

> *This situation does open up a discussion that the students can have about animal rights. You can set up the class to research more about animal rights and if there should be directions and use of animals for educational purposes. Stan could give the students time to make a poster of what they think throughout the week with their informational facts.*

Kyla also mentioned the idea of the ability to consider different perspectives, as she did in her first pedagogy case reflection. She stated with the help of the designed activity "*each student gets a chance to be heard and each student gets to hear other sides of the story and learn about what their classmates think.*"

However, she was not able to mention other ideas related to making science more relevant or learning of science. Hence, I categorized her online discussion post as Level 3.

Case reflection paper. In her case reflection, very similar to her first pedagogy case reflection, Kyla did not add new ideas related to categories that she did not include in her online discussion post. However, she deepened her conceptualization of other categories that she mentioned in her online discussion post. She elaborated on the idea of *doing research* that she mentioned in her online discussion post.

Kyla designed an activity about *animal cruelty (especially in the food business)* in detail and gave resources to use. As she was describing purposes for teaching this SSI-based activity, she mentioned many ideas such as challenging students' own beliefs and attitudes (HOTS) and engaging in authentic scientific practices (learning of science). She stated that:

> *I also think this would be a good project for students to do because it will help them be independent from what they have grown up knowing either from their parents or what they learn from society. Talking about animal cruelty in the classroom is not inappropriate because Stan is giving his students room to form their own facts and opinions and he is creating scientists who will explore and discover the topic together and independently.*

Kyla also elaborated on ideas about how to enhance students' ability to consider multiple perspectives and suggested having students create a poster museum showing different perspectives on the main issue. She did not create any ideas related to making science more relevant but she mentioned ideas related to all other categories (i.e., HOTS, learning about science, learning of science). Accordingly, I categorized her second pedagogy case reflection as Level 4. She was also able to mention several ideas related to all categories on her instructional resource design reflection and during the interview. These findings will be presented in the Research Question 2.2 section.

Mary. As stated earlier, Mary shared during her interview that the current and relevant nature of the Zika Virus topic inspired her as a teacher to discuss these issues in the future. This was evident in her reflection on the case in which she stated that:

> *I really enjoyed this case study (Zika Virus) and would definitely like to implement a similar task into my future classroom. It is so important to teach students how to think critically about a topic and then how to defend their own position. SSIs would be a brilliant way to keep students up to date on current issues while developing these critical thinking skills. And hopefully introducing some fun class discussions into our classroom environment.*

This excerpt suggested that Mary was able to identify purposes for teaching SSIs (e.g. being informed about current issues, critical thinking) even in the first case activity. She improved her understanding of SSI-based teaching throughout the activities and identified more reasons in her pedagogy case reflections that are discussed in the following sub-sections.

The first pedagogy case. Similar to Kyla, Mary shared positive opinions about the second pedagogy case during her interview but did not mention her experiences with the first pedagogy case explicitly. However, she was able to identify several purposes for teaching SSIs in both of her reflections that are presented in the following sub-sections.

Online discussion. Unlike other participants, Mary did not develop a detailed online discussion for the first pedagogy case. On the other hand, she was able to identify purposes such as doing research and backing up opinions with scientific facts in her post while she was analyzing the problem of the case. She also suggested a solution to the problem and stated that:

> *I do not think the debate should go on as planned. I think the students have learned the goal of scientific research. I just feel nothing good can come out of the debate at this point in the class. I would assign the students to write a persuasion paper using scientific facts to back which ever opinion they choose now that they have extensively researched both sides of the debate.*

Mary provided ideas related to the learning of and about science categories in this excerpt but she did not provide any other ideas related to the making science more relevant or the higher-order thinking skills. Accordingly, I categorized her online discussion post as Level 2.

Case reflection paper. Mary demonstrated her improved understanding of the purposes of teaching this issue in her case reflection. She elaborated on the idea of changing the debate assignment to another activity such as writing a persuasion paper. She stated that:

> *My suggestion would to be to let the students create a poster, technology (power point), tri board or write an opinion piece describing their view on the debate of the Spotted Owl and its receding habitat. By changing the assignment in this way, it allows students to become informed on a local topic, had them conduct research in order to defend their opinion scientifically but they do not have to share this opinion aloud if they choose not to. By allowing them the choice on how they choose to present their argument they are showing their content knowledge but in a safe space.*

This excerpt suggested that Mary was able to identify purposes related to different categories such as making science more relevant (e.g., being informed about current issues), learning about science (e.g., learning how to defend opinion scientifically), and learning of science (e.g. understanding and articulating scientific information). I categorized her case reflection as Level 3 since she did not mention any ideas related to the developing higher order thinking skills category.

The second pedagogy case. Mary shared during her interview that the second pedagogy case made her think about how to bring controversial issues into her future classroom. She stated that:

> *The lobster one was helpful in the way that you're trying to do a fun activity at the end and you're maybe creating the socio-scientific issue by not realizing what issue you may be bringing up in your class… So I think that that one just made me think about how to bring it into the classroom and how to deal with it if you accidentally bring it into the classroom, if that makes sense.*

She shared some appropriate pedagogical strategies to solve the problems depicted in the case in her online discussion post and developed a comprehensive reflection paper including suggestions to turn the lesson into an SSI activity. The analysis of her online discussion and reflection paper are discussed in the following sub-sections.

<u>Online discussion.</u> As stated earlier, some prospective teachers needed more guidance on how to turn the lesson into an SSI-based activity to address the problems depicted in the case. Mary was one them thus she did not share any ideas on how to change this lesson into an SSI-based activity. However, she shared many pedagogical strategies to address the problems depicted in the case. About the lobster-cookout, she stated that:

I definitely do NOT think Stan should go on with his lesson as planned. If I were Stan I would go turn off the boiling water and re direct the student's attention to the front of the room. When I had gotten the classes attention once again I would explain to them that our new Lobster friend will actually just be a guest in our classroom for the day and I would love if we could all come up with a name for our new friend just after we read a story.

Although Mary did not include any suggestions related to SSI-based teaching, she was able to create one of the most comprehensive reflection papers for the case after additional guidance. The analysis of her reflection is presented in the next sub-section.

Case reflection paper. First of all, Mary was able describe how to turn the lesson into an SSI activity in her case reflection paper. She stated that:

I would begin by having students discuss their feelings towards cooking the lobster for food. I would write all of the opinions or thoughts on this topic down onto the board. After the discussion I would ask students what they would possibly like to know more about on this topic. I would question animal's rights, overpopulation and human's dietary needs.

When she was explaining her hypothetical activity, Mary was able to identify one purpose related to learning of science (e.g., understanding and articulating scientific information) and one purpose related to HOTS (e.g., challenging their own ideas). She stated that:

After briefly discussing a few sides to how people may view this topic I would allow the students some time to see if they could locate any information on their curiosities on the topic online. After allowing a specified time on research I would big the group back into *a group discussion. I would ask if any of their research changed their mind on the topic or if they discovered any new information they would like to share with the class.*

Furthermore, she mentioned ideas related to learning about science (e.g., learning how to use scientific knowledge) and making science more relevant (e.g., being connected with real-life topics) categories.

After another discussion I would send students to their desk and ask them to write a letter to anyone involved in the issue. The letter could be to fisherman, to consumers, to the lobster, etc. In this letter I would like to see their view on their chosen topic expressed and backed with scientific facts. This activity will help the students be more informed on animal rights or on the reasons people consume/ hunt animals.

Mary mentioned at least one idea related to all categories so I categorized her case reflection as Level 4. Moreover, she finished her reflection with a very positive attitude towards using SSIs in the classroom. She stated that:

There are many socio-scientific issues that could stem from this lesson that could positively benefit the class and help them to become more informed citizens on a particular topic. Socio scientific issues can be found in the most unlikely places within a classroom if the teacher is always keeping an open mind and looking learning opportunities.

Even though Mary did not create detailed online discussion posts for the pedagogy cases, her reflection papers included different ideas related to all categories. Mary had a simple conceptualization of SSI-based teaching at the beginning of the semester, she briefly mentioned ideas such as being informed or developing critical thinking skills in her first SSI case reflection (i.e., Zika Virus) and did not include any ideas related to teaching in her second SSI case reflection. However, she was able to identify different purposes for teaching SSIs in her first pedagogy case (Level 3) and she even furthered her understanding in her last reflection paper (Level 4). She was also able to mention several ideas related to all categories in her instructional resource design reflection and during the interview. These findings will be presented in the following section.

Research Question 2.2: Translation of Understanding into Planning

To explore how prospective teachers translated their understanding of SSI-based teaching into planning, I integrated a concluding activity after they completed all case activities. Session 6 was devoted to this planning activity (see in Learning Activities section in Chapter 3). Participants developed an instructional activity for an SSI topic in groups and wrote individual reflections on their designs. As mentioned earlier, each group presented their instructional resource design in class and students voted to choose the *"best instructional resource design"*. All primary participants of this study were members of the group whose design was voted as the best by the instructor and students of the course. I will present findings from primary participants' reflections in the following sub-sections.

Findings from the Primary Participants' Instructional Resource Design Reflections

Alex. In her instructional resource design reflection, Alex was able to mention ideas related to the making science more relevant category such as being informed about current issues and connecting science with other subjects. She explained that they chose their topic because of its current and relevant nature. She stated that:

> *In our Instructional Resource Design, my group decided to discuss the current issue of flooding and flood safety. For this lesson, we will talk about past floods, like New Orleans experienced in Hurricane Katrina, current floods, like Savannah experienced in*

Hurricane Matthew, and floods in general. Our lesson on flooding allows the students to create a hands-on environment in which they can simulate a flood and decide what measures would best protect the landscape that they created.

Alex was able to identify the purpose of creating an integrated curriculum even in her first pedagogy case reflection. Supporting her conceptualization of this purpose, she explained how they applied this in their design and stated that "*This active experience merges the science lessons about geography, weather, and natural disasters with a social lesson about current events and the measures that we as humans can take to educate and lesson the devastating effects of flooding."*

The group was able to connect the lesson design to standards related to teaching scientific information (learning of science). All of the participants shared the standards and discussed how they related to the design. Alex stated this connection as follows:

> *Our socio-scientific lesson directly correlates with the fifth grade Earth and Space science standard, S5E1. This standard states, "Obtain, evaluate and communicate information to identify surface features on the Earth caused by constructive and/or destructive processes." We focused specifically on part "c" of this standard which states, "Ask questions to obtain information on how technology is used to limit and/or predict the impact of constructive and destructive processes." When the students create their own landscape, they will also be paying attention to the features on the Earth that the water from the flood will flow through.*

Alex also mentioned how their design was intended to help students engage in authentic scientific practices (learning of science) and think critically about scientific information (HOTS). She stated that:

…the students will create their own miniature landscapes with their choice of flood control methods. The students will pour water into their landscapes, record their findings, and share with the class. The final portion of the lesson is where most of the social exploration will occur. The class will have an in depth conversation about why the flood control methods in New Orleans failed and how this disaster could have been prevented or reduced…

Alex explained that they also developed the design in a way that could help their students understand the importance of science in everyday life (learning about science). She explained this aspect as follows:

In our plans we created an exit slip as a form of assessment. This slip will account for any questions that the students still have regarding floods, and will lead into the next day's discussion which will address the roles that the students can have in aiding the devastation of Hurricane Matthew and how science can help us to prevent future disasters.

She had a striking end to her written reflection and shared many positive thoughts related to SSI-based teaching. She stated that:

Our lesson provides the students a chance to fulfill standards that are required for their grade level as well as staying informed about current issues. This topic, bringing news into the classroom, has been talked about throughout this course, and I have started to realize just how important it is to keep students informed. Contrary to some belief, children are very capable of discussing controversial issues, and it is the teacher's job to provide these opportunities.

In the excerpt above, Alex specified the importance of being informed about current issues and how the methods course helped her to think about this. She also demonstrated a positive attitude towards using SSIs with young students, later in her interview as well. Alex identified all main purposes of teaching SSIs (i.e., making science more relevant, development of HOTS, learning of science and learning about science) and explained how they were integrated into the instructional resource design; thus I categorized her reflection as Level 4.

Erica. In her reflection, Erica was able to identify several ideas related to the making science more relevant category such as being informed about current issues and understanding the world around you. She stated that:

> *This topic relates to society in that these measures affect the livelihood and safety of citizens living in areas prone to flooding. They should be knowledgeable about measures in place that are there to prevent flooding and/or manage it once it comes.*

Similar to all other participants, Erica explained how their design connected to standards and was able to identify purposes related to learning about science such as promoting scientific literacy and learning how to use scientific knowledge. She mentioned that:

> *This lesson ALSO connects to the Next Generation Science Standards in that it covers almost all of the Science and Engineering Practices that are laid out within the standards: "asking questions and defining problems", making and using models, planning and implementing investigations, interpreting data, "constructing explanations and designing solutions". We will also want our students to show how they obtain and communicate information.*

In addition to discussing the Next Generation Science Standards, Erica explained how other topics can be brought in to enhance learning of science. She stated that:

The water cycle can be brought into this discussion, even if it's not necessarily an aspect of the 5th grade standards. We also have to discuss flood control and management (levees, dams, storm drains, other flushing methods). These topics require principles of physics and engineering in order to better understand the devices and means in which prevention and flushing mechanisms operate.

In her reflection, Erica did not identify any purposes related to developing HOTS, thus I categorized her reflection as Level 3.

Kyla. Similar to Alex and Erica, Kyla described how they chose the topic, how they would start the lesson, and how the lesson would enhance students' understanding of scientific information at the beginning of her reflection. Regarding the learning of science category, she also explained their opening activity and how they designed it with the purpose of engaging their students in authentic scientific activities. She stated that:

To begin our lesson we showed a video all about floods…Then, we would provide different materials that the students could use to help stop the flood from happening. We would give them a little help, but we would let them experiment to find their own conclusions. After the experiment, we would explore what worked and didn't work and then add what we learned to our chart.

In terms of the learning about science category, similar to Alex, Kyla also mentioned the idea of understanding the importance of science in everyday life. She stated that:

I think talking about flood control and hurricanes helps students talk about serious issues that happen to people around them and might even directly affect them. Seeing videos of people's homes being flooded, or even swept away, is eye opening to a 5th grader to understand that science is more than doing experiments in class.

Kyla mentioned several ideas related to the making science more relevant category. For example, she mentioned the purpose of being connected with real-life issues and stated that "*Ultimately we want to connect what we learn to what is currently happening. It is our job as teachers to show how floods and other natural disasters affect our World."* Similar to Alex, Kyla pointed to the purpose of connecting science with other subjects (i.e., integrated curriculum). She shared that:

> *We learn about history in school, but very rarely will we talk about current events and how these events are affecting us now. Bringing in the topic of Hurricane Matthew brings in a relevant current event that is scientific and can also branch into social studies as well. If the students are really intrigued about this topic, we can even bring in math; research and calculate how many inches of water it takes to flood different areas with different geographical regions.*

She was even able to suggest other topics to further explore socio-scientific issues in her future classroom. She stated that "*After we do this lesson, we could even tie it into climate change and talk about whether or not humans are affecting these natural disasters as well as other climate issues like global warming."* This excerpt suggests that Kyla has the ability and enthusiasm to integrate SSIs in her future classrooms. Kyla also concluded her reflection with a very positive attitude. She stated that:

> *Overall our lesson is just the beginning of discovering a socio-scientific topic that can lead to many other discussions about the controversial and current events that are relevant to our students. We hope that our lesson inspires our students to be hands on with their learning, gain knowledge in current events, and have a lot of fun learning about science and real topics.*

In terms of the higher order thinking skills category, Kyla identified one generic idea in her reflection. She stated that "*Socio-scientific topics are more than just controversial issues, they are issues that should be discussed and left open-ended for the students to create their own beliefs, feelings, and opinions about."* Throughout her reflection, Kyla mentioned ideas related to all other categories (i.e., making science more relevant, learning of science, and learning about science) and explained how they were integrated in the instructional resource design. Accordingly, I categorized Kyla's instructional resource design reflection as Level 4.

Mary. Among all primary participants, Mary developed the most comprehensive reflection paper even though the group worked together and created the same instructional resource design. She first explained how and why they chose the topic and how it is a current and relevant topic (i.e., making science more relevant). She stated that:

> *When choosing a topic for this assignment we first began thinking about a socio scientific issue that has recently affect our lives recently. Very recently, many people were affected by Hurricane Matthew and many of our students had mentioned things to us about the hurricane in our placement classrooms. Our lesson fits the definition of a socio scientific issue because it would be socially relevant to our students because of the recent hurricane along the East Coast and it allows the students to explore political and economic aspects of flood control (especially pertaining to Hurricane Katrina).*

She explained that the group aimed to enhance their students' understanding of scientific information (i.e., learning of science) and nature of science (i.e., learning about science). She mentioned that:

> *Our lesson reviews the aspects of flood control, the reason flood control was not used properly for hurricane Katrina and allows students to explore how flood control could be*

used through a model project. During our lesson we challenge students to understand that science is tentative and scientific ideas are affected by the social and historical understanding.

Mary was the only student that explicitly talked about higher order thinking skills. She shared how they planned to challenge their students to think critically about a socio-scientific issue. She stated that:

> *In our lesson, by addressing the difficult issues such as "What else could the city of New Orleans done to minimize the damage of Katrina?" and then we further challenge them to apply the knowledge. We explore Hurricane Matthew, his damage and the precautionary methods people took in order to prepare for the storm. These questions challenge students to develop their higher order thinking skills.*

Mary explained more purposes that were included in their lesson related to the making science more relevant category such as being involved in community and being informed about current issues. She concluded her reflection as follows:

> *Finally, after the students have explored the topic in depth the students will be asked how they can be an active participant in the issues surrounding flood control or in the current devastation of Hurricane Matthew. Our lesson challenges students to not only connect information from the national curriculum but they are becoming more informed, well rounded global citizens through this lesson exploration.*

Mary identified all main purposes of teaching SSIs (i.e., making science more relevant, development of HOTS, learning of science and learning about science) that were integrated into their instructional resource design, thus I categorized her instructional resource design reflection as Level 4.

Research Question 2.3: Experiences with CBLe for Conceptualization of SSI-based Teaching

To explore how prospective elementary teachers perceived the value of the designed CBLe for their conceptualization of SSI-based teaching, I conducted inductive analysis of interviews with primary participants. Other extracts and quotes from online discussions and reflection papers, in which participants expressed their opinions, provided triangulated evidence for this sub-question. The primary participants appreciated the designed CBLe as well as the concluding planning activity as they interpreted the learning experiences as a way to enhance their conceptualization of SSI-based teaching for several reasons that I will present in the following sub-sections.

Being Prepared for Future Challenges

To explore how participants perceived the value of CBLe on being prepared for future challenges of SSI-based teaching, I asked many open-ended questions during the interviews. All of the primary participants shared their appreciation for the case-based activities and expressed that they felt more prepared for teaching SSIs in their future classrooms. Many other participants expressed their appreciation in their online discussion posts and reflection papers. For example, Alex shared that:

> *I definitely feel a lot more prepared than I did but there's still a huge part of – I think anyone who hasn't technically started their teaching career yet, I'm just nervous about all of it. I'm nervous about whether I'll teach the right things or whether I'll get to all the standards or whether the kids will understand things.*

Similar to Alex, Erica shared some general concerns related to ideas we had in discussions of pedagogy cases. Erica stated that:

> *I know that it's not going to be easy and it's going to take time and I'm going to have to sit down and really think about what I'm doing, and even having to defend myself. But I feel prepared now that just being in this class and going through the different issues and seeing how it brings up like ethical issues and moral issues and different views of society.*

Erica also mentioned that nothing would help with being prepared as much as actually experiencing it but case-based learning was *the second best experience*. She stated that:

> *…Being exposed to those kinds of things* [SSI-based activities] *now, I feel like that I can use them as like a reference point for when I do face those challenges. There's nothing like going through it first hand, I feel like that will give you the best experience, but this is the second best. It's like we get to explore it and see things that actually happened without having to go through them. So I feel like that prepares you as much as you can be before experiencing it yourself.*

Even though findings suggested that participants expanded their conceptualization of SSI-based teaching after the last activity, Kyla shared that case activities were more helpful for her conceptualization of SSI-based teaching than the example in-class SSI-based activities when I asked which activities were more helpful for understanding of SSI-based teaching. She stated that:

> *I think the cases just really challenged my thinking more because those are things – like the oil spill and the edible insects are things that I feel like I would learn about and definitely teach, but the cases are challenging of how you would teach it and that's a little more interesting. I'm interested in that because I want to know how I can best teach the children these topics, but then I also want to know things I can't teach. So, probably both, but case studies is probably a little bit more.*

As mentioned earlier, Kyla had the highest level for her second pedagogy case reflection supporting the efficacy of case activities for Kyla's conceptualization of SSI-based teaching. Kyla also shared that she was "*ready to fail*" but that the cases helped her to think about challenges that she had never thought about before. She mentioned the importance of being careful about controversial issues and knowing the background of students as you bring these issues into the classroom, which were ideas we discussed in class for the first pedagogy case. She stated that:

> *I think the genetic one really made me think of that because you never know who is in your classroom and whose family is maybe going through that or even the spotted owl about the families who were directly tied to the issue. So that probably challenged me the most to think about that. But then the Zika virus helped me [to understand] I need to talk about these things so that they're* [students] *thinking about it. I definitely feel very strong about talking about it but it's just being careful about how I do it.*

Mary shared her feelings of nervousness about potential challenges she may face in the future but she also mentioned many positive opinions about how cases helped her to prepare for future challenges. When I asked her "*how prepared do you feel for overcoming those challenges?*" she stated that:

> *So I'm nervous about writing the lesson and not seeing the potential things that could happen in the classroom and being unprepared for those. It's impossible to see every issue that may happen when bringing up these issues in the classroom and so I think the course helped better prepare us to think on our feet and handle the situation in a positive way and hopefully continue to respect everyone's opinions. Keep a positive classroom*

environment, but also keep a realistic classroom environment where they are learning that there are different sides to every opinion.

Similar to Erica, Mary shared that she felt as prepared as possible before actually experiencing the teaching of an SSI. She shared that:

I feel decently prepared, as prepared as I can feel before actually implementing a socio-scientific issue in a real classroom setting, but I would feel comfortable to prepare a lesson for a socio-scientific issue, I would feel prepared to implement that lesson and to take on any challenges that may come through that lesson. But, I think that personal experience would help me to be even more prepared for the next one for sure. I hope that I get to implement a lesson next semester like this.

These findings suggested that all participants felt more prepared for facing possible challenges of teaching SSIs and expressed their enthusiasm to integrate SSIs in their future classrooms after engaging in activities in the designed case-based learning environment.

Suggestions for the Model

To explore how prospective elementary teachers described their experiences with the CBLe, I included open ended questions about their positive and negative experiences with the activities, and asked for possible suggestions to improve the instructional model during the interviews. The primary participants mentioned several ideas related to the benefits of the activities, challenges of CBL, and suggestions for the model (e.g., such as adding more cases, giving less time for the reflection papers.)

First of all, participants appreciated the case-based pedagogy in general and thought that other teacher education courses could use this method. When I asked "*Are there any other*

courses in your teacher preparation program that could benefit from case-based pedagogy?"
Alex shared that:

> *I think all of them could, and I don't really know how you would use case-based pedagogy in say English or math, the forms that it would take may be a little bit different but I think that it was a type of learning that was super helpful to me. So I think by using case-based learning, what you're doing is you are kind of putting yourself in other people's shoes and learning through their eyes. I would assume that every other course could benefit from that.*

This excerpt suggested that Alex appreciated case-based pedagogy mostly because it provided opportunities for considering other people's perspectives and she thought all courses could benefit from this pedagogy. Erica shared more details about this idea and suggested that social studies and math courses in the teacher education programs could benefit from case-based pedagogy. Erica stated that:

> *I feel like that social studies would be a popular choice for the case-based learning just because you do experience discrimination or just other things that are really prominent and current and I feel like that would benefit from the case-based learning. I feel like you could bring it into math too… I guess just reading about a teacher and their methods for introducing their students to different topics within math, saying what went well and what didn't go well. You know, it wouldn't necessarily have the same controversial effect to it but I think it would still be a case study about what the teacher did, what happened, the effect on the students.*

This excerpt provided an illustration of Erica's appreciation of the value of CBL for her conceptualization of SSI-based teaching. Similar to Erica, Kyla stated that the social studies course could make use of case-based pedagogy. She stated that "*Social studies could definitely benefit from it because it was a lot about how we teach social studies in the classroom and a lot of that is controversial too… how you teach slavery or how you do different topics that may be difficult."* Mary also shared that:

> *I think any of our courses could benefit from case-based learning just because, as teachers, we'll be put in a lot of different situations and so you can modify your cases from the science curriculum to some issue that may have happened when differentiating a math lesson or a social studies lesson. So I think any of our courses could do that.*

Throughout the interviews all participants expressed their general appreciation of the case-based pedagogy and activities we had, especially the discussion activities. I started with one open ended question: *How would you describe your experiences with the case-based learning activities in this course?* As mentioned earlier, participants usually shared their general opinions about the pedagogy and emphasized that their favorite activity was in class or online discussions.

To better explore any negative experiences or activities that can be improved, I asked open ended questions such as *"Which activities hindered your learning?*" or *"what did you think about the reflections?"* All participants shared that nothing hindered their learning but three of them stated that writing the reflections was repetitive or frustrating, even though they had some positive opinions about it. For example, Alex shared that:

> *The only thing that I can think of in regards to this class, if we hadn't done that reflection then we may have been able to talk about more cases and I think it just kind of added more work when we had already talked about the case twice.*

On the other hand, she appreciated the opportunity to summarize her opinions and stated that "*it is repetitive but it's also helpful because there's a lot of times when you need to* *summarize a big hour long conversation so it was helpful to really be able to hone in my skills of summarizing."*

As mentioned earlier, Erica stated during the interview that discussions were her favorite activity of the case experience. When I asked what she thought about *other activities, such as writing the reflection*, she stated that:

> *Honestly I felt… I think at that point, when we had to do our reflections, I felt like I had already said everything that I needed to say in between the discussion we had in class and the original discussion post. I felt like I had already exhausted everything.*

And then she added that *"it might have helped if it was a little bit closer to our in-class discussion, if it was due not so quite like later on, maybe that wouldn't have felt that repetitive."* On the other hand, Kyla was also one of the prospective teachers who shared that her favorite activity was in-class discussions but she also noted that she found writing the reflections quite helpful. She stated that:

> *I thought it was helpful to put your thoughts together at the end of the whole process instead of just kind of leave it at the discussion. Because I think normally we would just leave it and then you would just kind of go on with your life, but to be able to have some sort of closure for yourself, closure for the situation, I thought that was pretty good. It wasn't too lengthy so I didn't feel like I was trying to get words together, I felt like it was easy for me to type.*

The points Erica and Kyla made here suggest an important implication for the design of the activities. As we developed the syllabus, we gave students one week to write their reflections after the classroom discussion, and this may be changed in future implementations. I still think writing reflections is an important component of the instructional model developed for this study since participants presented more comprehensive conceptualizations of the cases in their reflection papers compared to their online discussion posts.

This finding suggests that writing the reflections helped students synthesize their initial ideas and develop more complex conceptualizations of SSIs or SSI-based teaching. For example, Mary expressed her experiences with writing the reflections as very positive and shared that:

> *I liked writing the reflection just because it was reiterating what you had learned. So, in the classroom discussion, because I knew that I would have to reflect later, it caused me to like take notes and things. And since I do learn when I'm talking or writing, talking about it and then writing down those new ideas and then reflecting on it, I think it embedded that back into my mind.*

Similar to Kyla and Mary, many other students shared positive opinions about the benefits of writing the reflections such as improving their writing skills, articulating ideas, and summarizing what they learned through this writing task. On the other hand, instructors should be considerate about the due dates and length of the reflections so as not to hinder students' learning or motivation. For example, instructors could set up the due dates for a time (such as 48 hours) closer to the classroom discussion.

Triangulation of Findings for Research Question Two

To answer the second research question about participants' conceptualization of SSI-based teaching, I explored primary participants' online discussions and reflections to pedagogy cases and their instructional resource design reflections. Their answers to related interview questions also provided triangulated data for the exploration of this research question.

Findings suggested that the primary participants were able to identify some purposes of teaching SSIs related to making science more relevant and/or learning of science categories even in their first pedagogy case reflections. However, they had difficulties identifying other purposes such as developing HOTS or learning about science. Summary of participants' levels of conceptualization of SSI-based teaching is presented in Table 5.1.

Table 5.1

Summary of Findings for Research Question Two

	Data Source				
	Pedagogy Case 1 (Owl Case)		Pedagogy Case 2 (Lobster Case)		Instructional Resource Design Reflection
Participant Name	Online Discussion	Reflection	Online Discussion	Reflection	
Alex	Level 2	Level 2	-	Level 2	Level 4
Erica	Level 4	Level 4	-	Level 3	Level 3
Kyla	Level 3	Level 3	Level 3	Level 4	Level 4
Mary	Level 2	Level 3	-	Level 4	Level 4

For example, Alex was not able to identify purposes related to developing higher-order thinking skills or learning about science in her case reflections. However, she was able to mention several ideas related to all categories in her instructional resource design reflection and also during the interview. In her interview, she stated that:

> *I could definitely, if given the chance, I could see myself using similar things, you know, maybe modifying to whatever students I have or the area that I'm in or the age. But I could see myself using at least the part of it that's being active and using a story behind it, kind of giving a back story to whatever you're doing and also bringing in current issues that are relevant to them.*

This excerpt suggests that Alex was able to identify purposes of teaching SSIs related to the making science more relevant category such as being informed about current issues and connecting science with other subjects. When I asked her "W*hat would you like your students to* *learn when they engage in social scientific issue activities?"* she elaborated on other purposes such as being involved in the community, and also mentioned one idea related to HOTS (e.g., working together to solve a problem). She stated that:

> *Well, I think part of what I would want them to learn would be the fact that these issues are relevant to their lives and that they can affect them. I think I would really just want them to learn the value of working together to solve a problem while also learning the background of the issue. So just kind of the value of having an opinion, supporting it, and having the knowledge to support an opinion I think is a great life skill that kind of comes with this kind of pedagogy.*

The last sentence in this excerpt suggests that she also appreciated the purpose of teaching SSIs for learning how to use scientific information (learning about science). All of the participants provided more complex ideas and included new purposes increasingly in their second pedagogy case reflections and instructional resource design reflections except Erica.

As summarized in Table 5.1, despite her high level of understanding of the first pedagogy case, Erica did not develop a comprehensive second case reflection. The possible reasons for this were discussed in the analysis of second case reflection. She also did not include ideas related to developing HOTS in her instructional resource design reflection. However, Erica was able to mention several ideas related to all categories during her interview. Regarding the development of HOTS, she expressed a deeper understanding of how SSIs can help students develop these skills during the interview. When I asked her *"What would you like your students to learn when they engage in socio-scientific issue-based activities?"* She stated that:

> *Just being able to talk at perspectives other than their own and be able to understand them, not necessarily agree with them. In addition to the critical thinking, problem*

> *solving skills, seeking out answers that benefit the majority and… What is right and what is wrong, how do we know these things are right and wrong and I feel like so much to learn from them, embedded within critical thinking.*

Being able to identify all purposes for teaching SSIs in the first pedagogy case reflection and also in the interview supported the assertion that Erica developed a comprehensive conceptualization of SSI-based teaching. However, she did not demonstrate this understanding in her second case reflection and instructional resource design reflection because of finding the activities *a little repetitive.*

Kyla also had a limited conceptualization of SSI-based teaching at the beginning of the semester. However, she was able to identify different purposes for teaching SSIs even in her first pedagogy case online discussion (Level 3) and she even furthered her conceptualization in her last reflection paper (Level 4). Only vague conceptualization in her case reflections was related to the making science more relevant category but Kyla improved her understanding of this purpose after the example SSI-based teaching activity and designing her own instructional resource. She was able to mention several ideas related to all categories in her instructional resource design reflection. During the interview, her explanations suggested that she appreciated the purposes related to the making science more relevant category. She shared that:

> *I want them to connect it to their lives and have an opinion on current topics. I don't remember really being super passionate about the things I would learn in my history class and I want my kids these days who do show interest to be able to talk about things and connect them to the real world or connect them to hard topics.*

Mary also did not create detailed online discussion posts for the pedagogy cases, however her reflection papers included different ideas related to all categories. Mary had a simple conceptualization of SSI-based teaching at the beginning of the semester; she briefly mentioned ideas such as being informed or developing critical thinking skills in her first SSI case reflection (i.e., Zika Virus) and did not included any ideas related to teaching in her second SSI case reflection. However, she was able to identify different purposes for teaching SSIs in her first pedagogy case (Level 3) and she even furthered her understanding in her last reflection paper (Level 4). Similar to Alex, the only category absent in Mary's first pedagogy case reflection was the development of HOTS. However, she was also able to mention several ideas related to all categories in her instructional resource design reflection and during the interview. She shared a very insightful answer to the question about expectations from SSI-based activities during the interview. She stated that:

> *I hope that they would just take away just some deeper thinking skills, honestly. Take away whatever the curriculum points and just I hope that they have a positive outlook on the socio-scientific issues after we discuss it. I want to do fifth grade, so they're older in elementary but they're still very young and so just developing those high order thinking skills and being able to respect each other's opinions while doing the issue and then being able to see both sides of an issue even though they don't necessarily agree with something. So I hope that they would take away those kinds of things from my lesson.*

Overall, findings suggested that all students advanced their conceptualization of SSI-based teaching even after the second pedagogy case reflection, with the help of example SSI-based teaching and designing activities. Chapter 6 presents an overall interpretation of findings and implications for practice and research.

CHAPTER 6

CONCLUSION

Summary and Overall Interpretation of Findings

In this mixed methods study, an instructional design framework was developed for a case-based learning environment (CBLe) and implemented in a science methods course for early childhood education prospective teachers. Seven weeks of the course were devoted to different types of learning activities: (1) one introduction activity, (2) four case-based learning experiences, (3) one planning an instructional resource design activity and (4) one concluding activity.

The designed CBLe provided prospective teachers opportunities with analysis and reflection on authentic cases. The participants (four primary and twenty-two secondary) engaged in several activities for four cases such as participating in online and classroom discussions and development of a written reflection papers. Two socio-scientific issue-based cases (see Appendix C1 and C2) and two pedagogical cases that featured dilemmas of teaching and learning of socio-scientific issues in the classroom (see Appendix C3 and C4) were a centerpiece of the instructional activities. Later in the semester, the prospective teachers engaged in an example SSI activity for an elementary classroom and were asked to work as a group to develop their own instructional resource designs about an SSI of their own choice. Finally, the prospective teachers presented their instructional resource designs to the whole class and wrote individual reflections on their designs.

This study documented the participants' evolution of socio-scientific reasoning (SSR) skills, conceptualization of SSIs and SSI-based teaching during the case activities, and their translation of understanding into planning after engaging in the designed CBLe. The analysis of the participants' pre- and post-Socio-Scientific Issue Questionnaire (SSIQ) scores revealed that participants' post-SSIQ scores were statistically significantly higher than pre-SSIQ scores for three of the four constructs of SSR (i.e., complexity, inquiry, perspectives).

Four primary participants' online discussion posts and case reflections supported the assertion that engaging in case-based activities could enhance prospective teachers' conceptualization of SSIs, SSR skills, confidence to teach SSIs, and appreciation of the purposes of SSI-based teaching. Finally, the findings suggested that primary participants advanced their conceptualization of SSI-based teaching even after the second pedagogy case reflection, with the help of example SSI-based teaching activity (edible insects) and developing their own instructional recourse design. The chapter presents overall interpretation of these findings, implications for research and practice, suggestions for science educators and instructional designers, and future research directions.

The inquiry in this study focused on this overarching question: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching? This study attempts to answer the following research questions:

1. To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSIs?

    1.1. How does the CBLe support prospective elementary teachers' evolution of socio-scientific reasoning?

1.2. How do prospective elementary teachers' conceptualization of SSIs evolve during the SSI case activities?

1.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of socio-scientific issues?

2. To what extent does the CBLe influence prospective elementary teachers' conceptualization of SSI-based teaching?

2.1. How do prospective elementary teachers' conceptualization of SSI-based teaching evolve during the pedagogy case activities?

2.2. How do prospective elementary teachers translate their understanding of SSI-based teaching into planning after experiencing CBLe?

2.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of SSI-based teaching?

Essential interpretations of the findings are presented by integrating results related to the two research questions with theoretical discussions in the following section.

Overall Interpretation of Findings

RQ 1.1. How does the CBLe support prospective elementary teachers' evolution of socio-scientific reasoning? Descriptive statistics and statistical tests (Wilcoxon Signed-Ranks) were employed to explore the issue of change in participants' SSR to address the first sub-question of the first research question. According to descriptive statistics, students' post-questionnaire mean scores were higher than their pre-questionnaire mean scores for each SSR aspect. Statistical tests (Wilcoxon Signed-Rank) indicated that participants' post-SSIQ scores were statistically significantly higher than pre-SSIQ scores for three of the four constructs: (1)

complexity aspect of SSR, $Z= -1.97$, $p<.048$; (2) perspectives aspect of SSR, $Z=-2.498$, $p<.012$; and (3) inquiry aspect of SSR, $Z=-2.707$, $p<.007$.

As mentioned earlier, a review of the educational research literature indicated that no research is available on prospective elementary teachers' socio-scientific reasoning, and there are few studies reporting on prospective teachers' moral and/or informal reasoning practices. Topcu, Sadler, and Yilmaz-Tuzun (2010) reported that the prospective science teachers in their study were not particularly skilled at informal reasoning in the context of SSI and that sixty-one percent of participant responses were scored at a Level 1 or 2, indicating that most of the prospective science teachers were not able to engage in high levels of reasoning practices even when they were specifically prompted to do so.

The current study provided supporting evidence regarding prospective teachers' low levels of initial reasoning around socio-scientific issues. Forty-two percent of responses in the pre-SSIQ regarding the complexity and perspective aspects of SSR were scored at a Level 1 or Level 2 in the current study. Similarly, fifty percent of responses regarding the inquiry aspect were scored at a Level 1 or Level 2 and sixty-five percent of responses regarding the skepticism aspect were scored at a Level 1 or Level 2. However, participants of the current study improved their SSR scores in their post-SSIQ responses after engaging in the case-based learning environment, supporting the efficacy of the model to enhance prospective teachers' evolution of SSR.

RQ 1.2. How do prospective elementary teachers' conceptualization of SSIs evolve during the SSI case activities? Supporting the quantitative results, all participants presented more comprehensive conceptualizations of SSIs throughout the implementation of activities, increasingly in their second SSI case reflection and specifically for the complexity and perspectives aspects. The primary participants' low levels of conceptualization of the SSIs in online discussions posts compared to reflection papers supported the idea that in-class discussions were more effective in supporting their conceptualization of SSIs. In addition, all primary participants explicitly expressed that they found classroom discussions as the most valuable learning activity since they were able to hear their peers' perspectives and expand on their initial ideas about the cases. This might explain the difference between their levels of conceptualization for online discussion posts and reflection papers. All primary participants presented more comprehensive conceptualizations of SSIs or SSI-based teaching in their reflection papers on each case after they engaged in the classroom discussions.

Choi and Lee (2009) reported similar results in terms of their participants' evolution of problem solving skills regarding complexity and multiple perspectives aspects. They stated that participants "began with tendencies to simplify the given situation and identify problems from a single perspective, mainly the teacher's perspective" (p. 123). However, similar to this study, their participants began to understand the complexity of given situations and to acknowledge the possibility of different interpretations of problems from multiple perspectives throughout the implementation of case activities.

The lack of ability to consider multiple perspectives was especially evident in the first online discussion activity (Zika Virus case) when most of the prospective teachers considered some pros and cons but ultimately framed the issue being relatively simple with a single solution. However, after the classroom discussion, many of the prospective teachers reflected on how their ideas had evolved and acknowledged that the topic (Zika virus issue) was more complex than they initially thought. The participants were then able to assess the issue from multiple perspectives including the ones we discussed in class. Similarly, the primary participants began with tendencies to simplify the second SSI case in their online discussions (except Kyla), and they did not mention any of the ethical considerations that were evident in the case. However, all of them were able to identify the complex nature of the topic along with other features after the classroom discussions. The primary participants presented the highest levels of conceptualization regarding the perspectives aspect in both SSI case reflections supporting the assertion that case-based learning is an effective pedagogy for enhancing prospective teachers' ability to consider multiple perspectives.

RQ 1.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of socio-scientific issues? Similar to participants in Butler et al.'s (2006) study, the primary participants indicated that case reading, responding to questions in online discussions, and discussions are all interconnected and contributed to the development of their understanding of the SSI cases. Even though they shared that in-class discussions were their favorite activity, they also shared that they appreciated the purposes of other activities and felt that every process helped their reflection and meaning making. The primary participants in this study suggested that online discussions stimulated their thought processes by providing questions for reflecting and encouraged them to search for additional background information about the issue since they did not know much about the issues that were presented in the cases (e.g., Zika virus, genetic testing).

The prospective teachers pointed out that in-class case discussion, in particular, was effective in terms of expanding initial thoughts about case dilemmas by helping them to recognize new and different perspectives and discover more information from their peers relevant to the case dilemmas. Rather than being passive recipients of transmitted facts in science education, the prospective teachers learned from each other and from authentic cases.

Even a short-term training designed around case-based activities enhanced prospective teachers' conceptualization of SSIs, suggesting that the instructional design framework presented here is effective as a guide to develop a case-based learning environment consisting of selected information resources (e.g. case studies related to authentic socio-scientific issues) aimed at the pursuit of targeted learning goals (e.g. conceptualization of SSIs).

RQ 2.1 How do prospective elementary teachers' conceptualization of SSI-based teaching evolve during the pedagogy case activities? Findings of the study suggested that all students advanced their conceptualization of SSI-based teaching throughout the implementation of activities. All primary participants acknowledged that case-based activities challenged them to think about possible difficulties and purposes of teaching SSIs.

Similar to Kim and Hannafin's (2011) participants who had vague perceptions about relevant pedagogy (teaching with technology), in the current study, the primary participants conceptualization of SSI-based teaching evolved from positive but vague perceptions to concrete and clear understandings of purposes of teaching SSIs. At the beginning of the semester, during the SSI case activities, students' online discussion posts and reflections suggested that prospective teachers had simple conceptualizations of SSI-based teaching. Many students briefly identified purposes such as being informed in their first SSI case reflections (i.e., Zika Virus) regarding the question *"What would you do if one of your students mentioned his/her concerns about a possible spread of Zika virus in Georgia?"* However, all primary participants were able to identify different purposes for teaching SSIs even in their first pedagogy case and they furthered their conceptualizations in their second pedagogy reflection papers (except Erica).

According to the findings of this study, pedagogy cases were more useful in terms of supporting participants' conceptualization of SSI-based teaching than the SSI cases. As noted earlier, Espeja and Lagarón (2015) reported that regarding the appreciation of purposes of teaching SSIs, most of their participants retained the same level of appreciation throughout their study. The participants appreciated purposes related to developing higher-order thinking skills but had difficulty in identifying purposes related to developing scientific knowledge and learning about science. The researchers inferred that these results may be related to the limited time that was devoted to explaining the reasons to teach SSIs.

The current study adapted the example activity from Espeja and Lagarón's (2015) study and reported more positive results in terms of participants' improvement of ability to identify purposes of teaching SSIs after engaging in an example activity and developing an instructional resource design. Thus, it can be asserted that providing time for prospective teachers to become familiar with the pedagogy and increasing their exposure to relevant activities could possibly enhance their conceptualization of SSI-based teaching even further.

On the other hand, results of Espeja and Lagarón's (2015) study might be related to participants' views about socio-scientific issues. As reported in the literature review section, one recent study (Özden, 2015) explored prospective elementary teachers' views about socio-scientific issues. One interesting finding of the study was that most of the participants agreed or were indecisive about the statement: "Integrating SSI into science education simplifies science education." Ekborg et al. (2013) also reported that their participants shared views about *learning less science* and this may stem from their limited understanding of the characteristics of socio-scientific issues. Studies highlighted here suggested that prospective teachers usually do not have comprehensive understanding of SSIs and thus most of them do not realize that SSIs can also help students develop their knowledge of science and about science, probably because it is more difficult to relate these ideas to the aims of SSI activities (Ekborg et al., 2013; Espeja & Lagarón, 2015).

These studies, including the current study, presented conflicting results in terms of teachers' experiences working with SSIs. However, findings that are highlighted in the current study suggest several important implications for research and practice. First, an emphasis should be placed on characteristics of SSIs. Teachers may have difficulty in analyzing the ethical nature of SSIs, the conflict of interests (multiple perspectives), and the relationship between society and science. Additionally, teachers' interpretations of scientific content might be limited to "knowledge as a set of facts to be taken in by the students" (Ekborg et al., 2013, p. 613). It is important to highlight purposes of teaching SSIs such as enhancing understanding of nature of science and critical thinking skills along with scientific knowledge throughout the learning activities in teacher education courses.

RQ 2.2. How do prospective elementary teachers translate their understanding of SSI-based teaching into planning after experiencing CBLe? To address challenges mentioned above, the current study included explicit instruction about the characteristics of SSIs, provided opportunities for prospective teachers to experience SSIs as adult learners, modeled an SSI activity for an elementary classroom, and provided guidelines for the design of an instructional SSI activity with a national curriculum connection. Supporting the efficacy of the model, all primary participants were able to identify purposes related to the learning of and about science category in their final reflections and during the interviews. Findings suggested that all primary participants advanced their conceptualization of SSI-based teaching even after second pedagogy case reflection, with the help of example SSI-based teaching activity (edible insects) and developing their own instructional recourse design. All primary participants expressed that designing their own instructional resource helped them to better understand how to teach SSIs in their future classrooms.

My preliminary analysis of other participants' online discussions and instructional resource design reflections indicate that the vast majority of participants believed that teaching SSIs was very important and they explicitly appreciated the value of SSIs for their future classrooms in their online discussions and reflections. Moreover, this belief was even stronger in their final reflections for the instructional resource design assignment.

However, viewing an issue as important does not necessarily mean that teachers of science will address it in their classrooms (Hestness et al., 2011; Sadler et al., 2006). As noted earlier, there is no evidence that the use of case-based pedagogy affects prospective teachers' classroom practice (Grossman, 2005). Hence, the challenge is to see how these positive results translate into the ability to design and implement SSI activities in real elementary school classrooms. On the other hand, prospective teachers' "alteration of beliefs may later have a positive impact on their teaching practice" (Butler et al., 2006, p. 25). Even if the analysis of only four primary participants' instructional resource design reflections is included in this study, the instructor's evaluations of all participants' lesson plans and reflections were above the expectations (see Figure 3.9 in Chapter 3). All prospective teachers developed appropriate SSI-based instructional resource designs for the course assignment suggesting that they developed proper conceptualization of how and why to teach SSIs in their future classrooms.

RQ 2.3. How do prospective elementary teachers perceive the value of CBLe on their conceptualization of SSI-based teaching? All primary participants in this study stated that they did not have any knowledge of how to teach SSIs before taking the methods course and that they felt more prepared to teach SSIs in their future classrooms after engaging in the designed activities. Thus, it can be asserted that their self-efficacy to teach similar topics increased after engaging in the case-based activities. Yahaya et al. (2015) also reported that the integration of the SSI-based instruction significantly affected the prospective teachers' sense of efficacy in favor of the experimental group that showed a stronger sense of efficacy.

The participants of Ekborg et al.'s study (2013) also stated that they felt confident with using the developed case materials about SSIs in their classrooms after they engaged in the designed trainings. On the other hand, the researchers discussed reasons for how participants' feeling comfortable might be that they did not work with SSI according to the proposed framework. The participating in-service teachers used the cases to create interest when introducing a topic, but generally they did not emphasize ethical issues, the conflicts of interest or content about science, and they did not create awareness of the interdependence between society and science.

These results bring attention to one very important point for the current study and further research: how do participants translate their understanding of SSI-based teaching into practice? Participants in this study mentioned their appreciation of purposes related to these ideas, but they also mentioned that integrating controversial issues with ethical considerations might be challenging to integrate in elementary classrooms.

The prospective teachers in this study appreciated the designed case-based learning environment as they interpreted the learning experiences as a way to enhance their conceptualization of SSIs and SSI-based teaching. Implications for practice and research will be discussed in the next section.

Implications for Practice and Research

One overarching question formed the focus of this study: To what extent does a case-based learning environment (CBLe) influence prospective elementary teachers' conceptualization of socio-scientific issues (SSIs) and SSI-based teaching? Many implications for practice and research resulted from exploring the use of CBLe with elementary teachers as they learned about SSIs and how to teach SSIs in their future classrooms.

The primary participants of the study suggested that case-based pedagogy can be useful in many other teacher education program courses such as social sciences and math as the pedagogy makes learning more interesting, engaging and promotes understanding of multiple perspectives. This study contributes valuable insights and implications to the science education community at large, as I have proposed a framework, which has been designed to inform the instructors of science methods courses about case-based pedagogy, and thus can be adapted for different teacher education courses. I present several suggestions for practice and research in the following paragraphs (see Table 6.1 for a summary).

Table 6.1

Summary of Implications for Practice and Research

Implications for Practice	**Implications for Research**
Encourage discussion of how SSIs might be adapted for learners of diverse ages and abilities, and model effective activities	Further research studies should continue to track participants in the field for a number of years to fully understand and identify how teachers translate their understandings into teaching
CBLe can potentially support prospective teachers' self-efficacy for addressing relevant challenges that may come up any time in their future classrooms.	Further research may be conducted on the effects of engaging in SSI-based activities on prospective elementary teachers' motivation and self-efficacy to teach science
There is a need for developing relevant pedagogy cases	

Even short-time training can support prospective teachers' understanding of SSIs and their self-confidence to teach controversial issues	Further research on prospective teachers' experiences and learning with different types of case materials for SSI-based teaching and learning should be explored (e.g., with exemplary cases)
More exposure to case studies can provide more benefits to prospective teachers.	Researchers may work with prospective teachers who have limited experience with SSIs, engage them in more cases throughout their science methods courses, and explore their evolution of conceptualization of SSIs and SSI-based teaching.
Online discussions require careful preparation. Prospective teachers may have a tendency to simply "do the task." Encourage active participation.	Further research may be conducted on the strategies for creating effective online discussion activities for CBLe.

In reflecting on findings of this study, I perceive several areas in which the inclusion of SSIs in science methods courses may be particularly useful for advancing the goals of transformative science teacher education (Hestness et al., 2011). Opportunities to recognize that scientists are continuously gaining new knowledge about social issues with conceptual and technological relations to science can help prospective teachers better understand the practice of science, and better translate these practices to their students. Practicing strategies for making sense of current controversial issues, such as Zika virus and genetic testing, within teaching education programs may help teacher candidates gain confidence in integrating these issues in their future classrooms. These experiences will be most beneficial when science teacher educators encourage discussion of how these strategies might be adapted for learners of diverse ages and abilities, and model effective activities (Hestness et al., 2011).

Another goal which the designed CBLe can potentially support relates to prospective teachers' awareness for addressing relevant challenges that may come up any time in their future classrooms. In general, the findings from prospective teachers' engagement with the CBLe suggests that it helped them become more mindful of controversial issues, and knowledgeable of pedagogical approaches and potential challenges they may face when they integrate SSIs. To enhance these understandings, teacher educators can provide more examples of pedagogy cases including dilemmas of SSI-based teaching that may be appropriate for use in the elementary science classroom. When I started this research, I was not able to find any pedagogy cases related to SSI-based teaching in an elementary education context. Thus, I revised two pedagogy cases to make them more appropriate for use in elementary science classrooms. Researchers and teacher educators would need to develop their own cases related to SSIs since currently there is only a few available case materials found by the completion of this study.

With regard to reasoning around these issues, case-based activities within teacher education programs can help prospective teachers learn to teach how to explore issues with an open mind (NSTA 2003), and also to understand the challenges inherent in addressing socio-scientific issues (Presley et al., 2013). The results of this study indicate that educators and designers can selectively apply the design guidelines suggested in Chapter 2 to promote prospective teachers understanding of SSI-based teaching and learning (or other educational outcomes). Further, educators and designers can consider incorporating one or two case-based activities in methods courses since the findings of this study along with other studies supported that even short-time trainings supported prospective teachers' understanding of SSIs and their self-confidence to teach controversial issues (Hestness, McGinnis, Riedinger, & Marbach-Ad, 2011; Lee, Chang, Choi, Kim, & Zeidler, 2012; Yahaya, Zain, & Karpudewan, 2015). CBL can be implemented across different scales from individual activities to all class design. However, different implementation scales will likely require careful consideration for both instructors and student participants.

The participants of this study stated that they appreciated the online discussions however their conceptualizations were low in online discussion posts compared to their reflection papers. Most of the students required additional guidance on how to write their posts and had a tendency to simply answer the online discussion questions. Further research can be conducted on different ways to design more efficient online discussion activities to promote engagement. In this study, only 26 prospective teachers were enrolled in the science methods course, thus we were able to provide additional guidance for each student. However, implementation of these activities would require more effort in large-scale classrooms.

More exposure to case-based experiences can provide more benefits to prospective teachers. All primary participants of this study stated that they were motivated to engage in reading more cases about SSI-based teaching and learning. In a further study, researchers may work with prospective teachers who have limited experience with SSIs and engage them in more SSI cases throughout their science methods courses. Cases with different moral controversies may bring different cultural influences of prospective teachers with different backgrounds into the scene. In this study, the second SSI case (i.e., Genetic Testing, see Appendix C2) included a very controversial topic and led to a very engaging classroom discussion. The prospective teachers had different ethical considerations about the issue and their backgrounds affected their proposed solutions. Further research may be conducted on cultural influences of different cases in different settings.

The same categorical system for the analysis of case reflections and SSIQ utilized in this study could be used to determine if extended exposure to cases leads to significant changes in prospective teachers' conceptualization of SSIs especially for controversy and uncertainty aspects in the future studies. The findings of this study suggest that developing the conceptualization of these aspects are more difficult compared to developing perspectives and complexity aspects.

Exploring the efficacy of the integration of case materials related to SSI-based teaching and learning in a teacher education program would be a long-term study; the researcher would need to continue to track participants in the field for a number of years to fully understand and identify how teachers translate their understandings into teaching. Additionally, the focus of cases utilized in a similar environment should be studied.

In this study, I used pedagogy cases, which incorporate dilemmas of socio-scientific issue-based teaching. The participants reflected on the challenges that were presented in the cases and provided possible solutions. Accordingly, they shared many concerns regarding potential challenges of SSI-based teaching. They shared how thinking about these challenges made them feel more prepared but they might have developed negative attitudes toward integrating these issues in their future classrooms. Further research on the use of case-based activities for SSI-based teaching and learning should also utilize exemplary cases and prospective teachers' experiences should be explored. The variety and versatility of case based activities provides for many future research endeavors.

A final area for potential of research is in developing prospective teachers' motivation to teach science. When teachers and their students can build their understandings of the local relevance of a socio-scientific issue, they can make personal connections and understand the ways they may be personally impacted. Further research may be conducted on the effects of engaging in SSI-based activities on prospective elementary teachers' motivation to teach science. All primary participants in the current study stated that one of the most expected challenge is limited science time in elementary classrooms for their future teaching careers. And some of them shared that *science is not their strong suit.*

On the other hand, all primary participants appreciated that the SSIs provide opportunities for making science more relevant to students' daily lives, improving students' reading skills, science content knowledge, and higher-order thinking skills, as well as integration with social studies and mathematics (Zeidler & Nichols, 2009). When prospective teachers can understand potentials of SSIs and its global relevance, they take an even more profound step in understanding ways their lives and circumstances are interconnected with those of others. One of the participants of this study mentioned that when she learned about environmental effects of pesticides during our discussion of the Zika Virus case, she was very affected by the idea of bees dying. She called this as a wake-up call and wrote the following statement for her Zika virus case reflection:

> *Especially after the bees dying, when I first heard that in class discussion, that was one of the biggest wake-up calls…there's this whole argument: baby boomers ruined the earth and because they were so reckless and irresponsible… And so, I feel like it's so important to let these kids know what's going on at least in order for them to care later on, because me starting to learn these things now, -not that it's too late to learn these things now- but then I feel like at this point in my life, if I had learned before, I'd care so much more.*

By providing opportunities for making these connections, science teacher educators can begin to address the goals for fostering globally competent teaching (Hestness et al., 2011). This includes helping prospective teachers to consider the globally-significant ethical dimensions of socio-scientific issues, and preparing them to facilitate discussions around these with their students. The need for the integration of more SSI activities in all levels, especially in elementary level and in science methods courses in teacher education programs is evident in the literature and in participants' explanations in this study.

To help prospective and practicing teachers gain necessary attributes and prepare for challenges of SSI-based teaching, teacher educators should provide them with "access to examples and models of what it means to engage with SSIs in informed ways" (Sadler, 2011, p. 360) and researchers should explore the most efficient ways to prepare our prospective teachers for 21st century science classrooms. I will present recommendations for science teacher educators in the following section.

Recommendations for Science Teacher Educators

This study provides a number of insights into how science teacher educators might successfully incorporate socio-scientific issues into teacher education courses. Findings reported here suggest that case materials improved participants' conceptualization of SSIs and pedagogy for including similar topics in their own instruction. From the analysis of the prospective teachers' experiences with the developed CBLe, I synthesize a number of recommendations for teacher educators (see Table 6.2 for a summary).

Table 6.2

Summary of Recommendations for Science Teacher Educators

Recommendation	Description
Provide opportunities for students to familiarize themselves with SSIs	Multiple opportunities to enhance prospective teachers’ understanding of SSIs should be included either in the science methods courses or in science content courses by collaborating with science faculty to develop complementary courses
Integrate age-appropriate example activities	Prospective teachers may have difficulty in translating their understanding of SSIs to age-appropriate activities for their elementary-school learners. Spend time discussing and demonstrating how learning activities might be adapted for use across the elementary grade levels.
Integrate relevant pedagogy cases related to SSI-based teaching	Integrate cases of real teachers including pedagogical strategies, challenges, dilemmas and example activities to enhance conceptualization of SSI-based teaching.
Provide opportunities to develop a personal sense of why teaching SSIs is important	- Provide time and space to develop views about SSIs and SSI-based teaching - Make reflective opportunities a priority, and devote ample time to reflection activities such as online and/or in-class discussions, writing reflection papers.

Prospective teachers in this study were especially interested in the specifics of how a socio-scientific issue could be taught in an elementary science classroom. While our SSI case activities demonstrated activities for how to reason around an SSI, these activities were designed for an adult audience, in an effort to enhance participants’ own conceptualizations while demonstrating the pedagogy. Participants’ responses to this method were variable. Some of them shared that they enjoyed being able to research about relevant SSIs by themselves; however, one primary participant believed she would have difficulty in translating her understanding of SSIs to age-appropriate activities for elementary-school learners.

This sentiment suggests that science teacher educators should spend time discussing and demonstrating how learning activities might be adapted for use across the elementary grade levels. All primary participants shared that they found pedagogy cases more relevant and helpful for their future teaching career. Prospective teachers in this study responded especially favorably to learning about activities and resources that could be easily adapted for their own classroom use. For example, engaging in the oil spill activity (see Learning Activities section in Chapter 3), reading and discussing the pedagogy cases, demonstrating an example 5th grade SSI activity (see Appendix D), and developing an instructional SSI activity provided many teacher candidates with a sense of confidence that they could find resources and design activities to support their teaching.

On the other hand, findings of this study suggested that for prospective teachers to benefit the most from a CBLe for enhancing the conceptualizations of SSIs and SSI-based teaching, science teacher educators should provide opportunities for students to familiarize themselves with SSIs. Because prospective teachers may not have experiences with SSIs in their own educational experience, they will likely feel more comfortable if they have opportunities to develop an initial understanding before trying to share their opinions with their peers. Science methods course instructors might also help facilitate this by collaborating with science faculty to develop complementary courses geared toward enhancing prospective teachers' conceptualizations of SSIs. If science content courses involve opportunities to learn about socio-scientific issues like genetic testing or Zika virus within teacher education programs, then teacher education courses may focus more specifically on pedagogy around these issues.

A final recommendation is that prospective teachers should have time and space to develop their own views about SSIs and SSI-based teaching. In this study, prospective teachers were able to express their developing views through online discussions and reflection papers. The in-class discussions appeared to help prospective teachers question and develop their own values related to purposes of teaching SSIs and their future roles as science teachers. Because it is essential for teachers to develop a personal sense of why teaching SSIs is important, I recommend providing opportunities for prospective teachers to discuss and reflect on their own learning. Therefore, it is important to make reflective opportunities a priority, and to devote ample time to these activities.

There remains the need for resources from which teacher educators might draw on to integrate SSIs into their teaching and to help them meet their existing goals in the science methods courses.

Final Insights

In the science education literature, there has been an emphasis on SSI regarding students' decision making, conceptual understanding and interest on science, but there is very little research regarding teacher education for SSIs or about the difficulties of teaching SSIs in the classroom, especially at the elementary school level (Espeja & Lagarón, 2015; Sadler, Foulk, & Friedrichsen, 2017). Findings of the study suggested that engaging in case-based activities related to SSI-based teaching and learning enhances prospective teachers' conceptualization of SSIs, socio-scientific reasoning skills, confidence to teach SSIs, and appreciation of the purposes of integrating SSIs in their future classrooms. However, the primary participants of this study were all *higher achievers* in the course, and motivated to complete designed activities. The question of how the designed CBLe works with different types of prospective teachers (e.g., who have low pre-SSIQ scores) remains unanswered.

It is evident in the literature that prospective teachers usually do not develop necessary skills and understanding that enable them to teach SSIs in their future classrooms. However, this study suggested that SSI-based instruction is a promising method and prospective teachers develop positive opinions about integrating socio-scientific issues into their classes when they are trained and encouraged to do so. With few studies focusing on the use of SSIs in elementary classrooms, even less in elementary teacher education, improvement of prospective teachers' conceptualization of SSIs and SSI-based teaching is a wide-open field of study.

There are several questions that I want to explore in my further research studies: How prospective teachers translate their understanding of SSIs in real classrooms when they start teaching? How will they utilize these issues to enhance their students' interest in science, higher order thinking skills, learning of/about science? In addition, I plan to work with in-service elementary teachers to explore how the designed CBLe help them to develop strategies to teach SSIs in their classrooms. Further studies will shed light on the effectiveness of the case-based pedagogy and the proposed model with different participants in different contexts.

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APPENDICES

Appendix A

IRB Approval Letter

The University of Georgia

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Office of the Vice President for Research
Institutional Review Board

APPROVAL OF PROTOCOL

August 22, 2016

Dear Janette Hill:

On 8/22/2016, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Developing a Case-based Learning Environment for Supporting Prospective Teachers' Socio-scientific Reasoning
Investigator:	Janette Hill
IRB ID:	STUDY00003799
Funding:	None
Grant ID:	None

The IRB approved the protocol from 8/22/2016.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

Dr. Gerald E. Crites, MD, MEd
University of Georgia
Institutional Review Board Chairperson

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Appendix B1

Introduction to SSI Activity: Oil Spill

The Problem

What should be done to reduce the amount of oil spilled into the oceans?

Alternative Solutions to the problem

Consider the merits of many alternative solutions on this problem outlined below, and suggest a few of your own. Your ultimate task, as described on the following pages, will be to evaluate these solutions.

1. Oil tankers should be redesigned so that there is virtually no way that they can spill their load.
2. The government should charge extremely large fines for these companies which spill oil.
3. The United States, the largest oil consumer, should stop using oil and find an alternative energy source.
4. The oil companies should not be allowed to use large tankers. They should be forced to use many small tankers instead.
5. The government should take over the job that the oil companies currently have. The government, with extremely strict observation, should transport the oil to everywhere in the world it needs to go.
6. An oil vacuum should be developed and refined to clean up spills after they happen.
7. Oil should be transported by air instead.

8-10. your own alternatives.

Criteria for Evaluating Alternative Solutions

The alternative solutions are of varying quality. Your problem is to select the best alternative solutions. To do this, you will need to settle on a set of criteria for evaluating them. Some suggestions are given below, and you should be able to add a few of your own.

1. Will it help to protect the aquatic life from the dangers of the oil spills?
2. How much would it cost the Government (i.e. the tax payer)?
3. Is it a practical solution?
4. Does it reduce all sources of oil spills? (tankers, pipelines, refineries)
5. Is it technically feasible?
6. Would it cause oil companies to raise their prices?
7. Would it cause other forms of pollution?
8. Would other countries follow the United States' lead and adopt this practice?
9. Could it reduce the number of oil companies there by creating a monopoly?

10- 12. Your own criterion.

Systemic Evaluation of alternative Solutions

First, individually, and then in a group, consider the many alternative solutions and criteria for their evaluation. Choose the best five criteria, according to a consensus of your group.

List all ten possible solutions in the horizontal List all ten possible solutions in the horizontal rows of the grid on the next page. List the five criteria in the vertical columns.

Consider one criterion at a time! Rank each alternative in order from 10 (best) down to 1 (worst). Then add up the numbers horizontally across each row to determine an overall rating for each alternative. This may help you to decide on the best solution.

Decisions

1. What was the best solution according to the numerical values earned?

2. Do you see any problem with this solution? List a couple

3. How might you improve this solution? (Could you combine several high-ranking solutions?)

4. Now using just your personal feelings, what is the best solution to the problem?

Alternative Ideas	Criteria						Total Scores
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Scoring of Criteria: 3 points = Great
2 points = O.K.
1 point = Not So Good

Appendix B2

Introduction to SSI Activity: Vaccination

Adapted from: Solomon, J. (1991). *Exploring the nature of science*. Glasgow, Scotland: Blackie.

The Story of

Vaccination against Smallpox

In the eighteenth century, smallpox was a killer disease. There was no cure for anyone who caught. Then a doctor called Edward Jenner noticed something interesting. Milkmaids, who often caught a mild disease called cowpox from the cows, did not get smallpox.
Dr. Jenner had the idea that the cowpox somehow 'got in the way' of smallpox. He wanted to do an experiment to test out his idea. For his experiment, he chose a small boy - James Phipps - who had never caught smallpox.

First Dr. Jenner got some pus from a spot on the hand of a milkmaid, called Sarah Nelmes, who had cowpox. He then made a small cut in James' arm and rubbed in the pus. About five days later James became ill with cowpox, but he soon recovered.

Dr. Jenner then took some pus from the spots on a smallpox victim. Again, he made a small cut in James' arm and rubbed in the pus of this deadly disease. Dr. Jenner waited, but nothing happened. James did not get ill. It was a successful experiment.

Dr. Jenner called his method of protecting against smallpox 'vaccination' after the medical name for cowpox. Today this method has been so successful that doctors have managed to wipe out smallpox completely throughout the world.

After you read the story in class, assign the following roles to different groups.

Roles to be assigned to groups

James

You are eight and three-quarters years old and love fishing. You have gone to Sunday school a few times but you usually manage to escape and go down to the river. You don't want to learn to read. You don't want to start work either, but you know you will have to as soon as you are nine.

When you were little you fell out of a tree and broke your leg. Your father got Dr Jenner to set the broken bone and it hurt very badly. You have always been scared of Dr Jenner from that time. Once he gave you a medicine to cure your fever which was made from bitter aloes. You couldn't get the taste out of your mouth for a week afterwards.

You don't know much about smallpox except that your aunt had it. Now her face looks horrible with large deep pits all over it. You cannot even bear to kiss her.

Now decide:

Did you understand what Dr Jenner was going to do?
How would you feel about asking the doctor questions?
Now that you are safe from having smallpox would you advise your friends to have the vaccination too?

James' Mum

You did not go to school but have worked with your husband in the fields for many years. Now that he is gardener to Dr Jenner things are much easier.

You have had nine children but two of them died when they were only babies. You have never forgotten that. Dr Jenner did come and give the babies some medicine but it did not help them. He was not able to help your sister either when she died in childbirth.

James is your youngest and you know you spoil him a little, but you can't help it. He is always out fishing when your husband wants him to help in the garden. A month ago your husband suggested that James should be given smallpox now to prevent him from getting it later. That seemed terribly dangerous. You didn't sleep for a whole week worrying about it.

Now decide:

How do you feel about doctors?
What did you think when Dr Jenner explained what he was going to do to James?
Did you talk it over with your husband? If so what did you say to him?

Dr Edward Jenner

You were born into quite a wealthy family. When you were only 13 you began work apprenticed to a doctor, and you are now 47 years old. When you were very small your parents arranged to have you given smallpox, but you only had it mildly. Now you are safe from smallpox. You are 'immune' to it.

You have been interested in smallpox for at least seven years and have been making notes about all the cases you could find of people who had cowpox and then did not get smallpox. You are convinced that if you have cowpox you cannot get smallpox.

You did try an experiment six years ago. You put pus from a smallpox victim into the arms of several people who said they had already had cowpox. Some of them became very ill with smallpox.

These results puzzle you. Even though other scientists laugh at your ideas about vaccination, saying people might turn into cows, you want to try again.

Now decide:

Did you do this experiment to get scientific fame, or to help people?
How did you persuade Sarah to let you take pus from her arm?
How did you persuade James' parents to let you use James for your experiment?
When James was ill were you worried about what might happen?

James Aunt

You are the sister of James' Dad and have never been married. You caught smallpox when you were twelve and nearly died. You have large ugly pox marks on your face. You are also very deaf in one ear from having had the disease.

You have been working as a cleaner and a nurse in a neighbouring town. When there was an outbreak of smallpox there you looked after the ill and dying. No one else would go near them. It was terrible. Many of the children died without their parents. Most people kept away from you too, because they thought you might carry the disease on your clothes. It was hard even to get any food. You have never forgotten it.

You have taught yourself to read and know a little about the ideas that doctors have about smallpox. You are interested in the possibility of vaccination. You have always been very fond of your nephew James.

Now decide:

What questions would you ask Doctor Jenner?
Are you in favour of vaccination?
Do you think it should be tested?
What advice did you give to James' parents.

James' Dad

You never went to school and have worked on a farm since you were very little. It was very tiring work. Now you are nearly fifty, as near as you can tell. You have an easier job as Dr Jenner's gardener and you are very pleased. He is a very good employer.

You grow vegetables for Dr Jenner, and he allows you to take some home. He also lets you and your family live in the cottage by his gate. You have had nine children but two of them died as babies. That is quite common in the village.

James is your youngest son and he is nearly old enough to go out to work and bring in some more money for the family. James has always been healthy but you think he is lazy. You have discussed whether he should be given the smallpox now, so that he will not get it later. Your wife was against it.

New decide:

What are your feelings towards Dr Jenner?
What did he say to you about vaccinating James?
What did you reply, and what did you secretly think about it?
How did your wife react?

Sarah Nelmes

You are 13 years old and have been a milkmaid since you were eight. It is long, hard work. Your family are poor and have always lived in the village.

Just a week ago you caught the cowpox. Most of the other milkmaids you know have had it too. It hurts and you have seven large blisters on your hands which have gone yellow with pus. You didn't worry too much about it because your friends tell you it will go away in about a week. No one ever dies of cowpox.

You know Dr Jenner. He has looked after your mother when she was very ill last year, without asking for any payment. You think he is a kind and very clever man. He can read and write and has even been to London.

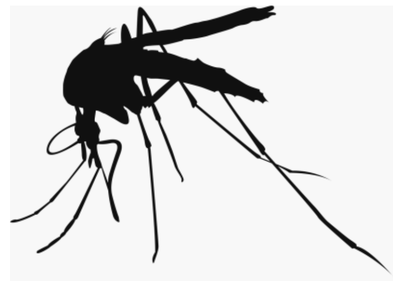
Now decide:

What did you think when the doctor said he was going to cut into one of your blisters?
Do you trust Dr Jenner?
What questions did you ask him?

Appendix C1

Case #1: To Spray or Not To Spray (SSI Case)

*To Spray or Not to Spray: A Debate Over Zika Virus and DDT**



** This case is a modified version of the original case by Frank J. Dinan and Joseph F. Bieron Department of Chemistry and Biochemistry, Canisius College. Source: The National Center for Case Study Teaching in Science, University at Buffalo, State University of New York*

As they settled into the office of Mr. Mali Sahriti, the United Nations Secretary for Public Health, all the participants of the impending discussion were nervous. Each was determined to press the points that would persuade Mr. Sahriti in his or her favor. Here, at last, was their chance to influence the United Nations decision on whether or not to ban the global use of DDT or to allow its use for the control of Zika virus.

Each of the three visitors to Secretary Sahriti's office, Dr. Nicole Lund, a tropical disease specialist with the World Health Organization, Sergio Ricupero, the ambassador from Brazil, and Dr. Patricia Canavan, a DDT expert and representative of the Sierra Club, were well prepared for the meeting. They had studied the issues carefully and were anxious to present their views to the secretary, hoping that they could influence his recommendation on DDT's future use.

Secretary Sahriti began the meeting. "Welcome, and thank you for coming. I know that you all have strongly held, expert views on the proposed global ban on the use of DDT that the United Nations Organization is considering, and I am most anxious to hear them. As you know, I must make a recommendation to the Secretary General in the near future on whether the United Nations should invoke a worldwide ban on the use of DDT by 2016 or not. Since I am not as informed as each of you on aspects of this issue, you will have to provide me with some of the background that underlies your positions. Perhaps we could begin with you, Dr. Lund."

Nicole Lund, a physician specializing in tropical diseases, had been with the World Health Organization (WHO) for six years. Her work at WHO as well as her prior training was focused on Zika virus and its control.

"Thank you, Mr. Secretary, I'd be happy to start. As you are aware, even though WHO is a part of the United Nations, we are strongly opposed to the proposed ban on the use of DDT. Our reasons for this are quite straightforward. As the World Health Organization on February 1st, has declared the Zika virus a "Public Health Emergency of International Concern", following a dramatic increase in cases of **microcephaly** (underdeveloped brains in babies) linked to the virus, it is time for us to resume production of DDT to eradicate any mosquitos potentially carrying the virus. "As I am sure you are aware, Zika infections are caused by mosquito bites, and nothing else is as effective as DDT for the control of mosquito populations. Zika is spread by mosquitoes of the Aedes genus, which can breed in a pool of water as small as a bottle cap and usually bite in the daytime. The yellow fever mosquito, Aedes aegypti, takes several bites for each blood meal and prefers biting people; it accounts for most Zika infections. This mosquito is common in the United States typically in Florida and along the Gulf Coast, although it has been found as far north of Connecticut in hot weather."
"May I add to Dr. Lund's comments, Mr. Secretary?" asked Sergio Ricupero.

"Certainly, Mr. Ricupero, please do."

"It is important to realize that Zika poses as a global and international threat, and that today most of those affected live in poor, underdeveloped parts of the world. Prior to 2015, outbreaks have occurred in Africa, Southeast Asia, and Pacific Islands. In May 2015, Zika virus transmission was confirmed in Brazil and outbreaks are currently occurring in many countries. The number of babies born with suspected microcephaly or abnormally small heads since October has now reached nearly 4,000. In the worst affected area, about 1% of newborns have suspected microcephaly. The Brazilian authorities believe that the increase is caused by an outbreak of Zika virus. As many as 150 babies were born with microcephaly in 2014. The brain condition can be deadly or cause intellectual disability and developmental delays. In the United States, reported number of locally acquired mosquito-borne cases is 6 and travel-associated cases is 1,818 by August 3rd. Travelers returning from areas where the virus is being spread may become sick after returning home to or visiting the US.

Nicole Lund seemed eager to her views at that point. "Mr. Secretary, I should also mention that as of today, there is no effective vaccine against Zika, and we cannot say with any certainty when and if one will be developed. As you may know, Australia once extensively and successfully used DDT to until it was banned. Beginning in the 1940s, the insecticide application of DDT immediately brought down the world death toll from many insect-vectored diseases, especially malaria. There were spectacular, life-saving results around the globe. In 1946, before the use of DDT, Sri Lanka (then British Ceylon, population 6.657 million) had 2.8 million cases of malaria, and 12,500 deaths that year. After large-scale spraying against mosquitos began on the island nation, the number of malaria cases in 1963 fell to 17, with only one death! In the state of Georgia, U.S., malaria, formerly widespread, was completely eliminated by 1950 after DDT spraying was introduced in 1945. Agriculture gains were also significant, as DDT was effective against plant bugs, beetles, ticks and other pests."

"In 1973, after DDT had been used for malaria control for over a decade, there were less than 400 cases of malaria in all of South Africa, and in 1977 only a single malaria death occurred. However, South Africa yielded to the political and economic pressure from the developed nations and stopped the use of DDT in 1995; its rate of malaria infections has quadrupled, and hundreds of additional deaths have occurred since then?" Mr. Ricupero interjected.

Secretary Sahriti leaned forward in his chair and said, "Why do you say that South Africa's decision to ban DDT use was the result of political and economic pressures from the developed countries?"

"Because, Mr. Secretary, the developed countries are major contributors to the economies of the underdeveloped nations, and they often insist on the ban of DDT use as a condition for their aid. This is a clear case of the developed world imposing its values on poor nations regardless of the consequences affecting those nations. I am sure you realize that malaria or Zika are not problems in most of the developed world, although that may be changing now."

The Sierra Club representative, Patricia Canavan, was visibly agitated. She said, "May I make some observations that would add a bit of balance to our discussion, Mr. Secretary?"

"Of course, Dr. Canavan."

"The reason that the developed countries want DDT banned from use worldwide is that its use presents an unacceptable risk to our environment and to our health. It is a risk that we simply cannot afford to take. DDT, which first came into use as an insecticide in the 1930s, played a crucial role helping Allied forces protect themselves from mosquitoes carrying malaria in World War II, and eventually helped eliminate the deadly disease in the U.S.

However, despite its successes, public opinion turned quickly in the 1960s as an outrage grew over DDT's potential risks to human health and animals, and many countries joined the U.S. in ultimately banning its use.

Today, health officials caution that, while the benefits of the pesticide can outweigh health concerns in some contexts, the decision to spray DDT to combat Zika would be premature and potentially very misguided.

DDT is so stable in the environment that it takes many years for it to decompose after it is exposed to air and water. Ten years after DDT began to be used, studies found it in even the most remote areas of the world, places where it had never been applied. Wind and water transport DDT all over the globe.

And then, it began to show up in birds, fish, domestic animals, and humans. DDT accumulates in fatty tissues, and is passed from mothers to their infants during breast-feeding. Nursing infants all over the world were ingesting DDT from their moment of birth." Nicole Lund shifted uneasily in her chair as she responded, "What you say is true, Dr. Canavan, but would you please tell us how many human deaths DDT has caused among the billions of human beings that have been exposed to it?"

"I think you know very well that DDT has not been proven to be the direct cause of any human deaths, Dr. Lund. I also think that you know that the 'precautionary principle' demands that we not take risks whose consequences we cannot predict."

"I am afraid that I am not aware of the details of the precautionary principle, Ms. Canavan," Secretary Sahriti interjected. "Could you enlighten me about it?"

"Certainly, Mr. Secretary. The precautionary principle requires that when an activity raises potential threats of harm to humans or the environment, it should not be undertaken even if some cause and effect relationships are not fully established scientifically. So we must assume that the potential risks posed by future use of DDT are such that we cannot take a chance and allow it to be used."

"Let me see if I understand this concept," said the secretary. "The precautionary principle maintains that some technological activities pose such grave potential threats to our well-being that they should not be undertaken, even if definitive scientific evidence is not available to establish that the activity will cause the harm. Is that correct, Dr. Canavan?"

"That's right. The principle might seem a bit unreasonable at first glance," Patricia Canavan replied, "but if you consider the totally unanticipated problems caused by the use of asbestos and PCBs as well as the harm done to the ozone layer by chlorofluorocarbons you can understand why use of the precautionary principle is necessary."
"One more question, if I may, Dr. Canavan. Is it true that the precautionary principle focuses only on the risks associated with a technology and not the benefits that may result from its use?"

"Yes, because the potential risks associated with some technological activities are so grave that regardless of the benefits that may be derived from them, they must not be undertaken. Besides, we have seen that the risks associated with a new technology are often not apparent until it is in use, and then it is too late to undo the harm that has been done."

Sergio Ricupero cut in, "Mr. Secretary, the question that you have raised about the benefits is exactly why the precautionary principle, so beloved by environmentalists, is not a reasonable guideline in many areas, and especially so in the case we are considering here. I believe that the developed world is far more concerned with the theoretical long-term risks of DDT use than it is with the needless and very real deaths of millions of people, mostly children, in the developing countries like Brazil. Think of the good this could do."

Patricia Canavan replied, "How can we know, though, that long-term chronic exposure to DDT won't do irreparable harm to us all, and to our children? There is no doubt that DDT does bioaccumulate in humans and throughout the environment. If its use is allowed to continue we may pass a point of no return, one where irreversible harm has been done."
Nicole Lund countered, "Despite the great public outcry caused by Rachel Carson's book *Silent Spring*, claims that the risk to human health and the environment caused by DDT has never been confirmed or replicated by any scientific inquiry, even after the passage of almost 40 years. And there is no evidence that DDT has ever caused harm to a single human being. We simply cannot afford to close our eyes to DDT's benefits and focus only on its potential risks."

"And there is a way to keep any risks that may be involved in DDT's use much lower than they have been in the past. A recent study conducted in Belize has demonstrated that DDT protects people against malaria not only by killing mosquitoes, but mainly by repelling them. It showed that only three percent as many mosquitoes entered huts sprayed with DDT on their interior walls as entered unprotected huts. If DDT is used in this way for Zika virus, in small amounts and only in enclosed spaces, it presents a greatly reduced environmental and health risk."

"That may be true," answered Patricia Canavan, "but how can we be sure that DDT intended for use in this way will not be used in agriculture, and in other ways that will spread it widely into the environment?"
Ambassador Ricupero responded, "DDT would only be provided in small amounts, and it would be used only by trained indoor spraying technicians. These would be the conditions for its use."

"I don't think anyone would believe," replied Patricia, "that if DDT is provided to all sorts of people in all sorts of places it wouldn't be misused. Sooner or later, it would once again become a major threat to both our health and the environment."

"I agree that we cannot reduce the risk to zero, Dr. Canavan," said the ambassador, "but certain risks must be accepted to provide health benefits in the least developed parts of the world. We have to balance these potential risks against some certainties. The certainties are that number of babies born with suspected microcephaly or abnormally small heads since October is nearly 4,000 and rising temperatures will trigger a surge in cases as the mosquito population multiplies if we deny the public health benefits that come from using DDT."

Patricia responded, "I understand your point, Ambassador Ricupero, but once the DDT genie is out of the bottle again, we may find it impossible to control. Not even the most farsighted among us could begin to imagine the damage to the environment and to human health that could result from its use. Technological dangers sneak up on us, and by the time that we realize that we are in danger, it is often too late to prevent the damage. May I remind you of the ozone, PCB, and asbestos examples once again?"

Secretary Sahriti leaned back in his chair, folded his hands before him, and said, "I am afraid that our time is up and I must bring our discussion to a close. I thank you all for coming to this meeting. Your arguments have been most enlightening and have raised many important issues. I assure you that I will consider all of the points that you have raised very carefully before making my recommendation to the Secretary General."

For Discussion and Reflection:

1. What do you know about the issue of using DDT?
2. Have you heard or read anything related to Zika virus?
3. How do you think that the question of using DDT for Zika virus control vs. banning its use worldwide will be resolved?
    a. Is your answer to this question the same as your view on how this matter should be resolved? Explain.

4. What do you think about using DDT for Zika virus? Explain your reasons?
5. What are the strengths, weaknesses, and implications of the precautionary principle as a method for deciding whether a technology should be used?
6. Compare risk/benefit analysis to the precautionary principle. Which of these methods do you feel would generally lead to better decisions on questions involving potential applications of technologies in society? On what reasoning is your conclusion based?
7. Why do you think Patricia is against the use of DDT? Do you think that she made a strong argument?
8. What would you do if one of your students mentioned his/her concerns about a possible spread of Zika virus in Georgia?

Additional Resources:

https://www.21stcenturysciencetech.com/articles/summ02/DDT.html

http://www.cdc.gov/zika/geo/united-states.html

http://www.who.int/emergencies/zika-virus/articles/mosquito-control/en/

http://www.cdc.gov/zika/vector/range.html

Appendix C2

Case #2: Selecting the Perfect Baby (SSI Case)

Selecting the Perfect Baby: The ethics of "Embryo Design"

Julia Omarzu
Department of Psychology,
Loras College, Dubuque, Iowa

The research team assembled quietly in the lab. There were some difficult decisions to be made today. Kelly, a new research assistant, looked forward to the discussion. Privately, she hoped Dr. Wagner and the rest of the team would agree to help the couple that had appealed to them.

"Good morning, everyone," Dr. Wagner began the meeting. "We have a lot to talk about. I'll summarize this case for those of you who may not have had time to read the file. Larry and June Shannon have been married six years. They have a four-year-old daughter named Sally who has been diagnosed with Fanconi anemia. Sally was born without thumbs and with a hole in her heart. Shortly after her birth, she began suffering symptoms related to impaired kidney function and digestion that have only increased in severity. Fanconi anemia is a progressive disease that often results in physical abnormalities and a compromised immune system. Sally needs a lot of special care and has already had several surgeries. She can't digest food normally or fight off infections as easily as a normal child would. If she doesn't receive a bone marrow transplant, she will develop leukemia and die, most likely within the next three to four years. Neither Larry nor June had any clue they were both carriers of this disease."

"A frightening diagnosis," said Kevin, a research technician. "Difficult to live with, as well. Not only will they probably lose this child, they must be crushed about the possibility of having another child with this illness," commented Liz Schultz, the team's postdoctoral researcher in gynecology and fertility.

"Exactly their problem," continued Dr. Wagner. "The Shannons are interested in having another child and have approached us regarding pre-implantation genetic diagnosis (PGD). They are aware of the risks and the odds of success. They are anxious to begin the process as soon as possible."

"Kelly, you're new to the team, so let me summarize the PGD process for you. It's a three-step process, with chances of failure and complications at each step. First, in-vitro fertilization (IVF) is performed. Some of June's ova would be removed and fertilized with Larry's sperm outside of June's womb. If this procedure works, we should have several viable, fertilized embryos. Our second step is to perform genetic analysis on the embryos, removing a cell from each and testing for the presence of the Fanconi anemia genes. If we find embryos that are free of Fanconi's, we can then perform the third step: implanting the healthy embryos back into June's uterus."

"Wait a minute," said Kelly. "How many embryos are we talking about? They just want one child, not a half dozen."

Dr. Wagner laughed. "Yes, I know. But during the in-vitro fertilization and implantation processes, we almost always have embryos that do not survive. There is only about a 23% chance of any implanted embryo thriving. There is a better chance for a positive outcome when we remove and fertilize multiple ova. In this particular case, the odds of a multiple pregnancy are very small, given the limitations on the ova we will be able to implant."

"OK, I know I don't understand all of this. But how can Mrs. Shannon produce that many eggs all at the same time?" asked Kelly. "She wouldn't normally do that, would she?"

"No," said Liz. "So before we even begin any of these procedures, June would have to take hormones to increase the number of ova she releases. As Dr. Wagner said, there are risks involved with every step of this procedure. Hormone therapy can have some side effects, including mood and cognitive effects. Some women suffer physical complications as well, although this is relatively rare. There are some studies that link hormone therapy to increased risks of ovarian cancer, although there is other research that contradicts that."

"Plus," Dr. Wagner added, "along with the risks to June, there is no guarantee that the procedure will be successful. Many couples must undergo the IVF procedure more than once before the implantation is successful in producing a healthy, full-term baby. In this case, it will be even more complicated because we cannot use all of the fertilized embryos but must limit ourselves only to those that are free of Fanconi anemia."

"But we've done several of these types of procedures with a pretty high rate of success," said Kevin. "Why should this one be different? You've screened the couple, right, and you said they're aware of the risks?"

"Yes, but this case is very complicated." Dr. Wagner sighed. "The Shannons have requested not only a Fanconi-free child, but one that will be a perfect bone marrow match for Sally. Sally's illness may be treated with a transplant of healthy cells into Sally's bone marrow. Because Fanconi's patients are so fragile, however, the donor's cells have to be a near perfect match, and that's hard to find. Siblings are the best bet. In the meantime, Sally's condition is deteriorating. The Shannons naturally want to give Sally as many years of normal life as possible so they want to take aggressive action. They want to cure Sally's disease by planning and creating another child with specific genetic markers."

"How would that work?" asked Kelly.

"You've heard of stem cell research?" began Liz. "Stem cells are special cells that can produce all the different organs and tissues of the human body. They are found in embryos or fetuses, and are usually obtained for research from embryos that die or are rejected in fertility procedures. That is the kind of research that has been so politically controversial lately. But a less potent type of stem cell is also found in adult humans and can also be obtained from umbilical cord blood. If we were to help the Shannons, and the procedure was successful, the blood from their new baby's umbilical cord could be used for Sally's bone marrow transplant, resulting in no injury at all to the baby and a possible cure for the worst symptoms of Sally's illness."

"The Shannons are suggesting that we perform the PGD procedure as we normally do, but select only those embryos that are both free of Fanconi anemia, and are also a perfect match for Sally," said Dr. Wagner. "This presents some real ethical dilemmas for us. We have never tried this before. People have had PGD done to detect and prevent a variety of illnesses in their children, just as we have done here 3 before. But what we are proposing now would be selecting for a specific combination of genetic traits, a combination that will not benefit the planned child but will save an existing child. We will be selecting an embryo and then using it essentially as a blood donor for its sibling. It will be umbilical cord blood, which would be discarded anyway, but it's still a controversial procedure. If we agree, it also means we will be destroying embryos that are perfectly healthy, but are just not a match for Sally. I'm interested in pursuing this, but these are serious issues to consider. Not the least of which is that we may have trouble getting it approved. Before I run it past the review board, I want to know how you all feel about trying it."

"Well, I say go ahead with it. It will be a genetic breakthrough. In time, we'll be able to prevent all kinds of problems with this procedure. Why not start now?" urged Kevin. Another doctor on the team who had remained silent nodded her head in agreement. "I'm not sure yet how I feel about this," said Liz. "I feel a little uncomfortable with the precedent this might set. We'll be opening the door to who knows what type of genetic selection. Do we want the responsibility for that?" A couple of others on the team seemed to side with her.

"Yes," said Kelly. "But think about the poor Shannons. And especially Sally. Does she deserve to suffer just because we're arguing about ethical problems of the future?"

"Well, it sounds like we all need to talk about this some more before we can reach a real consensus," Dr. Wagner concluded. "I don't want to start on a case this important without everyone's agreement."

For Discussion and Reflection:

General question: *What do you think the research team should do? What should the Shannons do? Provide the rationale behind your suggestions.*

<u>Thinks to consider while elaborating on your suggestions:</u>

1. What are the basic processes of IVF and PGD?
    a. What risks are involved in this whole procedure?
2. What is so unusual about the PGD proposed by the Shannons?
3. What are some ethical issues related to the use of IVF? What do you think about those issues?
4. What are some ethical issues related to the use of PGD? What do you think about those issues?

<u>Source: The National Center for Case Study Teaching in Science, University at Buffalo, State University of New York</u>

Appendix C3

Case #3: I Like the Spotted Owl as Much as Fried Chicken (Pedagogy Case)

I like Spotted Owl Almost as Much as Fried Chicken

Source: US Fish and Wildlife Service

Norman Lederman

Should old-growth forests be logged for their valuable timber or should logging be stopped to preserve the habitat of the spotted owl? A first-year elementary teacher and newcomer to a small Oregon town, Sandy Blair (a composite of several teachers with whom Norman has worked) attempts to make science instruction relevant to her 5th grade students' lives by having them debate this question. As Norman explains in this open case, Sandy's efforts to use this emotionally charged issue to teach about the environment and ecology raised more controversy than she had expected and she is left wondering whether the decision to hold the debate is a wise one. A response by science educator Norm Thomason follows the case.

Prior to entering the field of teaching Sandy considered a career as a researcher in a medical laboratory. Following the completion of her master's degree in vertebrate physiology she participated in an internship in a medical laboratory. It was during this internship that Sandy became a bit concerned about the prospect of spending the rest of her life as a bench scientist. She enjoyed people and wasn't sure she would find fulfillment in a career with what she perceived as limited interpersonal opportunities. One of Sandy's friends suggested she might enjoy teaching and after further reflection she took the plunge and entered the teacher education program at a large Midwestern University. This wasn't a popular choice with Sandy's parents. They were very proud of the prospect of their daughter becoming a famous scientist. Her Chinese parents had always wanted her to become a medical doctor but a PhD was an acceptable alternative. Now their daughter not only was turning down her chance to be a medical doctor but also deciding to enter a field with little status or economic reward.

However the disappointment felt by her parents wasn't enough to deter Sandy from her newfound career goals, and she successfully completed the teacher education program.

During the program, Sandy was placed in a rural setting with an extremely creative Mentor teacher. She thrived in an environment where limited resources necessitated the use of creativity. Furthermore she appreciated the freedom from bureaucratic hassles afforded by the relatively informal administration of a rural school district. As a consequence of her highly rewarding preservice internship experience, Sandy set out to find a position as an elementary teacher in a rural school. How else could you explain how the daughter of a Chicago physician found herself as a first-year elementary teacher in rural Philomath, Oregon?

Philomath is a city of approximately 10000 people. The school district enrolls 1750 students and has one elementary school. The elementary school includes Grades K-5 and there are a total of 555 students. Philomath is known as a logging community; this means that most people are employed in ways that are somehow linked to the logging industry of Oregon. The adult community can accurately be described as blue collar. The population of Philomath has been increasing in the past few years because a wealthy logging industry executive provided an endowment that pays tuition expenses for 4 years to all students who graduate from high school. Consequently education-oriented individuals see some merit in moving to Philomath. Nevertheless, in Philomath the stress on education cannot be described as especially strong.

The principal of Oak Hills elementary school, Ms. Hope, is very supportive of her staff and is particularly interested in having science and mathematics curricula of the highest possible quality. It is not uncommon for the principal to walk in and out of classrooms on a daily basis. These visits are not threatening to teachers as the atmosphere is strongly supportive and the visits are motivated more by curiosity than evaluation.

The students and teachers have just returned from Christmas vacation and are ready to tackle the January/February doldrums, in which holidays are few and far between. It is also the rainy season in Oregon, which means there will be few days of sunshine or dry weather for several months. Sandy is beginning the portion of her 5th grade science curriculum that places a strong emphasis on the environment and ecology. During the fall semester students developed foundational knowledge of food chain and food web concepts; the spring semester is more capstone by design as students are expected to synthesize and apply their knowledge of food chains and food webs to larger ecological concepts.

For the next unit in science curriculum, Sandy wants to focus on concepts such as biodiversity, deforestation and community action. In general, Sandy's school attempts to provide science instruction that is motivational and active. Most important, there is a consistent and concerted effort to provide relevant context for all science concepts. A significant number of students in this small city will not be attending college, so teachers at Oak Hills elementary school want to offer a curriculum that develops scientifically literate students who will likely not take any additional science beyond high school.

Sandy started the unit with having her students watch the movie ***Lorax*** and asking students to discuss the three main characters, the Lorax; the boy; and the Once-ler, with the aim of exploring students' thoughts of those characters and their reactions to what those characters represent in our society. Sandy picked the Lorax to introduce the unit because it is a movie with an environmental message. The movie promotes conservation and protecting the environment. Therefore, Sandy thought her students would want to do more to help the natural world and the lesson imparted by the Lorax should spark positive discussions on what can be done to protect our planet.

There is currently a heated debate in Oregon about the logging of old-growth forests. These forests contain valuable timber that can reap high profits in the logging industry, and logging companies have been running short of places that provide productive yield. On the other hand old-growth forests are the primary habitat for spotted owls and the once-abundant population of this species has decreased perhaps by excessive logging, to a level that has placed it on the endangered species list. A few students mentioned this issue during the classroom discussion of the Lorax and Sandy sees this very timely issue as a wonderful hook to capture students' attention while learning basic principles of deforestation and how one element of a complex ecosystem can provide essential components to the survival of many species of plants and animals. What could be more relevant?

Although she is an inexperienced teacher, Sandy is well aware of the possible problems that can result from the discussion of controversial issues in her 5th grade classroom. Still, she wants to capture the energy of students' emotions and redirect it to facilitate the learning of science. She knows that there are strong feelings within the community about the spotted owl controversy. The community is not necessarily against discussions of controversial topics in school, but on this particular topic emotions run high.

Most important to Sandy is to be sure to structure her lessons in such a way that she cannot be accused of attempting to indoctrinate her students into one position or the other. She decides to organize her instructional unit around a debate and thinks she can use the debate as motivation to have students learn a lot about ecology. The general organization of her unit begins with students becoming aware of the controversy surrounding the population of spotted owls and efforts to continue logging old growth forest. Students are asked to take an informal stand on the issue through an oral discussion and written assignment. Sandy then place the students on debate teams being careful to ensure that at least half the students are on the side of the debate that is opposite to their actual beliefs. She had learned about this structured controversy debate approach in her science methods course. In theory, students having to publicly argue on a position opposite to their true beliefs will be motivated to be much more thorough in their research of the position they must defend. In short the debate technique is supposed to prevent the students from focusing solely on the perspective they had prior to the debate.

The unit Sandy has planned will last for about four weeks and it involves students in required laboratory activities and readings, student-designed investigations, and student-designed library search. From Sandy's perspective, the primary motivation is to prepare students for a class debate on whether to continue logging old-growth forests. The students all appear to be excited about the debate. Naturally, some would prefer to debate on the side opposite to what they have been assigned. Nevertheless, Sandy appears to have captured their attention, as students certainly do not mind focusing on a topic they talk about outside of school and in their homes each day around dinner table.

The students have been actively engaged in preparing for the debate for over two weeks. Sandy is extremely encouraged by the students' enthusiasm on independent assignments as well as their unusually high attentiveness during formal class meetings. On several occasions, the students have attempted to find out where Sandy stands on the debate, but she is careful not to let them know. The students are quite ingenious and maybe obtain more information about her beliefs than she realizes:

Johnny: So, Ms. Blair, do you think we should save the spotted owl?

Sandy: That is for you to decide.

Bob: Where did you grow up?

Sandy: Chicago.

Sally: What did your mother and father do?

Sandy: Didn't I already tell you my dad was a doctor and my mother had her hands full raising me and my sister?

Peter: That is right. Don't you ever pay attention Sally?

These types of interactions are not uncommon in Sandy's class. The students like her and are really interested in some personal aspects of her life. With respect to the upcoming debate, the students are well aware that Sandy's parents are not from a blue-collar background and lived in rather comfortable surroundings. They are also very aware that Sandy most likely holds the same views as those scientists interviewed on the nightly news and in the local newspapers. Many of Sandy's students have been discussing the upcoming debate with their parents, and their parents have been asking rather pointed questions about Sandy's background and beliefs.

It is now several days before the debate and Sandy decides that she should have a class discussion about the rules to be followed during the debate. After all she does not want the debate to turn into a shouting match. She really wants the students to focus on the scientific aspect of the controversy and how science, technology, and society are intimately related in such issues. What follows is a segment of Sandy's pre-debate discussion with her class.

Sandy: I think we need to be clear about the ground rules for the debate. I know you all have strong feelings and you have prepared well, but we need to make sure things are orderly and that everyone who wants to talk has a chance.

First, each team will have a chance to make some introductory comments. You will have one member of your team do this and he/she will have no more than 5 minutes. After each team has made their introductory remarks we will move into a rebuttal stage at which time each team will have 3 to 5 minutes to respond to the comments made by one of the other teams. We will keep rotating among teams until there is about 15 minutes left in the class period. Then each team will have 2 minutes to make some final comments.

I know I don't need to say this, but remember your arguments should be based on the scientific knowledge you have learned related to the spotted owl issue. Remember, the purpose of this is to use what you have learned in science to help make a decision.

Barb: How will you decide who wins this debate?

Sandy: There won't be a single winner. You all can win if you make sure that your arguments can be supported by the scientific facts.

Rick: So how will be graded? Won't the winners get higher grades?

Sandy: There won't be any winners and losers. You just need to defend your team's position with the facts.

Before much time passed, the students' discussion shifts from the rules of the debate to personal and family values. Many students in the class come from families in which the primary source of income is the logging industry, whereas others have parents who are either professionals or earn income from industries unrelated to logging. Consequently, the money provided by the logging industry is significant for the daily survival of some students' families, whereas other students have the "luxury" of being able to be primarily concerned with the environment and the survival of an endangered species. The discussion quickly turns to arguments about whose concerns should be given priority and whether certain individuals' beliefs and values should supersede those of others. The discussion quickly deteriorates into students from various teams arguing with each other about the stupidity of the other team's position. Sandy tries to redirect the discussion to little avail. The students obviously have a strong emotional stake in the controversy that goes well beyond Sandy's instructional intent.

The next day Sandy receives a message from Ms. Hope. She would like to talk with Sandy about upcoming debate. She has received angry phone calls from numerous parents concerning the upcoming debate. Those parents against the laws prohibiting the logging of old-growth forests are very concerned that Sandy is trying to convince their sons and daughters that saving the spotted owl is the most important priority. Several of these parents have lost their jobs because of the laws protecting the spotted owl's habitat. Those parents who happen to favor protection of the spotted owl are concerned that ideas other than science are being discussed in science class. They would rather only scientific knowledge be included in the science curriculum. Several of the parents are so concerned that they asked permission to attend the debate.

Later that day several students from the debate team against protection of the spotted owl's habitat are seen wearing buttons that say "I Like Spotted Owl Almost as Much as Fried Chicken." It is not clear whether buttons are meant to be humorous or the expression of sincere sentiment. The student body appears to be divided on how to interpret the intent of the buttons.

It is now Wednesday and the debate is scheduled for Friday. Tensions are high and many concerns are swirling around the heads of the faculty, students, administration and especially in Sandy's mind. Sandy has been losing sleep thinking about the debate but is convinced of its importance in developing scientifically literate youth.

For Discussion and Reflection:

1. What does Sandy think the students will learn by having this debate? Do you think the debate should take place as planned? Why or why not?
2. Should all students be required to participate in the debate? Should certain students be prohibited from participating? Should concerned parents be allowed to observe the debate?
3. What does Sandy believe about the spotted owl controversy? How might Sandy's beliefs affect how she grades students?
4. Some people in communities in Oregon and other Northwestern states believe that the spotted owl controversy is not science and should not be debated by students in elementary science. Do you agree or disagree? What are your reasons?
5. What should be done about those students not in Sandy's 5th grade classroom who have also expressed their concerns about the spotted owl controversy?
6. Are the problems Sandy faces her fault or was the reaction unavoidable? What school rules or policies might have helped Sandy avoid the problems or deal with them effectively?
7. For some of Sandy's students and their parents the spotted owl controversy is an either-or issue of survival: the survival of a species or their families' economic survival. What points of agreement or compromise could Sandy and/or her students introduce to encourage dialogue about issues regarding the spotted owl controversy rather than debate? What are key differences between debate and dialogue?

Adapted from Koballa, T. R. & Tippins, D. J. (2003). *Cases in middle and secondary science education: The promise and dilemmas (2nd ed.)*. Upper Saddle River, NJ: Prentice Hall.

Appendix C4

Case #4: The Day the Lobster Died (Pedagogy Case)

The Day the Lobster Died

Joseph P. Riley

This open case raised questions about the ethical treatment of animals in the elementary classroom. Stan, an experienced fifth grade teacher, faces a number of dilemmas when the lobster cookout he has planned for the end of his oceanography unit takes an unexpected turn. Stan is left wondering how he got into the dilemma and how he might find a way out. Questions of life and death, the issue of animals as a source of food, clothing, ethical questions about animal rights, and the treatment of these issues with elementary students all come into sharp focus for Stan on the day lobster died. Some thoughts on Stan's dilemma are provided by science teacher educator Merton Glass after case.

Stan noticed the sudden change on Erin's face. Her expression registered shock, as if she had just become aware of the awful truth. He would never forget the panic in her eyes. He stood transfixed as Erin's emotions plummeted from engaged curiosity to anxiety, then fear. Her chair crushed to the floor as she ran to the classroom door and out into the hall. 'Oh no! You're going to kill it!' she shrieked in disbelief. Stan stood motionless in front of the class. A look of astonishment swept over him as soon as another student ran from the room in tears. Pandemonium broke loose as some students hooted, hollered, and laughed while others sat in stunned silence.

Stan thought his idea to end oceanography unit with a "lobster cookout" deserved a self-congratulatory pat on the back. He knew that lobster was not readily available and that most of his students would not have had an opportunity to see or taste this "Down East" treat. He thought the activity would give the class an opportunity to learn not only about lobsters but also about how a marine animal can shape the economy, life, and identity of a region. It reflected the interdisciplinary approach to teaching he favored. He had searched his kitchen to find lobster artifacts collected over years – everything from a bib with the saying “ The lobster you eat today spent the night in Casco Bay” to the mallets, shell cracker, and tiny forks for getting at the lobster claw meat. His enthusiasm was high enough to sustain the two-hour drive to Atlanta where he could buy live lobster.

Stan was a fifth grade teacher in a small university town in southeastern United States. He was born and raised in New England and, before coming to this rural school, had taught in suburban school district outside of Boston for four years. He had come south to enroll in the graduate program of the nearby university. To establish residency, he had decided to he had decided to teach in the local school system while taking evening classes. He had a master’s degree in elementary education with an emphasis in science education.

Stan had started the lesson by showing the class a carefully wrapped box with ribbons and a bow saying, “I would like to make some observations about the box.” He had placed the lobster in the box and wrapped it before the class arrived. He wanted to reinforce students’ inquiry skills in making distinctions between observations and inferences. Stan believed that basic process skill of observing was central to teaching science at this level. He wanted students to be able to distinguish between observed and inferred information. Student attention focused on the shoe size box wrapped in gift paper. Enthusiastic student responses followed one after another: “There is a toy present inside!” “It has a red ribbon around it!” “It is about the same size as a shoe box.” “I can hear something moving inside!” Stan wrote the students’ responses on board. After the class discussed differences between observations and inferences, whether anyone could now identify which statements on the board are observations. Students were quick to eliminate guesses and identify observations. Stan then asked them for some inferences about what might be in the box. To make it more challenging he told the class they could ask only questions that he could answer with a yes or no. “Is it a plant?” “No,” Stan replied, “It is not a plant.” The class excitement began to build after he answered “Yes” to “Is it an animal?” The next series of questions were wild inferences about what it could be based on the size of the box. Finally a student asked, “Does it have a backbone?” “No, it doesn’t, but it is a great question.” Stan responded. He pleased with the level of questions that followed. After exhausting all of the students’ questions, Stan slowly unwrapped the gift box, opened it, and held up the lobster. “Oh, it’s a lobster! But I thought lobsters were red. This one is green!” one student exclaimed. “What’s its name!” With a smile, Stan responded, “We don’t name our food, Erin.”

The door slammed shut after the second student dashed from the room following Erin’s lead. The loud sound snapped Stan out of his stunned silence and brought a momentary lull to the classroom commotion triggered by Erin’s exit. This, he thought, cannot be happening. “All right, enough! His voice commended attention with volume and a somewhat businesslike tone. As things in the room calmed down, Stan quickly reviewed his options. Should he continue with the class as planned? Should he run after the students who had fled the room? “I want you to take out your paper and pens and write a thank you letter to Mrs. Carson." Emily Carson, a marine biologist with the university, had visited the class the day before.

This task bought Stan the time to follow the two students who had run from the room. He found them both in the hall crying. Erin sobbed inconsolably. Gretchen appeared more composed. Stan suggested that Gretchen accompany Erin to the restroom and return with her to the classroom after they settled down. Stan reentered the classroom and was relieved to see that the students were diligently working on their letters. The water in the lobster pot, hidden out of sight in the back of the room, boiled. Okay Stan, he thought to himself, what now?

For Discussion and Reflection:

1. Should Stan continue with the lobster cookout?
2. What is the message if he stops? What is the message if he continues?
3. How should animals be treated in science classroom?
4. Should fifth graders be protected from such life experiences?
5. How might the lesson changed to avoid or soften the issues raised by the children's unexpected behavior?
6. How would you turn this lesson into a socio-scientific issue activity?

Source: Tippins, D. J., Koballa, T. J., & Payne, B. D. (2002). *Learning from cases: unraveling the complexities of elementary science teaching*. Boston: Allyn and Bacon, c2002

Appendix D

Edible Insects Lesson Plan

Subject**:** Insect eating,practiced by different cultures historically, might be offering solution for current and future food related problems such as shortage, environmental impact, health, economical, ethical and son on.

Curriculum connections**:**

Knowledge of Science: Food pyramid, balanced healty diet, nutrients, insects.

Knowledge about Science:

a) Changing but durable nature of scientific knowledge. (Nutrition is being a challedged area of science and change of food pyramid over the years)
b) Social embededness of science (social needs and anticipated future social problems drives science to some extent).

Higher Order Thinking Skills: Realizing and reflecting on own assumptions and values, identifying arguments, analyzing quality of arguments, ability to identify reliability of sources.

***Target grade* level:** 5th Grade

Duration**:** 80 Min

Required Materials**:** Edible Insects pptx file**,** Worksheets, Web resources to explore, various insect samples.

Prerequisites**:**

Difficulties in teaching**:** Some students are afraid of bugs. Some religious and cultural beliefs forbid consuming insects.

Background knowledge related to SSI: Main claims for consuming insects include the following dimensions.

- More economical; May be harvested from wild or raised more quickly and economically
- As healty as conventional animal food products; rich nutritional content, disease-free
- Environmentally friendly; reduced space use, green house gases emission and water use

No controvercy were identified in the literature about consuming insects as food, but potential uncertanity is that 'Are we really going to rely on insects as our food source?'

Engagement (20 Mins)

- ➢ Start lesson by showing an interesting insect sample/or photo and ask students what they know about insects.
- ➢ Distribute some insect samples to observe some of the structural features with magnifying glasses.
- ➢ Talk about insects and their life cycle by taking student input
- ➢ Introduce the idea of consuming insects as food.
- ➢ Introduce the idea of healthy and balanced diet and food pyramid. How
- ➢ Show the pictures (Slide X) and ask the initial questions to engage students.
- ➢ Carefully listen student responses take notes to board and engage them critical discourse through facilitating both student-student and teacher-student interaction.

Exploration (20 Mins)

Distribute Resources of Exploring edible insects and worksheet 2.2 to students to review materials and analyze the arguments with a jigsaw cooperative work by each student working on a document and briefly describing their findings and negotiating their classification, leading to final typed up group document which is shared by the teacher. (If the students are not able to finish their work, give them as homework to complete)

Explanation (25 Mins)

- ➢ Gather all the student work and project on the screen to see larger picture of arguments from multiple resources.
- ➢ Ask students to comment on the quality of arguments and hidden assumptions. Ask students to comment on how convincing all the arguments together. Would they be willing to change their own diet (for sustainable world)? How strongly would they recommend to the others? What was the most convincing evidence that they would use to convince others?

Ask the following questions to engage students to learning *about* science through discussion.

- Based on edible insect topic what can you say about relations between science and society? What other social problems in the past influenced scientific work? Funding?
- Even if the humans do not change, food pyramid and intake recommendations have changed several times over the decades? What might be the reasons for this? Can we still believe that food pyramid is a useful idea?

Elaboration (10 Mins)

Possible elaboration activities might be the following.

- You have seen all argument in favor of eating insects, what would be your counter argument? Can you come up with any?
- Find out what edible insects there are in our own region/country. Are there any dishes people eat traditionally that we do not know of?

Evaluation (ongoing throughout the lesson)

- Ongoing self-evaluation of the students and monitoring of the teacher on student in meeting the objectives of the lesson through participation to the lesson.

Source: http://www.ssieurope.net/deliverables.html

Appendix E

IRB Consent Form

Case-based Learning for Supporting Socioscientific Issue-Based Teaching

I am/We are asking you to take part in a research study. Before you decide to be in this study, it is important that you understand why the research is being done and what it will involve. This form will to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you.

Principal Investigator: Dr. Janette Hill
The University of Georgia

Purpose of the Study

The purpose of this study is to learn how case-based learning supports your teaching and learning of the socio-scientific issues.

Study Procedures

If you agree to participate, you will be asked to

1) **_____** Complete a pre and post socio-scientific issues questionnaire. Each will take approximately 15 minutes and you will complete the questionnaire in class.
2) **_____** Participate in an interview and answer questions about your learning experiences. This interview will take approximately 30-45 minutes and will take place toward the end of the semester. The interviews will be audio taped.
3) **_____** Give access to assignments you submit (e.g. case reflection papers, instructional resource design, online discussion posts).

(Please indicate your willingness to participate by checking the items above)

Risks and discomforts

- No risk or discomfort is expected.

Benefits

- While there may be no direct benefit, your feedback will provide insight to the academic research community and society at large about effective strategies for designing case-based learning environments in teacher education. Findings from this study may prove useful in enhancing and creating student-centered learning and teaching practices of socio-scientific issues.

Audio/Video Recording

There will be audio recording for the interview if you volunteer to participate.

Privacy/Confidentiality

There will be NO individually identifiable information used in the study. The researcher will not release any identifiable results from this study to anyone unless required by law. The results of the research study may be published, but your name or any identifying information will not be used. In fact, the published results will be presented in summary form only. Audio files of the interviews will be stored in the researcher's password protected laptop. The transcriptions of interviews of all audio files will be destroyed after the defense of the dissertation. To protect your information, any documents listing names will be de-identified and replaced with same pseudonyms. All data related to the study will completely be destroyed after 5 years following the defense of the dissertation.

Taking part is voluntary

Your involvement in the study is voluntary, and you may choose not to participate or to stop participating at any time without penalty or loss of benefits to which you are otherwise entitled. The decision to be in the study or not to be in the study and researcher's evaluation of your work will not affect your grades.

If you have questions

The researchers conducting this study are Mutlu Sen and Janette Hill. Please ask any questions you have now. If you have questions later, you may contact Mutlu at mutlusen@uga.edu or Janette Hill at janette@uga.edu. If you have any questions or concerns regarding your rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706.542.3199 or irb@uga.edu.

Research Subject's consent to participate in research:

To voluntarily agree to participate in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

__________________________ ________________________ ___________________

Name of Researcher Signature Date

__________________________ ________________________ ___________________

Name of Participant Signature Date

Appendix F

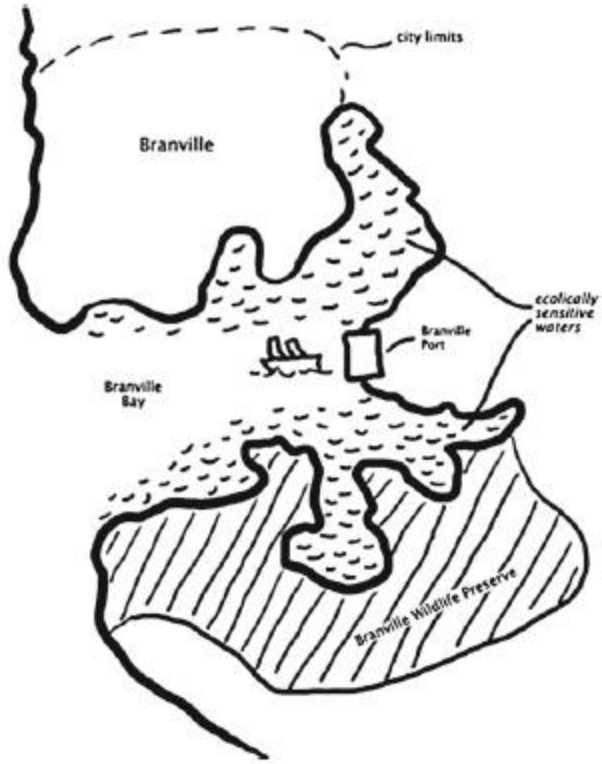
Socio-scientific Issue Questionnaire

This SSI Questionnaire provides the students with a short story related to a socio-scientific issue. After reading the short story, students will answer 5 open-ended questions.

SSIQ Prompt and Questions

(Adapted from Sadler, Klosterman, & Topcu, 2011)

Branville Bay is located on the Gulf of Mexico. The city of Branville has built up along the northern border of the bay, and a wildlife preserve has been established along the southern border. The Branville area was the ancestral home for several tribes of Native Americans. More recently Branville has become a major shipping port. Ships from all over the world dock at Branville Port delivering products like oil, clothing, toys, and fruit. These products are then distributed throughout the United States. Businesses in the US also use the port to send their products around the world (see the figure below). Branville Bay is a sensitive ecological area serving as the breeding grounds for many fish, birds, and other wildlife. There are strict laws that govern fishing in the most sensitive areas of the bay. However, these laws do not apply to the Native Americans still living in the area because they've claimed ancestral fishing rights in the area. Managers of the Branville Wildlife Preserve have started reporting declines in fish counts, bird counts, and water quality measures. These managers have concluded that the heavy ship traffic moving in and out of Branville Port is damaging the Branville Bay ecosystem. Port Authorities claim that their ships stay in deep water channels and do not travel into the most sensitive waters of the bay. They argue that the Native American fishers are the most likely culprits because they use boats and fish in the bay's most sensitive waters. Local leaders are trying to decide what to do.



Map of Branville Bay and the surrounding area

Questions:

1. Can the Branville Bay situation be solved easily?

(A) Yes

(B) No

If A, then: Explain why you think the Branville Bay situation should be easy to solve.

If B, then: Explain why you think the Branville Bay situation cannot be solved easily.

2. If you were responsible for deciding how to resolve the Branville Bay situation, would you need additional information regarding the situation before making your decision?

(A) Yes, I would need to have additional information to make a decision.

(B) No, I have sufficient information to make a decision.

If A, then: What kinds of additional information would be necessary for you to make a decision regarding the Branville Bay situation? If you were responsible for deciding how to resolve the Branville Bay situation, what would you recommend doing as a next step? Please explain why this would be an effective strategy.

If B, then: If you were responsible for deciding how to resolve the Branville Bay situation, what would you recommend doing? Please explain why this would be an effective strategy.

3a. In the previous prompt, you were asked to suggest a course of action for the Branville Bay situation. Describe the strengths of your proposed approach.

3b. Describe the weaknesses of your proposed approach.

4a. A group of concerned Branville citizens gathered to discuss a solution for the Branville Bay situation. The group suggested that Native American fishing permits in the most sensitive waters of the bay be reduced by half and that ship traffic be reduced by 1/3 (i.e., only 2/3 of the current number of ships traveling in the bay could continue coming into the bay).

4b. How do you think Branville Port Authorities would respond to this suggestion? Please explain your response.

4c. How do you think Native Americans in Branville would respond to this suggestion? Please explain your response.

4d. How do you think managers of the Branville Wildlife Preserve would respond to this suggestion? Please explain your response.

5. In response to the previous questions, you commented on how three different groups (Port Authorities, Native Americans, and Wildlife Managers) would respond to a proposed solution. Which of the following statements most accurately reflects your responses?

(A) The Port Authorities, Native Americans, and Wildlife Managers would have similar responses to the proposed suggestion.

(B) The Port Authorities, Native Americans, and Wildlife Managers would have different responses to the proposed suggestion.

If A, then: Explain why you expect the Port Authorities, Native Americans, and Wildlife Managers to have similar responses to the proposed suggestion.

If B, then: Explain why you expect the Port Authorities, Native Americans, and Wildlife Managers to have different responses to the proposed suggestion.

Reference: Sadler, T. D., Klosterman, M. L., & Topcu, M. (2011). Learning science content and socioscientific reasoning through classroom explorations of global climate change. In T. D. Sadler (Ed.), *Socio-scientific issues in the classroom: Teaching, learning and research* (pp. 45–78). Dordrecht: Springer

Appendix G

Instructional Resource Design Assignment Explanation

For this assignment you will select one class activity and design your own instructional resource for classroom use. You should make the instructional material and include all necessary components (See examples below).

Subject**:** What is the SSI to teach? Name the topic and explain it briefly.

Curriculum connection**:** Which objectives/topics in the national curriculum are related with the selected SSI. Consider content knowledge, NOS and HOTS.

Target grade level**:** What is the appropriate grade level for the lesson plan?

Duration**:** How long does the lesson take?

Required Materials**:** Are there any worksheets, webpages, lab materials etc. needed for the lesson?

Prerequisites**:** Which skills and knowledge are required to teach the selected SSI?

Possible Difficulties in teaching**:** Are there any cultural values or beliefs that should be considered while teaching the lesson?

Background knowledge related to SSI: Main arguments, evidence, sources and concerned participants, controversial claims and uncertainities.

Engagement	Engage student with the topic through variety of ways (questions, performance, video, story, pictures etc.) with the purpose of getting attention and finding out student knowledge and ideas about the topic studied.	Show insect eating people photos, dishes. Start making connections between balanced and healthy eating and sources of those. Possibility of food scarce in the future.
Exploration	Let the students research / read / analyze the issue with guidance.	Give students edited Reading /website to explore, gather data and analyze with worksheet to complete in small collaborative groups and monitor/guide groups while working.

Explanation	Students explain their understanding of concepts, processes and arguments for conceptual coherence	Give students chance to share results and argue their point through facilitating the classroom discourse. (Ask questions, evidence, show inconsistencies, underline and organize important ideas/findings. Connect discussion to nature of science through questions to explore.
Elaboration	To further extend and build on learning, students are provided opportunities to apply what was learned in context.	For the "eating insects" topic, students can be asked to find out what edible insects live in their own region.
Evaluation	Continues at all phases of instruction to guide students to self-evaluation and improve lesson.	Throughout the lesson, questioning and feedback are used to encourage student self-assessment and metacognitive activities.

* You should also include a one-page reflection in which you discuss:

1. Which socio-scientific issue is being addressed via the instructional resource design

2. Considering multi-dimensional nature of SSI, how the selected topic for the lesson plan fits the definition of SSI.

3. In depth discussion of the science content in the activity and relation to society.

4. How selected topic can be connected and integrated to the national curriculum.

Your instructional resource project should look very professional and clearly demonstrate your best work over a period of time.

Source: http://www.ssieurope.net/deliverables.html

Appendix H

Interview Guide

Case-based Learning to Support Prospective Teachers' Socioscientific Issue-Based Teaching and Learning

Introduction

Hello, as we get settled in I'd like to spend a few moments discussing the purpose of this interview. As you know, my name is Mutlu Sen and I am a doctoral student in the Learning, Design, and Technology program at the University of Georgia.

This interview is conducted as part of my dissertation study titled **Case-based Learning to Support Prospective Teachers' Socioscientific Issue-Based Teaching and Learning.** The focus of the interview is on your experiences of case-based activities you have engaged in your science methods course. These interviews are very important for me to gain a broader understanding about how case-based learning model works for this class. Interviewing participants of this course is really valuable and I am excited to learn about your personal views and experiences in our course.

Before we start, I'd like to briefly remind you of confidentiality and the consent form. The information that we discuss today will be kept confidential; meaning I will not use your name or any other information that might identify you and this interview will have no bearing on your grade. You can skip any question that you do not want to answer. I anticipate that the interview should take about 30-45 minutes and I will be mindful of the time. I will be audio-recording the interview. To protect your identity, I will not use your name during the interview. Audio-recorded files will be destroyed upon completion of the research. If there is ever a moment that you would like to stop the interview, please let me know and we can stop. Do you have any questions before we begin?

Ok then, I would like to start our conversation by getting to know you and your previous learning experiences a little better…

1. How would you describe yourself as a learner?

    a. When do you learn most?
    b. When do you learn least?

2. What were your experiences with case-based learning (CBL) before taking this course?
    a. If the participant has prior experience: Tell me a little bit more
    b. If the participant does not have prior experience: Now that you have taken this course; what is your understanding of CBL?

3. How would you describe your experiences with case-based learning activities in this course?

    a. Which activities facilitated your learning? (Advantages of CBL?)
    b. Which activities hindered your learning? (Disadvantages – challenges of CBL?)
    c. Are there other courses in your teacher preparation program that could benefit from the use of case-based pedagogy?

Transition: Let's talk about Socioscientific issue-based teaching and learning in detail. We have been talking about the term "socio-scientific issues"…

4. What is your understanding of SSIs?

5. What were your experiences with socio-scientific issue-based teaching and learning (SSI-TL) before taking this course?

    a. If yes: Explain your experience
    b. If no: What is your understanding of SSI-TL

6. In what ways did CBL help or hinder your understanding of socio-scientific issues?

    a. What experience(s) were the most effective in supporting your learning of socio-scientific issues?
    b. Why?

7. What do you think about the role that SSIs might play in your future classroom?

    a. Could you elaborate on this?
    b. What would you like your students learn when they engage in socio-scientific issue-based activities?

8. How did your experiences in the course influence your beliefs about learning and teaching of SSI?

9. What challenges might you face in teaching socio-scientific issues in your future classroom?
    a. How did any of the case activities help you think about these challenges?
    b. How prepared do you feel for overcoming those challenges?

Summary and Conclusion

I believe that we are coming to the end of our time together. Your responses have been very helpful and I appreciate your openness with me. Before we finish the interview, I would like to ask, is there anything else you would like to share? Is there anything that feels like it went unsaid?

This has been a very helpful interview and I have enjoyed hearing your responses. I noticed several themes like… (Summarize here). Do you think I summarized these correctly? Did I leave anything out; get anything wrong? Are there any other things that stand out to you from the interview?

I want to thank you for spending this time with me today. Your answers have helped me to better understand your experiences in the course. If I have any follow-up questions, may I contact you again?